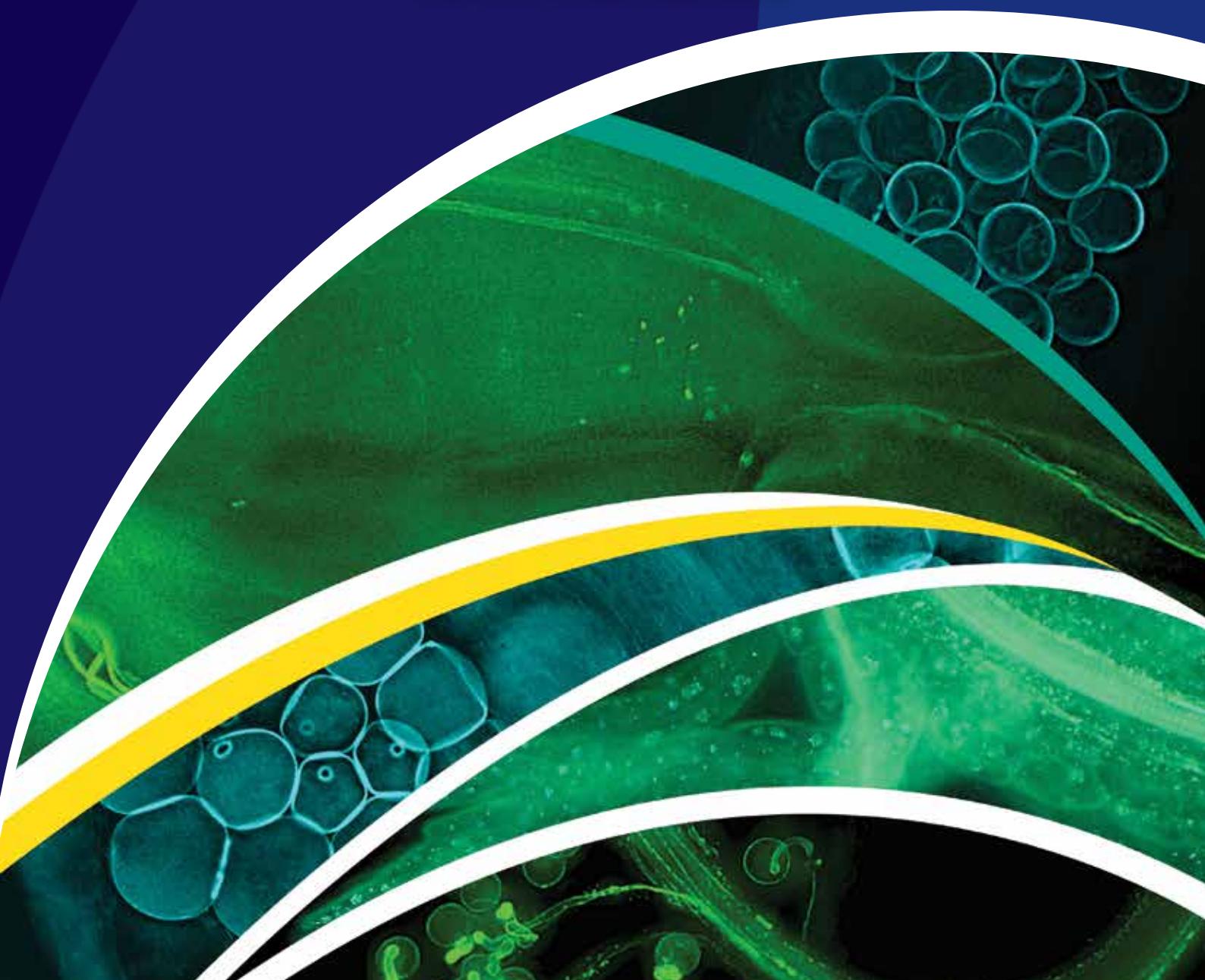




Irrigation Research &  
Extension Committee

# FARMERS' NEWSLETTER

NO 195. RICE R&D 2016





# In this edition



Irrigation Research &  
Extension Committee

Water use efficiency through high yields .....	6
Bitterns in rice project: the first four years .....	10
Target plant population for yield and profit .....	12
Improved rice variety management information .....	16
New tools for measuring and managing variability ....	20
New options for weed control in aerial sown rice .....	22
Improved control of barnyard grass in DPW rice .....	24
Trialling microwave-based weed management for rice .....	26
Repeat rice – what it means for pests and diseases .....	29
Managing rice blast in Australia for the future .....	32
Alternative management of rice straw .....	35
Seeding forage legumes after rice .....	38
Profitable rice for northern Australia .....	42
Social factors influencing technology adoption .....	45
Remote sensing P1 nitrogen uptake in rice .....	48
Overview of new short season breeding lines YRM70 and YRK5 .....	51
New process assists breeding of cold tolerant rice ....	54
Crack formation in rice grains .....	58
Developing cold tolerant Australian rice varieties .....	62
Analysing rice aroma using flavour metabolomics ....	66
Rice proteins .....	68
Rice bran protein – a “healthy” opportunity .....	70
Leading rice industry event returns to the Riverina .....	73
IREC Executive Committee and Advertiser's Index .....	75

## **Administration & Advertising**

The IREC Farmers' Newsletter is published by the Irrigation Research & Extension Committee. This Rice R&D Special Edition is the first to be delivered solely in an electronic format and will be distributed to irrigators and their advisors in the Lachlan, Murrumbidgee, Murray and Goulburn valleys.

General editions of the Farmers' Newsletter are distributed exclusively to members of IREC. If you wish to become a member either contact the IREC office or join via the [IREC website](#).

Businesses and organisations interested in advertising in the IREC Farmers' Newsletter should contact the IREC office.

### **IREC Office Manager: Hayley Wordsworth**

**IREC, Lot 255, Research Station Road,  
Griffith NSW 2680**

**P: 02 6963 0936 • M: 0418 402 197**

**E: irec@irec.org.au**

## **Editorial**

The IREC Farmers' Newsletter welcomes all suggestions and contributions for articles from irrigators, advisors and researchers in government and commercial sectors. If you have suggestions for articles or wish to contribute an article please contact the Editor. Please submit articles for the next edition, Autumn 2017, to the editor by 1 February, 2017.

### **The Editor: Lucy Kealey**

**IREC, Lot 255, Research Station Road,  
Griffith NSW 2680**

**M: 0417 043 982**

**E: lucykealey@bigpond.com**

## **Design & production**

Leysa Flores M: 0448 304 007 E: leysa.flores@gmail.com

## **Photography**

Cover: Fluorescence microscopy and imaging provided by Dr Mark Talbot, Plant Cell Biologist and Microscopist based at NSW Department of Primary Industries, Yanco Agricultural Institute. Unless otherwise indicated, all photographs are attributed to the author of the article in which the photograph appears.

### **Disclaimer:**

Articles contributed to the IREC Farmers' Newsletter are prepared by experts or professionals in their field or by persons with extensive experience in the subject areas. Accordingly, these articles are accepted in good faith as being the most relevant and accurate information available at the time of publication. Information contained within this newsletter has not been independently verified or peer reviewed, and advice is given at the reader's risk. Products or services may be identified by proprietary or trade names to help readers to identify particular types of products but this is not or intended to be an endorsement or recommendation of any product, manufacturer or service provider.

ISSN 0467 - 5282



## IREC Foreword

**THIS** edition marks a momentous point in the history of the IREC *Farmers' Newsletter*. This edition is the very first to be published in a digital format. The *Farmers' Newsletter* has been a prominent publication for irrigators of the southern Murray–Darling Basin since the 1940s, keeping them up to date with new research and cutting-edge technology.

IREC believes that going digital will open the *Farmers' Newsletter* to a wider audience, particularly younger farmers. This complements IREC's move to a range of digital information services, such as bimonthly email updates, YouTube clips, and podcasts; and it will enable greater interaction between IREC and irrigators through Twitter and Facebook. Supplying the *Farmers' Newsletter* in digital format will enable the flow of real-time information, which will benefit all our members.

IREC would appreciate your feedback on the new digital format and welcomes your thoughts and constructive critique.

IREC has a long and proud history of working with rice industry and I am pleased that this relationship continues to this day. I find it fitting that our first digital edition of the *Farmers' Newsletter* is also a special Rice R&D edition.

I encourage you all visit the new IREC website and follow IREC on Twitter (@IRECNSW) and Facebook (irecnsw), as this is a great way to stay in touch with relevant information.

I hope you find this edition enjoyable reading.

**Rob Houghton**

Chairman, IREC



## Rice R&D Foreword

**WELCOME** to this Rice R&D edition of the IREC *Farmers' Newsletter*.

Finally, it seems that the weather gods are smiling on us for a change. Seasonal conditions have improved dramatically over the last few months, dams are filling and water allocations are improving rapidly in the Murray and Murrumbidgee valleys. After several years of declining rice production, this season's outlook is much brighter; an optimism that now needs to be turned into tonnes of rice.

Maintaining an effective research, development and extension programme has been difficult over the past few years. Hopefully, the perseverance and efforts of everyone involved will bear rewards for all producers in the upcoming season. Serious decisions need to be made in the coming weeks and months: decisions on water availability and water use, decisions on varieties, methods of sowing and timing, and decisions on nutrient management and weed and pest control.

SunRice has openly stated that we need to produce upwards of 900,000 tonnes of rice to maintain our premium quality markets. The forthcoming limited release of YRM70 and YRK5, two much shorter growing season varieties, offers new opportunities for later plantings based on later water availability. The new varieties also provide better flexibility for double cropping programmes and lower water use. There are more exciting improved varieties to follow in coming years. Many of the projects highlighted in this edition of the *Farmers' Newsletter* focus on issues that should help producers lift productivity and profitability on farm.

One of the major changes to rice RD&E in the past year has been the relocation of RIRDC from Canberra to Wagga Wagga, which has seen a loss of key personnel. The rice industry has taken a positive approach to these changes and hopefully the relocation to the Charles Sturt University campus and the recruitment of new staff will be completed soon. A fresh start gives us a chance to re-evaluate how and how much we should invest in RD&E. This coincides with the start of our new five-year plan with a re-emphasis on lifting water use efficiency, through many different approaches.

I would like to thank all the researchers and extension staff, who have contributed to this edition of the *Farmers' Newsletter*. Many of these people work in isolation of each other but it is publications like this and the annual Rice R&D workshop in August that pull all these parts together.

A strong and vibrant rice industry is essential for the ongoing prosperity of our farms and our region. Hopefully, the information in this edition will help push us all to better outcomes.

**Ian Mason**

Chairman, RIRDC Rice R&D Committee



- A terraced bankless layout with 120–150 mm step between flat bays enables precise water management for rice crops. Photo MARK GROAT



# WATER USE EFFICIENCY THROUGH HIGH YIELDS

## QUICK TAKE

- A number of rice growers achieved yields of 15 t/ha or more in the 2015–16 rice season.
- Water use efficiency of 1.2 t/ML was achieved in a top-yielding crop grown on a well-designed and well-maintained irrigation layout.
- Understanding crop nitrogen requirements before and during the growing season is a critical component of a high-yielding rice program.
- Rice yields have increased over time due to improved varieties, better irrigation layouts and new chemical and fertiliser inputs.

**When pioneers of the Murrumbidgee Irrigation Area started growing rice in 1924, they would never have dreamt that rice could yield 15 t/ha.**

**Leah Garnett, Gae Plunkett and**

**Troy Mauger**

Rice Extension Project

In the 2015–16 rice growing season a number of growers achieved a rice yield of 15 t/ha or higher. One grower averaged 15.1 t/ha on 36 ha and 14.3 t/ha over the whole 100 ha crop. Over the last three years the same grower has averaged 13.5 t/ha for his rice.

So, what are the important management steps for a 15 t/ha crop?

- Do not be afraid to move dirt to achieve a good layout with high inflows, fast drainage and a re-use system. When landforming, topsoiling is important. The 15.1 t/ha grower owns a laser bucket so

that he can polish some paddocks each summer to maintain a zero grade.

- Do not hold back on chemical and fertiliser inputs where required.
- Understand the rice crop's nitrogen requirement:
  - do NDVI and NIR tests, even over Christmas, for the ability to ground truth and to make informed topdressing decisions
  - know the paddock history and the effect of different enterprises on nitrogen reserves, for example grazing compared with continuous cropping.
- Ensure high water levels at microspore and maintain the banks to allow for this; keep water levels low prior to panicle initiation (PI) to ensure a short plant.

## The 15.1 t/ha rice paddock

Location:	Benerembah
Layout:	Terraced bankless with flat bays
Previous crop:	Oats
Area:	36 ha
Variety:	Reiziq
Yield:	15.1 t/ha
Water use:	12.7 ML/ha
Water use efficiency:	1.2 t/ML
ReiziqA price:	\$415/t
Gross income:	\$6267/ha
Variable costs <sup>1</sup> :	\$1925/ha
Gross margin/ha:	\$4341
Gross margin/ML:	\$342

<sup>1</sup> Plant breeders rights

<sup>1</sup> Includes water delivery charges only



- Topsoiling is important when levelling irrigation layouts, to ensure soil fertility and structure across the field are as uniform as possible.

## Growing 15.1 tonnes

### Layout and soil

The paddock had six bays, each 6 ha in size, on a terraced bankless layout with flat bays and a 120–150 mm step. It was last landformed in 2012 when cut areas of more than 10 cm were deep ripped and at least 5 cm of topsoil was applied. The deepest cuts were up to 26 cm.

The soil was a transitional red brown earth and the paddock historically had low water use. The previous two crops were grazing oats. Single super was applied at a rate of 200 kg/ha to the last oat crop to build up phosphorus in the soil.

### Fertiliser

Both urea and a starter fertiliser were broadcast before spreading the seed. In the fill areas, urea was applied at 250 kg/ha and Rice Energiser at 150 kg/ha; and in the cut areas, urea was applied at 315 kg/ha and Rice Energiser at 225 kg/ha. Liquid zinc fertiliser was applied to the seed (in the auger) immediately before sowing. The grower was unsure if the zinc seed treatment had much effect on the seedling growth but because he has had trouble with establishment in the past, he was willing to apply it at the cost of \$3.75/ha.

### Sowing

Reiziq seed was broadcast at 160 kg/ha. The seed and fertiliser were rolled in after spreading. The grower aimed to bury the seed to stop seedling drift in windy conditions and to prevent crop damage by ducks. The number of ridge roller operations depended on the firmness of the seedbed.



- Seed and fertiliser were rolled into the seedbed after spreading and prior to fill-up to prevent wind and duck damage. Photo MARK GROAT



- NIR sampling is important to determine nitrogen topdressing rates.

**Table 1. Crop operations and inputs**

Date	Operation	Input (per ha)
Prior to sowing	Disc	
	Scarify	
	Grader board	
	Re-form banks	
	Broadcast starter fertiliser	150–225 kg/ha Rice Energiser
	Broadcast urea	250–315 kg/ha urea
22 Oct	Broadcast seed	160 kg/ha Reiziq
		5 L/t liquid seed dressing
	Ridge roll	
	Flush and fill	
31 Oct	Contract aerial spray	3 L/ha molinate 2 L/ha Taipan 150 mL/ha Lorsban
12 Nov	Contract aerial spray	3 L/ha Saturn 150 g/ha Londax 150 mL/ha Dominex Duo
End Dec	NDVI image, PI cuts and NIR tissue tests	
6 Jan	Contract aerial topdress	200 kg/ha urea
	Drain	
12 Apr	Harvest	

### Flush and fill-up

The bays were flushed before fill-up. Each bay took approximately 12 hours to get the water on and off. The grower said the soil should dry out but not enough to walk on it after the first flush. Fill-up was within 10 days of flushing, depending on the weather. Directly filling up with permanent water has been tried but experience shows that rice establishment is greatly improved by including a flush before fill-up.

### Weed control

The grower was not worried about the flush resulting in weeds germinating because he had confidence in his herbicide program. He used two herbicide modes of action for barnyard grass (molinate and Saturn®) and for dirty Dora (Saturn and Londax®). The broadleaf weeds were controlled with Taipan®. Taipan, molinate and Lorsban® were applied within 10 days of filling the paddock when the rice was just starting to germinate. This was followed with Saturn, Londax® and the insecticide Dominex Duo®, 13 days later.

### Water levels

The water level was kept as low as possible during the season so the plant stayed short and the developing panicle was close to the soil surface. This meant that when the water level was increased to 25–30 cm after panicle initiation, the developing panicle was under water and insulated from the cold. The water level was monitored using a depth peg.

### NIR sampling

At panicle initiation, the grower did his own NIR sampling. Sampling provides him an opportunity to get out into the crop to see how it is going, as well as helping determine nitrogen topdressing rates.

Before PI, the grower had an NDVI image taken by satellite and used the image to select six places in the crop to sample, to make three composite samples. When the NIR test results were received the grower decided on a topdressing rate that was within the range of recommendations for the three samples. He doesn't top dress at variable rates because of the difficulty of doing so by plane.

### Drainage and harvest

The crop was drained 21 March when there were 5–10% milky grains. It was harvested 12 April with a John Deere 9750 rotary header with a 25-foot draper front. The crop was uniform and delivered at 20% moisture.

The total water use of the rice crop was 12.7 ML/ha.

### Benefits of R&D and grower innovation

Rice growing has seen many changes since 1924, and particularly since the 1950s. Research, development and grower innovation have resulted in improved varieties, better irrigation layouts, new chemical and fertiliser products, and matching of management and inputs to soils and paddocks, which have enabled incremental steps in yield over time.

On the farm that grew 15.1 t/ha of rice in the 2015–16 season, a combination of suitable soil type, layout and management (including sowing within the recommended planting window), high water levels after panicle initiation, accurate fertiliser rates and weed-free crops resulted in an outstanding yield.

Rice Extension will continue to investigate the factors that most influence high yields throughout the rice growing areas. High yields are a large factor contributing to good water use efficiency, i.e. getting the most tonnes of crop out of every megalitre of water.

Rice Extension acknowledges that many growers follow the latest crop production recommendations, have similar rice growing practices to those outlined in this report and produce the best yields that their land and business can achieve.

### RIRDC Project PRJ-009296

Rice Extension Coordination

### Acknowledgment

Thank you to the grower of the 15.1 t/ha crop for sharing the information used in this report.

### More information

Gae Plunkett  
Rice Industry Extension Coordinator, Leeton  
M: 0419 790 019  
E: gplunkett@rga.org.au



## **Yenda Producers Co-operative Society Ltd**

### **General Merchants, Fertiliser Spreading**

*Suppliers of all growers' requirements*

#### **YENDA**

**James Mann**  
0427 5666 73

**Tom Brewer**  
0437 5666 89

**Steven Serafin**  
0427 5666 92

**Ann Furner**  
0467 6810 07

#### **LEETON**

**Sam McGrath**  
0427 5666 53

**Elizabeth Munn**  
0427 5666 56

**Josh Hart**  
0427 5666 71

**Geoff Miller**  
0427 5666 91

#### **GRIFFITH**

**Peter Hill**  
0427 5666 50

**Dean Andrighetto**  
0427 5666 69

**Geoff Bray**  
0427 5666 65

**Paul Geddes**  
0427 5666 76

*Fertilisers ~ Fertiliser Spreading ~ Fencing Materials  
Agronomic Advice ~ Animal Health ~ Dried Prune Agents  
Fuels and Oils ~ Herbicides Cartage ~ Hardware*

**Yenda Branch: (02) 6961 3300      Fruit & Case Branch: (02) 6968 1268**

**Leeton Branch: (02) 6953 9000      Griffith Branch: (02) 6966 8900**



# **4 ways we can improve irrigation efficiency on your farm**

**GPS TECHNOLOGY  
PROJECT MANAGEMENT  
EXPERIENCE  
KEY SUPPLIERS**

**RIVERINA EARTHWORKS HAVE:**

- ✓ The greatest range of equipment in the district
- ✓ Local permanently based staff throughout the Riverina
- ✓ Over 25 years of experience in Irrigation Farming
- ✓ Third Party Certified Safety Management System

**RIVERINA  
EARTHWORKS**  
YOUR TOTAL EARTHMoving SOLUTION

For more information  
call us on 0411 825 824  
or visit our website  
[www.riverinaearthworks.com.au](http://www.riverinaearthworks.com.au)

Proud  
Members of



- Riverina rice crops support the largest known breeding population in the world of the endangered Australasian bittern.



# BITTERNS IN RICE PROJECT: THE FIRST FOUR YEARS

## QUICK TAKE

- Riverina rice fields support around 40% of the global population of Australasian bitterns.
- The bitterns use rice fields for breeding, nesting and raising fledglings.
- Rice crops provide enough cover to hide the secretive birds, as well an ample supply of food to support a growing population.
- Growers can undertake a range of actions that will benefit bitterns and most importantly foster an environment that creates abundant prey and a season with sufficient time for the chicks to fledge before harvest.
- The Bitterns in Rice Project has also shown the value of rice fields to a wide range of other waterbirds and wildlife.

**It all began in 2012 with the simple idea of learning more about a strange waterbird — the Australasian bittern (*Botaurus poiciloptilus*) — and its use of rice crops.**

### Matt Herring

Charles Darwin University, Darwin

### Neil Bull

Ricegrowers' Association of Australia, Leeton

### Anna Wilson

Riverina Local Land Services, Coleambally

**W**HAT might rice growers be able to do to help this globally-endangered waterbird? Fast-forward to 2016, with four rice seasons now under our belt, and the Bitterns in Rice Project has grown to become a widely recognised win-win example of the potential for wildlife-friendly farming in Australia.

The total population estimate for the Australasian bittern is just 1000–2500 mature individuals, with most of those residing in south-eastern Australia and New Zealand. With the ongoing support of rice growers, we have been able to apply a random sampling approach to our bittern surveys and population modelling. In a nutshell, we now know that in most years the rice crops of the New South Wales Riverina support around 40% of the global

population of the species. It is clear that rice crops play a key habitat role, together with a mosaic of natural wetlands on public and private land.

Bitterns typically arrive in rice crops about two months after sowing when there is enough cover to hide them. In November 2015, there was a significant sighting of at least 30 bitterns at Fivebough Swamp near Leeton, just prior to rice crops becoming suitable for bitterns, highlighting the importance of a wetland network.

Males establish territories in rice crops at the beginning of summer and their iconic booming calls, linked to the legend of the bunyip, can be heard until February. From our work, we now also know that there is widespread breeding. Pairs are common but it is not unusual for a male to attract more than one female. At a site near Griffith, three nests in adjacent rice bays, each with an attending female, were found within the booming territory of one male. We speculated that he may have a particularly resonant boom or that his rice field harboured a rich supply of tadpoles.

## Traditional is best

One of our key findings is that bitterns prefer rice crops with more traditional sowing methods that involve early permanent water. We hypothesised that it was related to prey and during the 2015–2016 season we verified this. Direct drilled and other delayed permanent water crops had substantially less prey leading into the peak breeding period for bitterns.

A wide range of prey was found in crops favoured by bitterns, such as dragonfly larvae, water beetles, mosquitofish (*Gambusia holbrooki*) and common carp (*Cyprinus carpio*). By far the most abundant prey was tadpoles. There were four species, the spotted marsh frog (*Limnodynastes tasmaniensis*), barking marsh frog (*L. fletcheri*), plains froglet (*Crinia parinsignifera*) and southern bell frog (*Litoria raniformis*), the latter a threatened species itself, with strongholds in the Coleambally Irrigation Area and the western Murray Valley.

There is a range of actions that rice growers can take to benefit bitterns, such as controlling foxes and cats, maintaining grassy banks and supplementing rice fields with adjacent habitat areas, but central to bittern friendly rice farming is fostering management that creates abundant prey and a season with sufficient time for the chicks to fledge before harvest. We have observed fully-fledged young at harvest time and the prospect of ramping up the bittern yield is a key focus for the future.

## Southern winter home

But what about the rest of the year when there is no rice? Where does the world's largest known Australasian bittern breeding population go for winter? Thanks to a successful crowdfunding effort that united irrigators and conservationists for a common goal, the answers are emerging.

The first bittern to be satellite tracked was Robbie, named by the Coleambally Irrigation Cooperative after Mark Robb, as a fitting tribute to his efforts on the project. Robbie's journey became legendary, as thousands of people followed him for 323 days while he stitched together seemingly disparate wetlands across south-eastern Australia. At harvest time, only nine days after we met him, he flew 557 km from Coleambally to Pick Swamp, a restored wetland on the South Australian coast. He moved 20 km back into Victoria to another recently restored wetland, Long Swamp, and stayed for four months before returning to the Riverina. He landed at Lake Wyangan near Griffith, just a stone's throw from one of the most important bittern wetlands in

the Riverina, Campbell's Swamp. He was too early for the next rice season though, and slowly made his way back south.

Robbie provided us with our first insights into the network of wetlands that these bitterns rely on outside of the rice season. His fame grew and when we lost contact there was an outpouring of despair and intense media interest, culminating in a live television interview on BBC World News. Robbie was officially the most famous bittern in history. He had highlighted the important role of both restored swamps and agricultural wetlands.

Fortunately, we had added new bitterns to the tracking crew. There was Vin, named by the Murray-Darling Wetlands Working Group as a tribute to a long-standing member, Vin Byrnes, who'd recently passed away. At harvest Vin flew 191 km towards Sydney before we lost contact near Temora.

Coly-Lion came courtesy of the Coleambally Lions Club. Like Vin, he was an adult male that we'd lured into a cage trap with the help of a mirror and a speaker playing the booming call. He stayed tight within his territory until harvest time. But then the transmitter failed and we lost contact. Amazingly, some eagle-eyed observers at Tootgarook Swamp, south of Melbourne on the Mornington Peninsula, spotted a bittern with a little lump on its back. It was Coly-Lion, 395 km from his Coleambally rice crop breeding territory.

Then there was Neil from Murrami near Leeton. The Ricegrowers' Association of Australia named him after one of its own, Neil Bull. Neil didn't disappoint either. He took a 450 km U-turn of sorts via the Wakool River floodplain near Swan Hill all the way to Moodie Swamp, north of Benalla.

Another bittern named COG, representing the Canberra Ornithologists Group, stayed put in Murrami channels. Four of our first five bitterns made big movements at harvest time, with three heading south into Victoria. Next season we'll be trying harder than ever to catch the elusive females and see what they do.

## Benefits of irrigation

In February 2016, we hosted the Threatened Species Commissioner, Gregory Andrews. With the announcement that the Australasian bittern had been added to national priority list of threatened bird species, the visit was about seeing what the Bitterns in Rice Project was all about. We were able to take Gregory to an active bittern nest and he was delighted. The opportunity to marry farming and threatened species conservation couldn't be clearer. He kept thanking individual rice



● Threatened Species Commissioner, Gregory Andrews, with a bittern chick near Coleambally.

growers for being custodians of one of the world's rarest birds. The sentiment was well received and taken as an acknowledgement from Canberra that there can be environmental benefits to irrigation.

Along the way, we have uncovered the value of rice fields to a wide range of other wildlife. In our first season we documented 87 endangered Australian painted snipe, six migratory shorebirds from the northern hemisphere, breeding by broglas and roosting eastern grass owls. Large populations (probably exceeding 10,000) of Baillon's crake, glossy ibis and whiskered tern have also been documented, and the list goes on.

Our work has highlighted the overlooked conservation role of irrigation areas and constructed habitats, especially agricultural wetlands like rice fields and farm dams. We are challenging the dominant paradigm that land and water should only be managed for the environment or for agriculture, rather than having a dual purpose.

## RIRDC Project PRJ-007956

Bitterns in Rice Research Project

## Acknowledgment

The Bitterns in Rice Project is funded primarily by Riverina Local Land Services through the Australian Government's National Landcare Programme. For regular updates, including the movements of the tracked bitterns, visit [www.bitternsinrice.com.au](http://www.bitternsinrice.com.au) or follow the Bitterns in Rice Project on Facebook.

## Further information

Matt Herring  
E: mherring@murraywildlife.com.au  
M: 0428 236 563  
W: [www.bitternsinrice.com.au](http://www.bitternsinrice.com.au)

● Chris Dawe and Tina Dunn counting plants in one of the aerial sown plant population experiments.



# TARGET PLANT POPULATION FOR YIELD AND PROFIT

## QUICK TAKE

- The recommended plant population for all current commercial rice varieties in the Murray and Murrumbidgee valleys is 100–300 plants/m<sup>2</sup>.
- Rice grain yields do not decline due to plant number until plant populations are less than 40 plants/m<sup>2</sup>.
- The minimum plant population required to cover input costs of production is 10 plants/m<sup>2</sup>, if plants are uniformly spaced and best management practice is followed.
- It is not recommended to sow more than 150 kg/ha of seed for any variety or sowing method.

Researchers have determined guidelines of plant populations and sowing rates for current rice growing practices in the Murrumbidgee and Murray valleys.

**Brian Dunn, Tina Dunn, Craig Hodges and Chris Dawe**

NSW Department of Primary Industries,  
Yanco Agricultural Institute

**John Fowler**

Murray Local Land Services, Deniliquin

**T**HE RIRDC-funded project *Influence of plant population on rice growth and grain yield* has been investigating the optimum plant population required to maximise rice grain yield, and determining how low plant populations can go before yield is reduced and if high plant populations lead to reduced grain yield due to increased sterility.

A series of 20 field experiments was established during the three years of the project to fully investigate plant

populations in both aerial and drill sown rice. Experiments were located in both the Murrumbidgee and Murray valleys, covering a range of soil types and using several current rice varieties. The aerial sown experiments were conducted in commercial farmers' fields (Table 1). A range of sowing rates and row spacing was included in the drill sown experiments and nitrogen rates and timing were also investigated (Table 2). Intensive monitoring and data collection was conducted on the experiments to determine the factors involved in plant population that impact rice grain yield.

## Recommended population

No difference in grain yield was observed for plant populations between 40 and

**Table 1. Aerial sown plant population experiments conducted in the project. All experiments were located in commercial rice fields with the farmer managing field preparation, water management, nitrogen and pesticide applications.**

Season	Site	Variety	Sowing rates (kg/ha)
2013–14	Mayrung	Reiziq	25, 50, 75, & 150
	Bunnaloo	Sherpa	25, 50, 75, & 150
	Morago	Reiziq	25, 50, 75, & 150
	Jerilderie	Opus	25, 50, 75, & 150
2014–15	Mayrung	Reiziq	25, 50, 150 & 450
	Bunnaloo	Opus	25, 50, 150 & 450
	Morago	Reiziq	25, 50, 150 & 450
	Jerilderie	Reiziq & Opus	25, 50, 150, 300
2015–16	Mayrung	Sherpa	25, 50, 150 dry & 150, 450 pre-germinated
	Bunnaloo	Reiziq	25, 50, 150 dry & 150, 450 pre-germinated
	Murrami	Langi	25, 50, 150 dry & 150, 450 pre-germinated

**Table 2. Drill sown row spacing and plant population experiments conducted in the project.**

Season	Site	Variety	Row spacing (cm)	Sowing rates (kg/ha)	Nitrogen rates (kg N/ha)
2013–14	YAI*	Reiziq, Sherpa	18, 27, 36	25, 50, 150, 300	90, 150
	Jerilderie	Reiziq, Sherpa	18, 27, 36	25, 50, 150	90, 150
2014–15	YAI	Reiziq, Topaz	18	25, 50, 150, 300	60–60, 120, 180
	LFS	Reiziq, Langi	18, 27, 36	25, 50, 150	180
	Jerilderie	Reiziq, Opus	18, 27, 36	25, 50, 150	180
2015–16	YAI	Reiziq, Topaz	18	25, 50, 150, 300	90–60, 90, 150
	Jerilderie	Reiziq, Koshi	18	25, 50, 150, 300	90–60, 90, 150
	LFS	Reiziq, Langi	18, 27, 36	25, 50, 150	240
	Jerilderie	Reiziq, Opus	18, 27, 36	25, 50, 150	150

\* Yanco Agricultural Institute

740 plant/m<sup>2</sup> where a direct comparison between plant population and grain yield was measured in over 800 research plots (Figure 1). It is recommended that growers in the Murray and Murrumbidgee valleys aim to achieve a plant population between 100 and 300 plants/m<sup>2</sup> for all sowing methods. This provides a buffer should establishment problems occur.

High grain yields can still be achieved with plant populations less than 40 plants/m<sup>2</sup> but there is a declining trend in yield with decreasing plant population (Figure 1). Uniformity in distribution of the plants becomes increasingly important in maintaining grain yield at plant populations less than 40 plants/m<sup>2</sup>.

As plant population decreased, the number of tillers each plant produced and the number of grains per panicle increased. Both of these factors combine to help to maintain grain yield at low plant populations.

The varieties tested included Reiziq, Sherpa, Langi, Opus, Topaz and Koshihikari and they all responded similarly to changes in plant population.

#### Lower plant population limit

The lower plant population limit is

dependent on the cost that a grower puts on the inputs used to grow the crop and if the crop is aerial or drill sown. Gross margin analysis using 2015 input costs and contractor rates reveal that yields of 4.8 t/ha for aerial rice and 3.7 t/ha for drill sown rice are required to cover the gross margin input cost of a crop (Table 3).

A minimum plant population of 10 plants/m<sup>2</sup> can achieve these critical yield levels provided the plants are uniformly distributed and best management practice is followed (Figure 2).

At low plant populations the distribution of plants is often more important than the number of plants in maintaining grain yield. Therefore it is recommended that the rice ring (0.2 m<sup>2</sup>) be used to determine plant population and distribution. Ten plant counts, using the ring, should be obtained for each zone in the field with different plant population levels. When 10 plants/m<sup>2</sup> is the minimum target population, an average of two plants per ring from the ten rings counted would be required. If more than three of the rings have only one plant or one ring has zero plants then re-sowing the poor establishment areas in the field is recommended.

#### Upper plant population limit

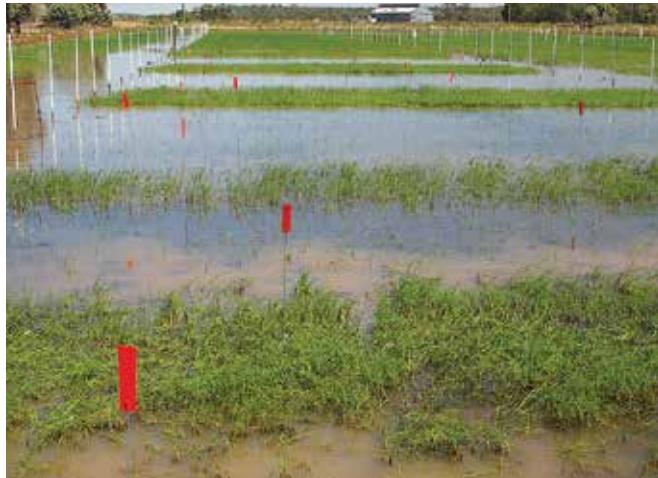
The upper plant population limit for aerial and drill sown rice and delayed permanent water is 300 plants/m<sup>2</sup>. The results are not conclusive regarding any impact very high plant populations may have on cold induced sterility, but there is no yield advantage in having a plant population greater than 300 plants/m<sup>2</sup> and seed costs will be higher.

There is no practical or economic benefit in having very high plant populations. High sowing rates rarely result in improved plant populations when establishment problems occur. Sowing rates greater than 150 kg/ha are not recommended for any sowing method or any potential circumstances during the growing season.

#### Row spacing

Row spacing between 18 and 27 cm is recommended for drill sown rice. A row spacing wider than 27 cm is not recommended as missing rows or gaps in plants within rows cannot be compensated for by neighbouring plants and grain yield is reduced.

There is no advantage in row spacing narrower than 18 cm and no potential for increased grain yield. The required sowing equipment is more expensive to purchase



● Aerial sown density experiment showing the very high plant population where the seed was pre-germinated compared to the very low density where seed was spread on the soil surface prior to permanent water.

and maintain, and is more prone to blockages of trash.

## Sowing rates

Rice should not be sown at rates higher than 150 kg/ha for any variety or sowing method. To establish 200 plants/m<sup>2</sup> at a seed establishment of 40% requires a maximum sowing rate of 150 kg/ha. If the establishment at 150 kg/ha is as low as 20% there will still be 100 plants/m<sup>2</sup> established, which is sufficient to achieve maximum grain yield when best management practice is adhered to. Recommended sowing rates for rice varieties based on seed size and establishment percentage are presented in Table 4.

Increasing sowing rates to compensate for poor field layout, unsatisfactory seedbed preparation or unreliable sowing method is rarely successful at increasing plant population and not recommended.

## Sowing method

The broadcasting (spreading) of dry seed onto the soil surface and then applying permanent water to the field led to poor plant establishment in many experiments and is not a recommended sowing method. If dry broadcasting of seed is going to be practiced, the field must be flushed and then drained to allow the seed to access oxygen before permanent water is applied.

The significant economic and practical benefit of drill sowing compared with aerial sowing methods has been highlighted in this research. With water being such a valuable resource, it is critical that establishment is well managed or water productivity and crop profitability will be reduced. Drill sowing not only uses less water than aerial sowing but the losses in both input costs and amount of water used are significantly less if establishment is poor and it is necessary to abandon the crop.



● Collecting PI samples from the YAI drill sown variety by density experiment in 2015–16 season.

## Future research

Research into varietal differences in seed establishment percentage and establishment vigour will be continued so that sowing rates recommendations can be fine-tuned for all current varieties and provided for new varieties as they are released.

### RIRDC Project PRJ-008764

*Influence of plant population on rice growth and grain yield*

### Acknowledgements

This research was funded by the Rural Industries Research and Development Corporation and NSW Department of Primary Industries.

### Further information

Brian Dunn  
Research Agronomist  
T: 02 6951 2621  
E: brian.dunn@dpi.nsw.gov.au

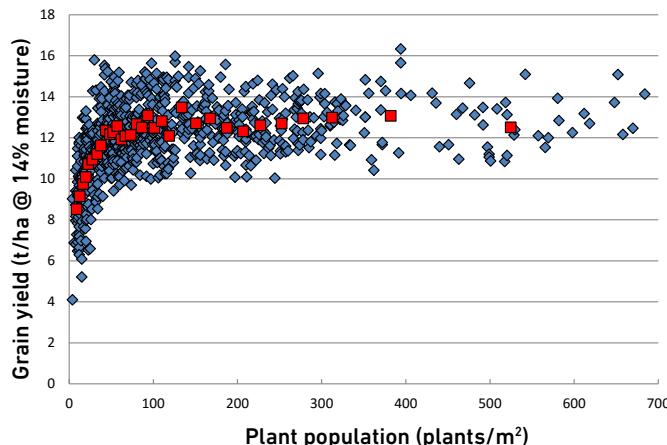


Figure 1. Grain yield obtained at different plant populations from 808 aerial and drill sown plots in the project, across all sites and seasons. Red squares are average of 25 data points.

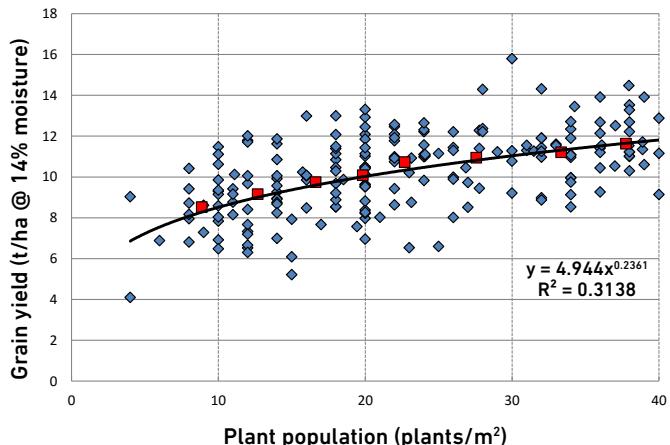


Figure 2. Grain yield obtained from all experiments at plant populations less than 40 plants/m<sup>2</sup>.



● Aerial photo of the row spacing experiment at Jerilderie in 2016, as the crop nears harvest.

**Table 3. Gross margin for growing a 10 t/ha rice crop in 2015**

Gross margin*	Aerial sown		Drill sown	
	\$/ha	t/ha	\$/ha	t/ha
Income 10 t/ha @ \$350/t	3500	10.0	3500	10.0
<b>Crop establishment costs</b>	<b>983</b>	<b>2.8</b>	<b>457</b>	<b>1.3</b>
Remaining season costs	708	2.0	827	2.4
Total gross margin costs	1691	4.8	1284	3.7
<b>Gross margin profit</b>	<b>1809</b>	<b>5.2</b>	<b>2216</b>	<b>6.3</b>

\* Water @ \$16/ML variable charge

**Table 4. Sowing rates required to meet plant population recommendations based on seed size and varietal establishment percentage.**

Variety	Sowing rate (kg/ha)
Reiziq & Topaz	150
Sherpa, Langi, Doongara, Opus, Koshihikari & Kyeema	130

## AGnVET Services for the best local service, right advice and quality products

AGnVET Services have been servicing and supporting rice growers for over 35 years, with quality branded products and local experienced agronomy teams delivering a range of on-farm services and advice, including custom blend fertilisers *Energiser* & *Utiliser*.

Coleambally	02 6954 4152	Bencubbin Avenue
Griffith	02 6964 2999	26-28 Banna Avenue
Jerilderie	03 5886 1609	19 Southey Street
Leeton	02 6953 3803	13-15 Brady Way
Hay	02 6993 3299	Cnr Lachlan St & Showground Rd



● Tina Dunn and Erika McAlister placing single grains in rows at 2.5 cm depth in seedling vigour field experiment.



# IMPROVED RICE VARIETY MANAGEMENT INFORMATION

## QUICK TAKE

- This project is assessing all new varieties prior to release so a variety-specific agronomic package of best management practice is available to growers.
- The recommended sowing dates for current varieties have been updated using 2015–16 phenology results from this project and data from previous seasons collected in the NIR and remote sensing project.
- Nitrogen rate and timing recommendations will be fine-tuned for current varieties and available for new varieties upon their release.
- Seedling vigour and percentage of seed established will be further investigated to assess sowing rates and establishment recommendations for all varieties.

**Investigation of management for current rice varieties will improve information for growers, so they can consistently achieve high grain yields and water productivity.**

**Brian Dunn, Tina Dunn, Craig Hodges and Chris Dawe**

NSW Department of Primary Industries,  
Yanco Agricultural Institute

**T**HE project *Rice variety nitrogen and agronomic management* commenced in July 2015 to investigate the agronomy, phenology and nitrogen management of all current varieties and new varieties as they near release. The aim of the project is to provide growers with improved agronomic information enabling them to make better management decisions, which lead to increased regularity of high grain yields and water productivity, with reduced risk.

To provide reliable and robust recommendations to growers, data must be acquired for all rice varieties covering different regions, soil types, sowing methods and multiple seasons.

'Variety by nitrogen' agronomy experiments will be conducted each season with extensive measurement of

rice establishment, growth, grain yield, yield components, lodging, grain quality and phenology. Results from each year's experiments will be combined to establish a large database of information on all rice varieties across a range of seasons and growing environments. Each season's results will be used to assess current agronomic recommendations for each variety and modify recommendations when required, to provide growers with improved agronomic management packages.

## 2015–16 results

Six variety experiments were established in the Murrumbidgee and Murray valleys covering a range of soil types across aerial, drill and delayed permanent water sowing and management methods (Table 1). A range of nitrogen rates and application timings was included in the experiments.

## Grain yield

Grain yield results for each variety, averaged over nitrogen rates, are presented

**Table 1. Variety experiments conducted in the 2015–16 season.**

Location	Sowing method	Sowing/first flush date	Varieties	Nitrogen treatments
Mayrung	Aerial	3 Nov	Reiziq, Sherpa, Koshi & Opus	6
Murrami	Aerial	29 Oct	Langi, Topaz, Doongara & YRL127	6
Leeton	Drill	2 Dec	Reiziq, Sherpa, YRM70 & YRK5	6
Yenda	Drill	27 Nov	Reiziq, Sherpa, Jarrah & YRM70	6
Jerilderie	Drill & DPW	1 Nov	Reiziq, Sherpa, Koshihikari, Kyeema, Opus, Topaz	2
Yanco	Drill & DPW	9 Oct	Reiziq, Sherpa, Langi, Topaz, Doongara, YRL127	2

**Table 2. Grain yield (t/ha@14% moisture) achieved for each variety when averaged across nitrogen rates (including a zero), in each experiment.**

Variety	Mayrung (Aerial)	Murrami (Aerial)	Jerilderie (Drill)	Jerilderie (DPW)	Yanco (Drill)	Yanco (DPW)	Leeton (Drill)	Yanco (Drill)
Reiziq	11.36		10.86	10.28	14.58	14.15	10.87	11.50
Sherpa	12.56		12.50	12.21	14.61	11.41	10.87	11.72
Langi		11.99			12.60	12.55		
Topaz		11.78	10.24	7.26	12.72	11.07		
Opus	11.53		10.92	10.40				
Koshihikari	8.73		10.60	10.01				
Doongara		12.04			13.15	12.68		
Kyeema			10.18	8.97				
YRM70							10.83	12.26
YRL127		11.78			12.62	12.02		
YRK5								9.49
Jarrah								11.75
I.s.d. (P<0.05)	0.44	n.s.	0.67	0.87	0.83	0.80	0.42	0.36

In Table 2, interpretation of the results is often complex with different growth durations of varieties affecting factors like the timing of microspore and flowering as well as haying off and lodging, which can impact grain yield of some varieties and not others in individual experiments.

In a brief summary, Sherpa yielded significantly higher than Reiziq in three experiments, had the same yield in three experiments and had a lower yield in one experiment.

YRM70, a short season potential replacement for Reiziq, produced the highest grain yield at the Yenda site, but the yield of both Reiziq and Sherpa was reduced by early draining and haying off. At the Leeton site, where the field remained flooded until all varieties were past physiological maturity, there was no difference in grain yield between YRM70, Reiziq and Sherpa.

The grain yield of all varieties was slightly less under delayed permanent water (DPW) than conventional drill but at the Jerilderie site the sowing date was too late for DPW and some varieties were severely impacted by cold at early pollen microspore (EPM).

### Phenology

The time that a variety takes to reach critical growth stages, such as panicle initiation (PI) and flowering, has a big impact on its management, particularly the sowing window. The timing of these growth stages can move a little between seasons due to different temperatures and also vary with sowing method and irrigation management. It is important that varieties are sown at the correct time for EPM to occur when there is the highest probability of warm minimum temperatures (i.e. from 15 January to 5 February). Sowing earlier or later than the recommended window increases the risk of low temperatures during EPM, which can dramatically reduce grain yield. Early sowing can also result in grain fill occurring during periods of high temperature, which can reduce whole grain millout.

The time of sowing or first flush, panicle initiation, microspore and flowering for each variety at a commercial nitrogen rate, in each experiment is shown in Figure 1. Sherpa is on average five days earlier to reach flowering than Reiziq, but when both are sown late their number of days to flowering is similar. The two new varieties near potential release, YRM70 and YRK5, are both shorter in maturity than Reiziq and

Sherpa, flowering 10–14 days earlier.

Phenology results from three seasons of experiments conducted in the rice NIR and remote sensing project (see page 48) have been combined with results for the 2015–16 season from this project to update the recommended sowing window for current varieties. The updated sowing windows have been included in the *2016 Rice Variety Guide* and will be discussed at rice pre-season meetings.

### Grain quality

Grain samples have been sequentially collected, from six experiments across varieties and nitrogen treatments, as they matured and went below 23% grain moisture. Collection of grain at this moisture level allows quality results to be determined before environmental factors such as rain or temperature fluctuations significantly impact grain quality properties. These samples are provided to the rice breeding and grain quality team for analysis. This provides a distinct value-adding component to the project, saving the rice breeding and quality team significant time and costs by not having to conduct experiments to gain the required samples.



● Aerial photo of drill sown rice agronomy experiments at Yanco Agricultural Institute, February 2015.

### Seedling vigour

An important aspect of rice agronomy is seedling vigour. Two experiments were conducted in a constant temperature room measuring the shoot and root growth of 13 current and future varieties. The same varieties were also tested in two field experiments, one on the heavy self-mulching clay soil at Leeton Field Station and the other on the red-brown earth at Yanco Agricultural Institute. Rows of seeds for each variety were planted at a depth of 25 mm and each day the number of seeds emerged was counted.

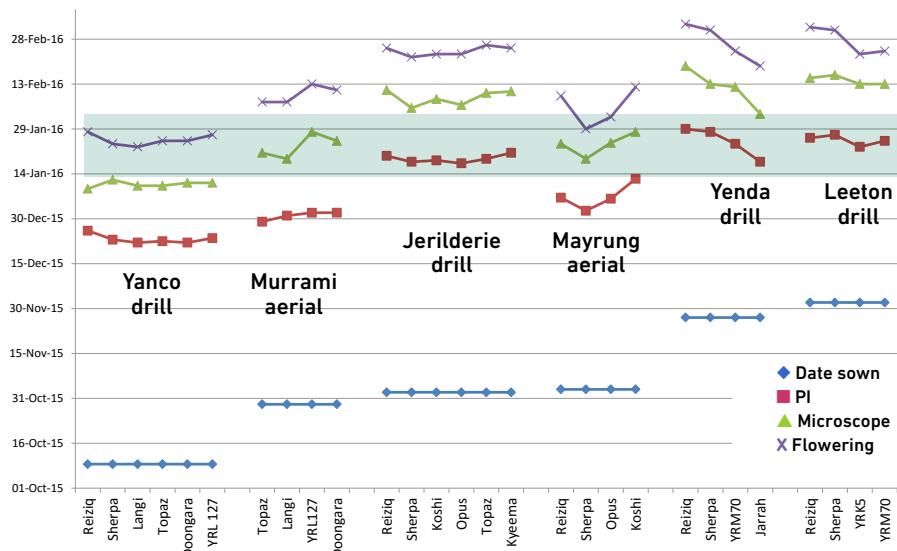
Varieties were compared on the time it took the seedlings to emerge from the soil and the percentage of seed established.

We currently only have one season of results, so recommendations are difficult to provide, but across laboratory and field studies Reiziq showed the best seedling vigour of all varieties and also the longest coleoptile length. When measuring seedling vigour, the environment the seed came from can have a large impact on the vigour of the seedling. To account for this environmental variability, seed was collected from the Yanco experiment and will be used in next season's experiments, to ensure we are only measuring genetic variability in seedling vigour.

### Future research

As further research is conducted over coming seasons the value of the information from this project will increase as will the robustness of the recommendations.

Phenology of current and new varieties will continue to be assessed and sowing date recommendations refined when required.



● Figure 1. Time of sowing or first flush, panicle initiation, microspore and flowering for each variety in six experiments, at commercial nitrogen rates. The green box illustrates the preferred time for microspore to occur to maximise probability of warm minimum temperatures.

Research into varietal differences in seed establishment percentage and establishment vigour will be continued so that sowing rate recommendations can be fine-tuned for all current varieties and provided for new varieties as they are released.

In future, as new varieties are released to the rice industry, there will be a good source of agronomic data from research undertaken in this project that will be used to develop a variety management package to be released with each new variety.

### RIRDC Project PRJ-009790

Rice variety nitrogen & agronomic

management

### Acknowledgements

This research was funded by the Rural Industries Research and Development Corporation and NSW Department of Primary Industries.

### Further information

Brian Dunn

Research Agronomist

T: 02 6951 2621

E: brian.dunn@dpi.nsw.gov.au

# BRUNO ALTIN & CO

## PTY LTD

The Precast Concrete Specialists



### Specialising in:

- Bankless channel systems
- Automated Water stops
- Winch Control Systems
- Irrigation, Cotton & Rice Farming

With a vast range of new & improved products, come in and visit our rural display for all your farming needs.

Australian  
Standard

AS/NZS 4058:2007  
Pre-cast Concrete Pipes  
(pressure & non-pressure)

Lic No. SMK00685  
Certified by SAI Global



BRUNO ALTIN & CO PTY LTD

HILLSTON ROAD, GRIFFITH NSW 2680

PH: (02) 6962 1184 F: (02) 6962 6611

E: sales@brunoaltin.com.au

www.brunoaltin.com.au

- Collecting data is as simple as tracing out the paddock boundaries with apps such as Drone Deploy. The app then takes control of the drone and it flies over the indicated field collecting multiple images.



# NEW TOOLS FOR MEASURING AND MANAGING VARIABILITY

## QUICK TAKE

- Low-cost drone-based platforms have taken off worldwide with global drone companies now releasing drones suited to agricultural monitoring with sub-\$2000 price tags, for example the DJI Phantom 4.
- Software providers, such as Drone Deploy and Pix4D, have developed apps that allow fully automated flights to collect very high resolution aerial data (sub-5 cm pixels) and process this data in the cloud.
- Specialised agricultural start-up companies provide multi-spectral and thermal camera add-ons for these drone platforms, further extending the usefulness of such aerial monitoring devices, particularly for looking at variability issues associated with crop water and nitrogen.

The widespread use and adoption of drones for many applications is driving innovation, allowing the collection of high resolution agricultural data to enhance farm management decisions.

**John Hornbuckle, James Brinkhoff and Carlos Ballester**

Centre for Regional and Rural Futures,  
Deakin University, Griffith NSW

**Thane Pringle**

Independent Precision Ag, Yenda

**T**HE use of drones around the world has increased significantly in the past 12–18 months. Major advances in drone technology are being rapidly commercialised and drones are becoming more common. Indeed, Apple stores now offer the range of DJI Phantom drones, which can be purchased alongside your next iPhone!

Deakin University's Centre for Regional and Rural Futures (CeRRF) has been investigating the use of these technologies in rice production systems for monitoring crop performance, with a view for using this technology to improve decisions on nitrogen use, water management and irrigation layouts.

## Easy to use? You bet!

A DJI Inspire drone, shown in Figure 1, is kitted out with its standard true-colour camera at the front, and additional multi-spectral and thermal cameras attached. Multi-spectral cameras for use on drones are rapidly decreasing in price, with options such as the Micasense Sequoia ([www.micasense.com](http://www.micasense.com)) now under the \$2500 mark. While much can be done with a standard camera for investigating variability, crop impacts are best picked up with a multi-spectral camera, which can collect data such as normalised difference vegetation index (NDVI). Cameras, such as the Micasense Sequoia, also can collect normalised difference red edge (NDRE) data, which have been shown to be particularly useful in monitoring nitrogen in rice and other crops, when compared with standard NDVI images.

Using drones has become extremely easy with tablet and phone-based apps such as

Drone Deploy, which automate the flying process. The main picture shows Drone Deploy ([www.dronedeploy.com](http://www.dronedeploy.com)) being used to automate flights over a given field. It is as simple as clicking on field boundaries, setting the flight altitude and the app then takes over the control of the drone, selecting the best flight paths to optimise image collection.

Once the drone lands, the captured images are downloaded from the camera, and uploaded to the internet. Cloud (internet) based apps such as Drone Deploy or Micasense Atlas then process the collected images, automatically stitching the multiple images together to provide a single high-resolution image of a whole field, and then automatically providing calibrated vegetation index images to the user. These images can then be shared between farmers and agronomists or other decision makers. Costs for these services are in the range of \$30 per month, or can be based off a fee per hectare, depending upon what best suits the user.

## What are the benefits?

One of the major advantages of using a low-cost drone platform is the ability to take images when wanted. Farmers don't have to wait for a neighbour or a scheduled plane flight. If they want an image before, during or after an irrigation, they have the ability to collect this data on the spot.

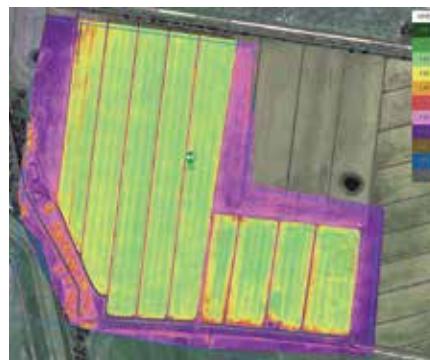
The second major advantage is the high resolution of these images compared with traditional satellite or plane based platforms. Rather than traditional satellite images, which generally feature tens of metres resolution, drone-based data is generally around 5–10 cm, allowing individual plant data to be collected. This has potential benefits for identifying weeds and allows impacts of events such as soil compaction from wet harvests to be seen in collected images. Additionally, cloud cover does not obscure image capture, which is sometimes an issue with satellite imagery.

Figure 2 shows an NDRE image collected from the drone-based platform shown in Figure 1. NDRE has been shown to be strongly related to chlorophyll concentration and therefore to plant nitrogen content. From this image, taken after topdressing, the effects of non-uniform spreading of urea from the spreader can be seen from the green/yellow striping.

Figure 3 shows late season rice crop images taken in late March. The variable crop maturity across the block and bays can be seen, along with the impact of the variable urea spreading, which is still evident. This variability in maturity will have



● **Figure 1.** The DJI Inspire drone with a standard true-colour camera at the front, and multi-spectral and thermal cameras that have been attached by the user for giving the drone customised capability.



● **Figure 2.** Normalised Difference Red Edge (NDRE) image of a rice crop showing effects of top-dressed nitrogen applied with a spreader. The non-uniform spreading pattern can be seen across the bays.



● **Figure 3.** Late season rice crop NDVI taken from a drone, showing variable crop maturity (the darker red areas are more mature). Also, the effects of old contour layouts can be seen, particularly in the lower right of the image.

an effect on final yield and grain quality and can be traced back to previous management decisions or effects from fertiliser, layout, soil type and levelling. This variability data can be used to optimise farm management and rectify the variability in the future. Customised input management based on this variability assessment has the potential to enable farmers to increase yields and farm profitability.

As a side note, the impact of the old contour layout can also be seen in Figure 3, particularly in the lower right of the image. These areas are generally maturing faster. Insights such as these are difficult to see with coarse resolution images such as those from satellites.

## What does the future hold?

As can be seen, the information collected from these drone-based platforms can be used to gain new insights into the effects of water and nitrogen management on plant growth. Strategies can be developed to maximise yields across the farm, based on analysing the best and worst performing areas. The technology is now at a price

point that is affordable. The automation and simplification of the data collection process will allow greater uptake by growers.

For those who would like further information, please contact us (see details following). Additionally, consider registering for the Deakin Drone Day to be held by Deakin University at Hanwood in October, where a range of drones, sensors and software will be demonstrated. It will provide hands-on use of a range of drones and sensing platforms and discuss data processing and subsequent decision making.

### RIRDC Project PRJ-010400

*Changes in rice water use – scoping study*

### Acknowledgement

The project would like to acknowledge the funding provided by the Rural Industries Research and Development Corporation.

### More information

John Hornbuckle  
M: 0429 862 920  
E: [J.hornbuckle@deakin.edu.au](mailto:J.hornbuckle@deakin.edu.au)  
Twitter: @CeRRF\_Griffith

● Aerial view of herbicide program trials at Cobram in January 2015.



# NEW OPTIONS FOR WEED CONTROL IN AERIAL SOWN RICE

## QUICK TAKE

- Two new herbicides with alternate modes of action are demonstrating promise in water seeded (aerial sown) rice for control of annual sedge and broadleaf weeds.
- Both herbicides can be delivered directly to floodwater at early growth stages to maximise application efficiency and rice crop yield potential.

Many weeds continue to compete with water seeded (aerial sown) rice, maintaining the pressure for ongoing development of herbicide products and programs for use in rice crops.

### Malcom Taylor

Agopraisals Pty Ltd, Cobram, Vic

AQUATIC broadleaf and sedge weeds such as starfruit, arrowhead, water plantain, alisma, spikerush and dirty Dora are common competitive weeds of water seeded rice. Their triggers for germination (rising temperatures coupled with light and anaerobic flooded soils) occur

simultaneously with the broadcasting of pre-germinated rice seed into ponded fields. Barnyard and silvertop grasses may also occur in these fields, however they tend to be concentrated on the higher points of a layout where low water levels increase the availability of oxygen.

Recommended herbicide programs for water seeded rice entail overlaying alternate modes of action to cover a broad suite of weed species.

**Supporting farm business owners since 1981**

Frustrated by the disconnect between your BAS (or P&L) and cash in the bank? We can help you understand the **flow of cash** through your business, and liaise with your banker.

Are you struggling with your business relationships or succession planning? We can help you understand hard-wired behaviour and how best to **work with people** in your business.

For more info visit [www.boothassociates.com.au](http://www.boothassociates.com.au) or give Michael a call.

**Booth Associates**  
Agribusiness and Environmental Solutions  
Level 1, 61-63 Yambil St Griffith  
(02) 6964 9911

Widespread experience with the rapid development of resistance to Londax® has taught us to ensure that wherever possible herbicides with multiple modes of action are used on the same cohort of weeds each season. Accordingly, we search for new herbicides that offer alternative modes of action to the products already in commercial use.

As part of this search an annual experiment is conducted that compares existing and new herbicides (i.e. with registrations pending) in programs for water seeded rice. Nineteen treatments were compared in the 2015–16 season to enable agronomists and rice growers to observe how existing and pending treatments may fit into recommended herbicide programs. Treatments were applied into floodwater in banded plots and replicated four times.

## 2015–16 results

Rainfall occurred during levee construction at the experimental site, enabling barnyard grass to germinate prior to inundation of the plots.

Severe competition occurred from early germinating barnyard grass that survived many of the treatments (e.g. Magister® and Saturn®). Ordrum® proved effective against this advanced barnyard grass, removing competition early. Barnstorm® was only marginally effective against barnyard grass due to high plant density and late removal.

Rice injury levels were generally low. The highest injury ratings were for Magister plus Taipan® and Ordrum followed by BAS 800.

Londax was ineffective against dirty Dora, arrowhead and water plantain. Starfruit remained susceptible to Londax.

Taipan applied at sowing was effective against dirty Dora, arrowhead, water plantain and starfruit.

BAS 800 at 2-leaf stage (rice) also proved effective against these four weeds.

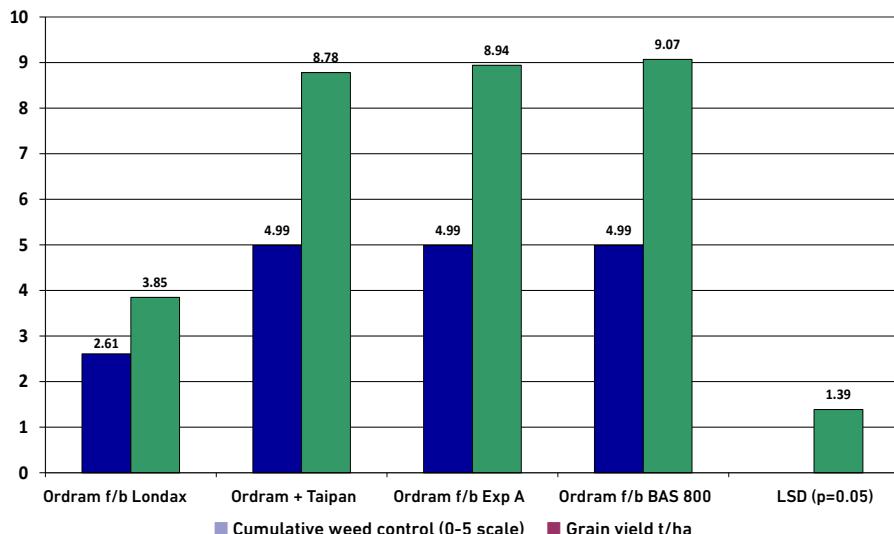
Gator® at 2-leaf stage (rice) controlled arrowhead and water plantain, but was less effective than BAS 800 against dirty Dora and starfruit.

A product identified as Experimental A controlled all four aquatic weed species at both application timings (rice 4-leaf and 1–2 tillers).

A product identified as Experimental B controlled all four aquatic weed species when applied at sowing.

The highest grain yield was obtained in treatments using Ordrum followed by BAS 800, Ordrum followed by experimental A and Ordrum plus Taipan (–/+ Basagran M60).

These results were encouraging as they demonstrated both the effectiveness of the commercial standard of Ordrum plus



● **Figure 1. Cumulative weed control ratings (0–5 scale) for barnyard grass, dirty Dora, starfruit, arrowhead and water plantain and grain yields (t/ha) for existing and new herbicides in water seeded Sherpa rice, Cobram, Victoria, 2015–16 season.**



● **Ordrum plus Taipan controlled dirty Dora, starfruit, arrowhead and water plantain. Two new products (still at the experimental stage) provided similar results.**



● **Ordrum followed by Londax failed to effectively control dirty Dora, arrowhead and water plantain.**

Taipan but also that of two new treatments under development, BAS 800 (HRAC Group G) and Experimental A (HRAC Group undisclosed). Both herbicides have been evaluated for multiple seasons in Australian rice. New treatments will offer rotational options of alternate modes of action to existing herbicides, thus broadening weed management options and bolstering the sustainability of rice weed management practices.

### RIRDC Project PRJ-009923

*Weed control in Australian rice*

#### More information

Malcolm Taylor  
T: 03 5872 2892  
M: 0427 722 892  
E: malcolmc.taylor@bigpond.com

**Table 1. Tradename and active ingredients of rice herbicides**

Tradename	Active ingredient
Londax	bensulfuron methyl
Ordrum	molinate
Magister	clomazone
Saturn	thiobencarb
Barnstorm	cyhalofop-butyl
Gator	carfentrazone ethyl
BAS 800	saflufenacil
Basagran M60	bentazon plus MCPA
Experimental A	undisclosed
Experimental B	undisclosed



- In 2015–16 five field trials tested post-sowing and sequential residual herbicide treatments to improve flexibility and reliability for barnyard grass control in DPW rice.

# IMPROVED CONTROL OF BARNYARD GRASS IN DPW RICE

## QUICK TAKE

- The control of barnyard grass is a particular challenge in fields of direct sown rice with delayed permanent water.
- Residual herbicides for rice such as Magister® (clomazone) and Stomp® (pendimethalin) are best applied post-flush, pre-emergence (PFPE) mixed with a knockdown herbicide.
- Sequencing these herbicides by repeat applications were tolerated by rice, however only minor improvements were demonstrated over the tank mixture applied at the recommended timing (PFPE).
- Advancing application timings to post-sowing (i.e. immediately after seeding, prior to initial flushing) reduced treatment efficacy.

Rice crops established with delayed permanent water (DPW) provide the perfect environment for barnyard grass germination and establishment.

### Malcolm Taylor

Agopraisals Pty Ltd, Cobram, Vic

WITH DPW, the rice crop is maintained in an aerobic state for prolonged periods prior to the mid-tillering stage of rice development. Flush irrigations and/or rain events encourage successive germinations of barnyard grass that must be controlled to prevent major reductions in rice yield potential.

Recommendations for weed management in DPW rice entail:

- field rotations to lower soil weed seed burdens
- clean seedbeds
- minimal disturbance at sowing
- contact herbicides prior to crop emergence (e.g. paraquat or glyphosate)
- timely application (post-flushing, pre-emergence (PFPE) of selective residual herbicides (Stomp® and Magister®).

Achieving the recommended timing for herbicide application can be challenging if rainfall events prevent access of ground-rig sprayers to paddocks. Trafficability is assured at the time of sowing, thus a post-sowing timing option (i.e. immediately after seeding, prior to initial flushing) would be advantageous to ensure pre-emergent herbicides are applied before crop and weed emergence.

Residual herbicides applied to DPW rice crops will often cease to be effective prior to permanent inundation.

In 2015–16 five field trials were conducted to test post-sowing timings of herbicide and also sequential residual herbicide treatments to improve the flexibility and reliability of herbicide programs for barnyard grass control in DPW rice. Plots measured 3 m x 8 m, were replicated four times and treated with a handboom delivering 100 L/ha. All plots were visually rated for crop injury and weed control, and harvested by direct heading with a small plot header.

## Post-sowing Magister

### Trial H52-15, Cobram

Magister @ 0.25, 0.5 and 1.0 L/ha was applied post-sowing and PFPE (alone or tank mixed with Stomp 440EC @ 3.4 L/ha). Gramoxone® @ 1.0 L/ha was added to all PFPE treatments to remove emerged weed seedlings.

Post-sowing applications of Magister (+/- Stomp) proved less effective in controlling barnyard grass than PFPE applications. Sequencing Magister (post-sowing) followed by Stomp (PFPE +/- Magister) provided the highest barnyard grass control ratings and rice grain yields in this experiment.

Rice injury ratings were acceptable with all treatments. PFPE applications of Magister were more injurious to rice than post-sowing treatments.

These results demonstrated that the PFPE timing of Stomp plus Magister provides superior results to post-sowing application of Magister (alone or tank mixed with Stomp), confirming the current timing recommendations. Increased rates of Magister (achieved by splitting the dose between post-sowing and PFPE) offered improved residual barnyard grass control. Thus whilst an earlier timing of Stomp plus Magister might ensure that applications are not delayed by wet fields, optimum results remain more likely using current PFPE timings.

## Split applications of Magister plus Stomp

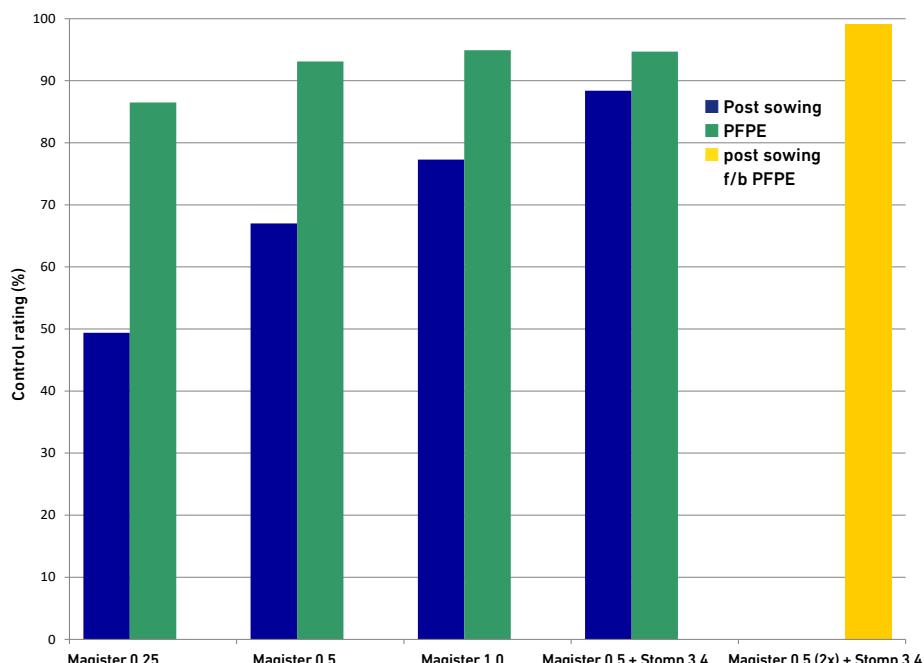
### Trial H10-15, Cobram

This experiment examined the crop safety and efficacy of additional early post-emergence treatments of Magister or Stomp (or both) in order to extend the period of residual control of barnyard grass. Magister @ 0.5 L/ha and Stomp @ 3.4 L/ha (i.e. the recommended combination) were applied PFPE and again early post-emergence (EPE) in a variety of combinations. Gramoxone @ 1.0 L/ha was added to all PFPE treatments to remove emerged weed seedlings.

No advantage was evident by splitting the dose of Magister plus Stomp. The full rate of the mixture was best when applied PFPE. Double treatment of Magister plus Stomp gave an advantage of prolonged residual barnyard grass control. EPE timing of Magister induced extra (transient) bleaching.

Sequencing full rate Magister plus Stomp followed by Barnstorm® (i.e. a common commercial practice) gave the best barnyard grass control and highest rice grain yield.

This experiment also demonstrated that the current recommended herbicide



● Figure 1. Barnyard grass control ratings (%) after treatment with Magister (alone or tank mixed with Stomp) herbicides, Cobram, 2015–16 season, Trial H52-15.



● Post-flush, pre-emergence is the optimum timing to apply residual treatments of Magister plus Stomp plus Gramoxone to control grass weeds in drill seeded rice crops.

Table 1. Barnyard grass control ratings and Sherpa rice grain yields after treatment with residual herbicides, Cobram, 2015–16 season, Trial H10-15.

Treatment and application rate (L product/ha)	Application timing*	Barnyard grass control (% control – average of 3 ratings)	Grain yield (t/ha)
Untreated control		0	1.46
Stomp 3.4 + Magister 0.5	PFPE	95.6	6.44
Stomp 3.4 f/b Magister 0.5	PFPE f/b EPE	88.4	5.93
Stomp 3.4 + Magister 0.5 f/b			
Stomp 3.4 + Magister	PFPE f/b EPE	96.8	7.79
Stomp 3.4 + Magister f/b			
Barnstorm 1.0	PFPE f/b PW	96.8	7.94
LSD (P=0.05)		5.8	0.96

\*PFPE –post-flush, pre-emergence; f/b – followed by; EPE – early post emergence; PW – permanent water

treatment of Magister plus Stomp (plus Gramoxone) applied PFPE was a robust and reliable recommendation. Repeat treatments did lift weed control ratings, however using an alternate post-emergence herbicide (Barnstorm) was better suited for use at the second timing (presumably) due to its superior efficacy against emerged barnyard grass.

### RIRDC Project PRJ-009923

Weed control in Australian rice

### More information

Malcolm Taylor  
T: 03 5872 2892  
M: 0427 722 892  
E: malcolmc.taylor@bigpond.com

● Comparison of microwave treated plot (left) with control plot (right)



# TRIALLING MICROWAVE-BASED WEED MANAGEMENT FOR RICE

## QUICK TAKE

- Microwave treatment of soil has been shown to be effective for killing weed seeds of a number of weeds, including seeds from previous crops and pastures.
- Rice growth throughout the season and grain yield at harvest were significantly higher in microwave-treated plots.
- With further development of the technique, microwave treatment has the potential to be a non-chemical weed management strategy for rice crops.

With increasing demand for more efficient and sustainable crop production, microwave treatment of soil has the potential to be a chemical-free weed management strategy.

**Graham Brodie, Muhammad Jamal Khan and Sally Foletta**

Melbourne School of Land and Environment,  
Melbourne University, Dookie Campus

**R**ESEARCH has shown that microwave energy can kill weed seeds in the soil. Experiments have demonstrated that raising the soil temperature above 80°C will kill seeds of wheat, ryegrass, rubber vine (*Cryptostegia grandiflora R.Br.*), parthenium (*Parthenium hysterophorus L.*), bellyache bush (*Jatropha gossypiifolia L.*), prickly paddy melon (*Cucumis myriocarpus*), wild oats (*Avena fatua L.*), white clover (*Trifolium repens*), and hemlock (*genus Tsuga*).

Recent studies have also indicated that microwave treatment of soil may also

enhance subsequent crop growth and yield. In fully replicated pot trials, the mean grain yields for wheat, canola and rice were 90%, 250% and 60% higher than the hand-weeded control pots, respectively; however these results are based only on pot experiments with no addition of nutrient to the soil.

This report outlines the results of a recent rice field trial, where the soil was treated by microwave before the crop was planted.

## Microwaving rice soil

A field experiment was undertaken at the Dookie College Campus of The University of Melbourne, east of Shepparton, Victoria. The experiment evaluated the effect of microwave irradiation of soil on weed emergence, plant growth and yield of rice.

An area of 73.5 m<sup>2</sup> was excavated and manually levelled into a turkey-nest pond so the area could be flood irrigated to grow rice. The experiment consisted of two treatments: untreated control (T<sub>0</sub>) plots and microwave treated (T<sub>1</sub>) plots. The individual 2.0 x 2.0 m plots were laid out with a 0.5 m untreated buffer zone between each plot, as shown in Figure 1.

The soil of the microwave treated plots (T<sub>1</sub>) was irradiated using two horn antennae (see picture) with internal dimensions of 110 x 55 mm, which were separately attached to two domestic microwave ovens (EMS8586V; Sanyo; Tokyo, Japan) operating at 600 W with a frequency of 2.45 GHz. The applied microwave energy density in the treated plots was approximately 730 J/cm<sup>2</sup>. The soil was watered to field capacity prior to microwave treatment to allow better heating in the soil. Infrared thermal images, captured with an infrared camera (C2; FLIR Systems Inc; Wilsonville, Oregon, USA) immediately after treatment of the area under the horn confirmed that the soil temperature exceeded 80°C (Figure 2).

The experimental plot was flooded to a depth of 5 cm and seed of the rice variety Opus was broadcasted by hand at a seeding rate of approximately 125 kg/ha.

Phosphorus (80 kg P/ha), potassium (60 kg K/ha) and zinc (4 kg Zn/ha) were applied to the entire experimental area at the time of sowing. Three split doses of nitrogen, equivalent to a total rate of 120 kg N/ha, were applied during the growing season.

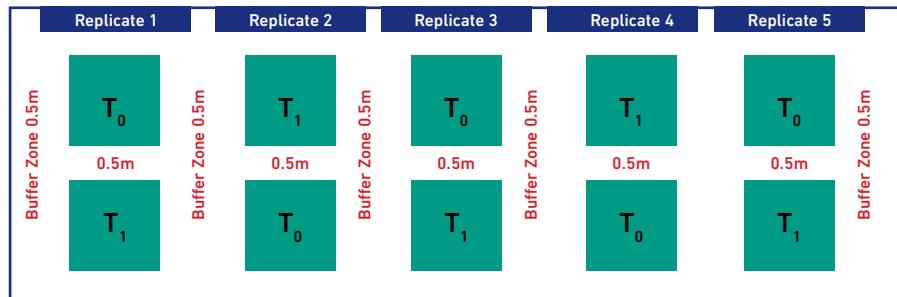
Netting was fixed over the experimental plot to reduce bird scavenging during the early stages of development.

An infrared gas analyser (LI-6400XT; LI-COR Inc; Lincoln, Nebraska USA) was used to measure the physiological parameters of rice at maximum tillering. Number of tillers, fresh biomass and dry biomass were measured for a randomly selected 0.09 m<sup>2</sup> quadrat drawn from each of the plots.

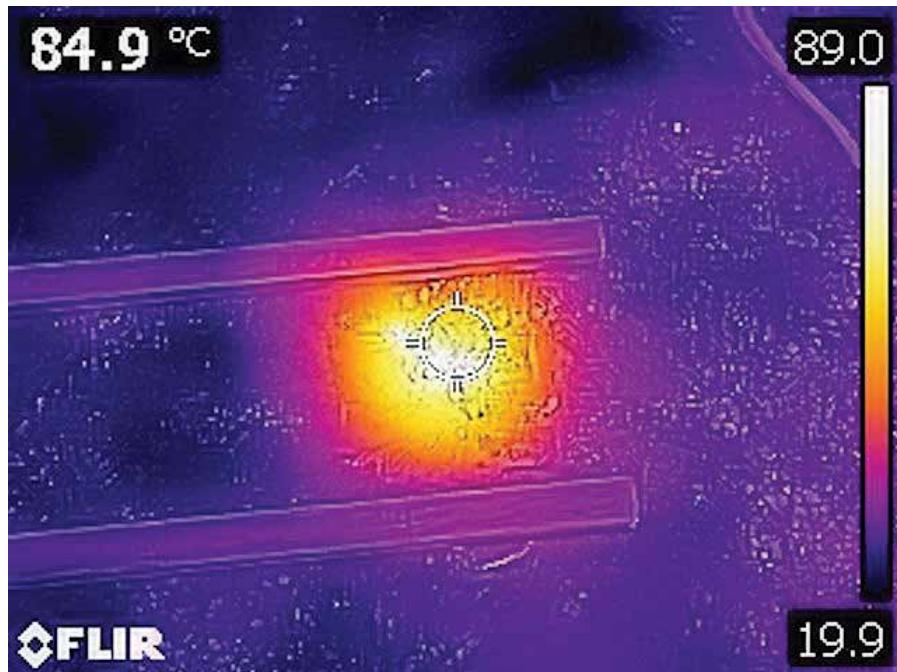
Weed population was counted for each experimental plot. Grain yield, fresh above ground biomass, dry above ground biomass, tiller density, weed numbers and weed biomass were all assessed at harvest time. Statistical analysis using analysis of variance (ANOVA) was undertaken.

## Rice growth after microwave

Microwave irradiation of soil reduced weed emergence in the treated plots by 81%. The main species of weeds found in the plots were: hairy panic grass (*Panicum effusum*), barnyard grass (*Echinochloa colona*), and dirty Dora (*Cyperus difformis*).



● Figure 1. Experimental layout of the two microwave treatments, untreated control (T<sub>0</sub>) and microwave treated (T<sub>1</sub>), of the rice field experiment located at Dookie College Campus, The University of Melbourne, Victoria in 2015–16.



● Figure 2. Infrared thermal image of the microwave heating pattern of the soil in field conditions for the rice experiment. The temperature in degrees Celsius (°C) of the soil is indicated by colour, according to the temperature scale on the right hand side of the image.

Table 1. Assessment of key rice crop growth parameters for microwave treated soil experiment

Measured parameter	Treatments		LSD <sub>5%</sub>	% Change from control
	Microwave treated	Control		
Fresh weight at panicle formation stage (g/quadrat)	416.8 <sup>a</sup>	225.5 <sup>b</sup>	116.3	85%
Dry weight at panicle formation stage (g/quadrat)	91.3 <sup>a</sup>	50.8 <sup>b</sup>	26.1	80%
Tiller density at panicle formation stage (number/quadrat)	104.0 <sup>a</sup>	61.5 <sup>b</sup>	32.2	69%
Chlorophyll content	42.3	43.6	3.3	-3%
Leaf area index	4.0	2.6	1.5	56%
Fresh total biomass weight at harvest (t/ha)	64.2	57.0	13.1	13%
Dry total biomass at harvest (t/ha)	31.1 <sup>a</sup>	25.6 <sup>b</sup>	4.2	22%
Grain yield at harvest (t/ha)	10.1 <sup>a</sup>	7.5 <sup>b</sup>	2.0	35%
Tiller density at harvest (number/quadrat)	419 <sup>a</sup>	292 <sup>b</sup>	113.9	43%
Weed density (number/ha)	44,000 <sup>a</sup>	237,000 <sup>b</sup>	94.3	-81%
Weed biomass dry matter (kg/ha)	54.0 <sup>a</sup>	306.5 <sup>b</sup>	174.0	-82%

(Note: means with different superscripts on the same line are significantly different from one another)

The average weed density in the untreated control plots was equivalent to 237,000 plants per hectare; and the average weed density in the microwave treated plots was equivalent to 44,000 plants per hectare (Table 1). Many of the weeds in the microwave treated plots were hairy panic grass, which may have invaded the plots later in the season.

Microwave treatment also enhanced many of the growth parameters of rice including the tiller density, crop dry weight and grain yield (Table 1). Some of these parameters were visually evident as shown in the photos on page 26. However, no significant difference was observed in chlorophyll content or leaf area index (Table 1).

The higher biomass and tiller numbers at panicle formation stage suggested that the rice plants growing in the microwave treated soil matured faster than those in the untreated soil; however, there was some compensatory growth in the untreated plots later in the season, as indicated by the reduced differences in biomass and tiller numbers at harvest. The faster maturation of the crop in the microwave treated plots was also observed in the difference in ripeness of grains near to harvest time. It was also observed in the difference in moisture content of the harvest biomass, with the mean moisture content of the biomass from the microwave treated plots being 131% (on a dry weight basis) and the mean moisture content of the biomass from the control plots being 150%.



● Prototype two horn antennae microwave system operated through two 2.45 GHz domestic microwave ovens to irradiate soil under field conditions.

## Conclusion

This trial demonstrated significant reductions in weed emergence during the cropping period due to pre-treatment of the soil with microwave energy. Significant yield increases were also achieved from microwave pre-treatment in this trial.

This research has also demonstrated that microwave soil treatment provides multiple benefits for rice production. Its immediate effect is to reduce weed emergence; however, it also enhances plant growth and crop yield.

Field experiments and small trials are planned for the coming season to further verify the potential of this technology, with the hope of a semi-commercial prototype system for larger field trials being developed in the near future.

### RIRDC Project PRJ-008765

*A study of microwave-based weed management in the rice industry*

### Further information

Graham Brodie

T: 03 5833 9273

E: [grahamb@unimelb.edu.au](mailto:grahamb@unimelb.edu.au)

*Providing our community with surveying  
and land development solutions*



For all your surveying and irrigation design needs  
including GPS 3D guidance files for landforming  
of civil and agricultural projects

Call us on 02 6964 3192  
[www.phlsurveyors.com.au](http://www.phlsurveyors.com.au)

- The rice snail *Isidorella newcombi* (shell height approximately 10 mm)



# REPEAT RICE – WHAT IT MEANS FOR PESTS AND DISEASES

## QUICK TAKE

- Repeat rice crops pose particular challenges for pest and disease management.
- Some pests like bloodworms will be unaffected — they will be no more or less abundant in repeat crops than in rice crops on 'new' ground.
- Aquatic earthworms are a declining problem now that growers who aerial sow rarely plant rice immediately after irrigated pastures.
- Snails and the disease stem rot become increased risks in repeat crops.
- While armyworms are unaffected by repeat cropping, other water-saving measures such as delayed permanent water in drill sown crops and mid-season drainage may increase armyworm problems.

**Repeat cropping, where rice is grown on the same paddock for two or more consecutive seasons, is becoming increasingly common as growers try to minimise water consumption.**

**Mark Stevens and Andrew Watson**

NSW Department of Primary Industries,  
Yanco Agricultural Institute

**U**SING the residual water in the soil profile after rice can reduce the water needed at fill-up for a subsequent rice crop and overall crop water consumption by up to 10%. However repeat cropping does come at a cost in terms of the risk posed by some common rice pests and at least one rice disease.

## Bloodworms and aquatic earthworms

Bloodworms (Figure 1) are the larvae of midges, which fly in from surrounding areas and lay their eggs just below the water surface. The midges often arise from larvae that have developed in non-rice

environments such as dams, channels and roadside puddles, and can disperse over long distances. The density of bloodworm infestations in rice seems to depend most strongly on the number of adult midges present in the area (which is linked to habitat availability), and to some extent the prevailing weather conditions. Wet winters followed by calm and mild crop establishment periods favour bloodworm colonisation of rice crops, however crop rotation status ('new' rice versus repeat rice) has little if any impact on bloodworm populations.

Aquatic earthworms (Figure 2) were a major problem when growers with dispersive clay soils, particularly in the Murray Valley, followed irrigated clover pastures with an aerial sown rice crop. Irrigated clover pastures are essentially 'worm factories' and when their use in rotations declined many growers found



● Figure 1. Rice bloodworms (approximately 18 mm) partially cleared to make their head capsules easier to see. Aquatic earthworms are generally much longer and do not have head capsules.



● Figure 2. Aquatic earthworms (approximately 60 mm)



● Figure 3. The adult common armyworm moth (wingspan approximately 35 mm)



● Figure 4. Pupae of a parasitic wasp developing inside a dead armyworm caterpillar

that the impact of aquatic earthworms declined as well. Whilst the best option for minimising aquatic earthworm populations is to precede rice with a dryland (or minimally irrigated) winter cereal crop, repeat cropping is also likely to keep populations at manageable levels. Where possible, drill sowing provides excellent protection against aquatic earthworm damage.

## Snails

Snail problems are closely linked to repeat cropping. When 'new' ground is flooded for rice production, snail infestations develop very slowly, as snails (main photo, page 29) and their egg masses enter the bays gradually and generally in quite low numbers through the supply channels. By the time significant populations develop the plants are past the establishment phase and no longer susceptible to damage, and there are also alternative food sources available, such

as algae and broadleaf weeds at the crop margins.

As the water level falls after irrigation ceases prior to harvest, snails tend to accumulate in the toe-furrows and near the water stops. While some of these snails die, a large number burrow into the soil and enter dormancy. Studies at Yanco indicate that 40–50% of these snails will still be alive if a repeat crop is sown in the following spring, and will emerge from dormancy to start feeding and reproducing immediately when the ground is flooded. The result? Large mixed populations of adult and immature snails at a time when the young plants are vulnerable to attack, and when there are few alternative food sources available. Breaking the cycle of repeat cropping generally solves the problem — at least temporarily — because dormant rice snails can't survive in the soil for more than 12 months at most.

Increased repeat cropping has led to a much greater emphasis on the chemical

control of snails and the use of copper sulphate (bluestone), the only currently registered treatment for snails, is known to be problematic. Soils with high levels of organic carbon compounds dramatically reduce efficacy, and copper has no impact on snail eggs. Work on niclosamide during the RIRDC-funded project *Improving pest and disease biosecurity in the Australian rice industry* resulted in an application to the APVMA for a commercial trial permit (limited area) for this chemical, which will hopefully be granted in time for the 2016–17 rice season. Niclosamide is effective against both snails and their eggs at a low application rate, does not produce persistent soil or water residues, is safe to the crop and is unlikely to be significantly affected by soil chemistry.

## Armyworms

Until around five years ago, armyworms were a fairly sporadic problem in rice, with



**● Figure 5.** Rice stem rot lesions at waterline level. INSET: Sclerotia of the stem rot fungus that persist in stubble between repeat crops.

only small numbers of crops affected. In recent years armyworm problems have become more widespread, and also more consistent from one season to the next. The reasons for this are unclear, however a new research project on armyworms in rice — the first one ever in Australia — started in July 2016.

What we do know is that the adult armyworm moths (Figure 3) migrate over large distances, and affect a number of crops other than rice, particularly winter cereals. There doesn't seem to be a difference between 'new' and repeat crops or between aerial and drill sown crops in terms of susceptibility of rice crops to armyworms attack, but evidence is mounting to suggest that mid-season drained crops and possibly those receiving delayed permanent water may suffer higher levels of armyworm damage. This may be because the lack of standing water is altering the microclimate in the crop in a way that damages the parasitic wasp and fly populations that help to regulate armyworm densities, but the most likely cause involves chemical 'signalling' by the plants. Water-stressed rice plants may be emitting a different blend of natural volatile compounds than non-stressed plants, allowing female moths to identify the stressed crops and target them for egg laying.

Armyworms are often heavily parasitised by other insects and initial work suggests this is also the case within rice crops. A single collection of mature armyworm from a crop near Jerilderie last season had

72% parasitism, with a further 11% dying from unknown causes and only 17% of larvae developing into adult moths. Most were parasitised by wasps, which finish development after the host dies (Figure 4), with one armyworm cadaver producing an astonishing 1094 individual wasps. At present the rice industry relies on broad-spectrum insecticides like chlorpyrifos for armyworm control, so there could be considerable benefit in developing newer selective chemicals that kill armyworms but have little or no impact on their parasitoids.

## Stem rot

In 2014, a farm in northern Victoria experienced yield losses of around 2 t/ha due to a heavy infection of stem rot. This was the first recorded incidence of a significant yield penalty associated with this disease in southern Australia. DNA sequence comparisons were made between the Victorian isolate of the fungus and an isolate from the MIA collected in 1995, and there was more than 99% similarity between the isolates for the genes sequenced. This indicates the Victorian isolate is not a new strain of the fungus — it is largely identical to the MIA strain. The yield loss at the Victorian property has been attributed to three factors working in conjunction: a previous history of the disease, repeat cropping and poor stubble management.

Stem rot is a disease that produces sclerotia (small dark-coloured propagules)

that remain infective within the crop stubble within the plant stems (Figure 5). If stubble is not effectively managed through burning, incorporation or removal, these sclerotia will be released when the next crop is flooded and infect the young plants. Increased repeat cropping makes effective stubble management harder to achieve, and together with potential restrictions on stubble burning it is more difficult for growers to ensure that damaging levels of stem rot do not persist from season to season.

Stem rot can cause rice plants to lodge, so any unexplained instances of crop lodging should be investigated, particularly as this disease may go unnoticed for several seasons until the density of sclerotia build up to the point where crop yield is affected. Pathogenicity tests have shown that none of the commercial rice varieties grown in southern Australia have any appreciable resistance to stem rot.

## RIRDC Project PRJ-07773

*Improving pest and disease biosecurity in the Australian rice industry*

## Further information

Pests — Mark Stevens  
T: 02 6951 2644  
E: mark.stevens@dpi.nsw.gov.au

Diseases — Andrew Watson  
T: 02 6951 2647  
E: andrew.watson@dpi.nsw.gov.au

- Disease symptoms of rice blast on leaves of rice plants. INSET: Collapse of rice plants caused by the blast disease in a field of northern Queensland in May 2014.



# MANAGING RICE BLAST IN AUSTRALIA FOR THE FUTURE

## QUICK TAKE

- Developing rice varieties with resistance to rice blast is considered the most cost-effective and environmentally-friendly way for the industry to address potential risk.
- Rice blast isolates collected from northern Queensland, the Northern Territory and northern Western Australia were characterised into five races.
- Among 25 international lines of known resistance, five genes showed broad-spectrum resistance to all five Australian races of blast.
- 19 Australian and international rice varieties were tested to identify resistant varieties for candidates in the Australian rice breeding program.

Rice blast is one of the most destructive diseases of rice worldwide. Its future management is critical for the northern and southern rice industries in Australia.

### Vincent Lanoiselet

Department of Agriculture and Food,  
Western Australia

THE have been outbreaks of rice blast, caused by the fungal pathogen *Magnaporthe oryzae*, in northern Australia, including northern Queensland, the Northern Territory and northern Western Australia but the pathogen remains exotic to south-eastern Australia where most of Australia's rice is produced. However, there is potential for rice blast to threaten rice in south-eastern Australia in the future.

There are incentives for growing rice in northern Australia, as it can help drought-proof the rice industry during dry seasons in south-eastern Australia, and it has demonstrated potential as cattle fodder for northern livestock industries. While rice blast is a significant concern to the Australian rice industry, it is a challenge to contend with if production of rice is to resume in northern Australia.

The use of resistant rice varieties is the most cost-effective and environmentally friendly way to manage rice blast. However before this project, there was a lack of information about the resistance of rice varieties to blast disease in Australia, which limited the options for managing rice blast through resistant varieties. In addition, the fungus *M. oryzae* evolves rapidly and many races of the pathogen have been reported across the globe. Identifying and mapping the distribution of rice blast races across Australia is an essential step in developing strategies for deploying existing resistant rice cultivars and for breeding new ones.

This project investigated the prevalence of rice blast races in northern Australia and determined the disease response of 25 international rice lines, with targeted resistance genes, to local rice blast races. Also, the disease response of 19 Australian and international varieties to local rice blast races was determined to help future breeding of resistant Australian varieties.

**Table 1. Rice blast isolates collected in northern Australia**

Isolate	Host collected	Origin	Year collected	Race
NT2015a	Rice ( <i>Oryza sativa</i> )	Tortilla Flats, Northern Territory	2015	IA-1
NT2014b	Rice ( <i>Oryza sativa</i> )	Tortilla Flats, Northern Territory	2014	IA-1
WAC13466	Rice ( <i>Oryza sativa</i> )	Kununurra, Western Australia	2011	IA-1
BRIP53372	Rice ( <i>Oryza sativa</i> )	Lakeland Downs, Queensland	2012	IA-1
BRIP53870	Canary grass ( <i>Phalaris canariensis</i> )	Clifton, Queensland	2010	IA-1
BRIP39772	Barley ( <i>Hordeum vulgare</i> )	Goodger, Queensland	2003	IA-3
BRIP15748a	Rice ( <i>Oryza rufipogon</i> )	Brandon, Queensland	1982	IA-63
NT2014a	Rice ( <i>Oryza sativa</i> )	Tortilla Flats, Northern Territory	2014	IB-3
BRIP53376	Rice ( <i>Oryza sativa</i> )	Lakeland Downs, Queensland	2012	IB-3
BRIP59311a	Setaria sp.	Millaa Millaa, Queensland	2013	IB-59
BRIP58447a	Rice ( <i>Oryza sativa</i> )	Clare, Queensland	2013	IB-59
BRIP25865a	Buffel grass ( <i>Cenchrus ciliaris</i> )	Banana, Queensland	1998	IB-59
BRIP15815	Rara grass ( <i>Brachiaria mutica</i> )	Julatten, Queensland	1987	IB-59

## Rice blast in Australia

Thirteen isolates of the rice blast pathogen were collected across northern Queensland, the Northern Territory and northern Western Australia (Table 1). The race status of each was characterised into five different races using an international race differential system (Table 1).

## Finding resistant genes

Resistance to rice blast can be controlled by a single gene, in which case the line of rice is described as monogenic. A set of 25 monogenic rice lines with targeted blast resistance genes (Table 2) was imported from the International Rice Research Institute (IRRI), and released from South Perth Post Entry Quarantine, Western Australia.

The *Pi40* gene, that has shown broad-spectrum resistance to rice blast in other Asian countries and Africa, was included in these lines. This novel source of resistance was extracted from a native wild rice species (*Oryza australiensis*) from northern Australia.

The disease responses of these 25 lines against the rice blast isolates belonging to the five races were determined, with the aim of identifying the genes with resistance to the rice blast races in Australia. Among the rice lines tested, lines IRTP19029 (gene *Pi40*), IRBL11 (gene *Piz-t*), IRBL20 (gene *Pi5(t)*), IRBL22 (gene *Pi9*) and IRBL23 (gene *Pi12(t)*) exhibited broad-spectrum resistance to all the rice blast races tested (Table 2).

## Testing against blast

Nineteen representative rice varieties grown in Australia with origin from Australia and five other countries were tested to determine their responses to the rice blast isolates (Table 3). These varieties were chosen as they represent either historically-demonstrated circumstantial evidence of resistance to rice blast in tropical northern Australia, or represent the spectrum of current commercial varieties with existing market value that have been recently grown in this region.

The aim of the work was to identify rice varieties with resistance to the rice blast isolates in Australia. Among the rice varieties tested, the Chinese variety SHZ-2 was resistant to all the rice blast races tested. The Australian variety Quest and the Chinese variety Yunlu 29 showed susceptible reactions to four of the races, and only moderate resistance to the remaining race (Table 3).

## Conclusions

The project provided information for the first time about the races of rice blast occurring in Australia. The 13 rice blast isolates collected from northern Australia belonged to five different races. Five genes having broad-spectrum resistance to all races were identified from 25 monogenic lines of rice. In addition, this study provided information about the resistance of rice varieties to Australian races of rice blast, and identified the variety SHZ-2 showing broad-spectrum resistance to these races.

This project provides valuable information and resistance sources for future breeding programs to screen and develop rice varieties

with broad-spectrum disease resistance that are adapted to Australian conditions. This will help to develop an economically viable rice industry in northern Australia, and increase the resilience of rice growers against this disease threat in traditional southern growing areas of Australia.

## RIRDC Project PRJ-008565

*Characterisation of rice blast races present in Australia*

The project involves the following scientists:

- Dr Vincent Lanoiselet, Department of Agriculture and Food, Western Australia
- Dr Martin Barbetti, School of Plant Biology and the UWA Institute of Agriculture, Faculty of Science, the University of Western Australia
- Dr Peter Snell, NSW Department of Primary Industries, Yanco Agricultural Institute.
- Dr Xiangling Fang, School of Plant Biology and the UWA Institute of Agriculture, Faculty of Science, the University of Western Australia

## Acknowledgments

We thank Dr Roger Shivas at the Department of Agriculture, Fisheries and Forestry, Queensland and the University of Queensland, Australia for providing some of the isolates. We thank Mr Andrew Barfield at Rice Research Australia Pty Ltd and Dr Russell Reinke at International Rice Research Institute for providing rice seeds.

## Further information

Dr Vincent Lanoiselet  
T: 08 9368 3263  
E: vincent.lanoiselet@agrif.wa.gov.au

Table 2. 25 monogenic rice lines imported from International Rice Research Institute (IRRI) and their disease responses to the rice blast isolates from Australia

Monogenic lines	Target gene	Race IA-1			Race IA-3		Race IA-63	Race IB-3	Race IB-59		
		WAC 13466	BRIP 53372	BRIP 53870	BRIP 39772	BRIP 15748a	BRIP 53376	BRIP 15815	BRIP 59311a	BRIP 25865	BRIP 58447a
IRTP19029	Pi40	R	R	R	R	MR	R	MR	MR	R	R
IRBL 1	Pia	R	R	MR	R	S	S	CR	CR	S	S
IRBL 3	Pii	R	R	S	R	S	S	R	R	S	S
IRBL 4	Pik-s	S	S	S	R	S	S	CR	CR	S	S
IRBL 6	Pik	S	S	S	R	S	S	CR	CR	S	S
IRBL 8	Pik-h	S	S	S	R	S	MR	R	R	S	S
IRBL 9	Piz	R	R	MR	CR	S	S	R	R	MR	MR
IRBL 10	Piz5=Pi 2(t)	R	S	R	R	R	R	R	R	MR	MR
IRBL 11	Piz-t	R	R	R	R	R	R	R	R	R	R
IRBL 12	Pita=Pi 4(t)	MR	MR	S	R	S	R	R	R	R	R
IRBL 14	Pib	R	R	R	R	S	S	R	R	S	S
IRBL 15	Pit	R	R	R	CR	S	S	R	R	S	S
IRBL 16	Pish	R	R	MR	R	S	S	S	S	S	S
IRBL 18	Pi1	R	R	R	CR	S	R	R	R	S	S
IRBL 19	Pi3	MR	MR	R	CR	S	S	S	S	S	S
IRBL 20	Pi5(t)	R	R	R	R	R	R	CR	CR	R	R
IRBL 21	Pi7(t)	R	R	R	CR	S	R	CR	CR	R	R
IRBL 22	Pi9	CR	CR	CR	CR	CR	CR	R	R	R	R
IRBL 23	Pi12(t)	CR	CR	R	R	R	R	CR	CR	R	R
IRBL 24	Pi19	MR	MR	R	CR	S	S	CR	CR	S	S
IRBL 25	Pik-m	CR	CR	R	CR	S	CR	CR	CR	R	R
IRBL 26	Pi20	R	R	R	CR	CR	MR	CR	CR	S	S
IRBL 27	Pita2	CR	CR	R	CR	S	CR	CR	CR	CR	CR
IRBL 29	Pita	MR	MR	R	CR	S	S	S	S	S	S
IRBL 30	Pi11(t)	CR	CR	R	CR	CR	MR	S	S	S	S

CR = complete resistance; R = resistant; MR = moderate resistance; S = susceptible.

Table 3. 19 selected rice varieties and their disease responses to the rice blast isolates from Australia

Variety	Origin	Race IA-1			Race IA-3		Race IA-63	Race IB-3	Race IB-59		
		WAC 13466	BRIP 53372	BRIP 53870	BRIP 39772	BRIP 15748a	BRIP 53376	BRIP 15815	BRIP 59311a	BRIP 25865	BRIP 58447a
Aamaroo	Australia	S	S	S	R	S	S	R	R	S	S
Doongara	Australia	S	S	S	R	S	S	R	R	S	S
Jarrah	Australia	S	S	S	R	MR	S	MR	R	S	S
Kyeema	Australia	S	S	S	R	MR	R	R	R	R	R
Langi	Australia	R	R	S	R	S	MR	S	R	S	S
Opus	Australia	S	S	MR	R	MR	S	R	R	S	S
Quest	Australia	S	S	S	S	S	S	MR	MR	MR	MR
Reiziq	Australia	S	S	S	R	S	S	R	R	S	S
Sherpa	Australia	R	R	S	R	MR	R	R	R	MR	R
Topaz	Australia	R	MR	S	R	MR	MR	R	R	MR	R
BR-IRGA-409	Brazil	S	S	S	R	R	R	R	R	R	R
Ceysvoni	Surinam	S	S	S	R	R	R	R	R	R	R
Koshihikari	Japan	S	S	S	R	S	S	R	R	S	S
Rikuto Norin 20	Japan	S	S	S	R	R	R	R	R	R	R
NTR426	Philippines	R	R	R	MR	MR	MR	R	R	R	R
NTR587	Philippines	MR	MR	MR	R	R	R	R	R	R	R
Shan Huang Zhan-2 (SHZ-2)	Guangdong, China	R	R	R	R	R	R	R	R	R	R
Yunlu 29	Yunnan, China	S	S	S	S	S	MR	MR	MR	MR	MR
Viet 1	Tawian	R	MR	S	MR	S	S	R	R	S	S

R = resistant; MR = moderate resistance; S = susceptible.

- 
- Most rice growers currently burn rice straw immediately after harvest to sow a winter wheat or canola crop and make use of subsoil moisture that remains after rice. Photo: MALCOLM TAYLOR

# ALTERNATIVE MANAGEMENT OF RICE STRAW

## QUICK TAKE

- Alternatives for burning rice stubble include removing it from the paddock for use as bioenergy, high value chemicals, niche silica products, plastics and building materials, as well as organic soil amendments and mulches.
- Transport of straw to a centralised bioenergy, bio-refinery or processing facility is currently cost prohibitive unless high value-adding is possible.
- A cross-sectoral approach is required whereby a number of different industries (e.g. wine, paper, cotton) may supply a bio-refinery type facility
- Domestic markets for garden mulch products offer high mark-ups that can overcome handling and transport costs.

Australian rice crops are some of the highest yielding in the world (approximately 10.5 t/ha) and typically they produce the same mass or more of straw.

### Wendy Quayle

Senior Research Fellow,  
Centre for Rural and Regional Futures  
Deakin University, Griffith, NSW

In a good season with high irrigation water availability, over one million tonnes of rice straw may be produced in southern New South Wales. The vast majority of rice growers currently remove straw immediately after harvest by burning, allowing time to get a winter wheat or canola crop sown and making use of subsoil moisture that remains from the preceding rice crop.

Generally however, burning is considered undesirable as a long-term solution, as it is considered to not only cause loss of soil nutrients, carbon and possibly beneficial soil organisms but it also creates air pollution with possible risks to human health. It is possible that government regulations may

be introduced to control burning if incidents of smoke affecting individuals or local communities are reported to the NSW EPA.

It is critical that growers do not lose the flexibility that burning offers in their farm management. Fact sheets and a web-based, weather-related tool developed by the Bureau of Meteorology are available that may assist growers to burn responsibly and identify the most suitable weather conditions for burning so that smoke is dispersed quickly and away from residential areas ([www.rga.org.au/f.ashx/Stubble-factsheet.pdf](http://www.rga.org.au/f.ashx/Stubble-factsheet.pdf)).

Nevertheless, at times, even responsible burning can generate plumes of unsightly smoke and particulates in the atmosphere, and the negative effects of burning from both agronomic and environmental aspects continue to raise issues for rice growers, the industry and the community. Consequently, there is a need for the rice industry to explore alternative ways of managing rice

straw that fit with farm operations, are economically viable and offer environmental protection.

## Alternatives to burning

Alternative on-farm solutions to stubble burning can include incorporation or retention of straw and stubble with all its associated benefits, including longer-term soil quality improvement and increased water retention. However, the volume of rice straw means farmers face difficulty with in-field straw management due to machinery requirements and labour cost of incorporation, nutrient and pesticide tie-up, build-up of weeds and disease, and uneven seedling germination and yield variability of subsequent crops.

Due to the unpalatability and low nutritional value of rice straw to livestock, use as stockfeed is limited other than during drought conditions when other fodder sources are unavailable.

There is a wide range of research around alternative uses for rice straw and the practicality of implementation of these uses. Alternative uses of rice straw include:

- bioenergy and chemicals (bioethanol, butanol, hydrogen, methane, furfural) building materials (lightweight concrete blocks, fibreboards, cement)
- industrial applications (absorbents, calcium silicide, activated carbon, filtration agents, and carriers in pharmaceuticals, rubber compounding)
- use of rice straw ash as an insulator in the steel industry
- erosion control
- recyclable paper products
- plastics and composites
- high-value nutritional bio-oils
- rice straw composts through integrated animal management
- biochar and char-ash-clay mix soil amendments.

The most critical constraint in removing rice straw off farm for other uses is its low bulk density, which makes it expensive to transport. At the industry scale, high value-adding is required from this low-value material for economic viability. On-farm processing may offer an alternative shorter-term solution.

## Best-bet alternatives

### 1) Industry-wide solutions

Industry-wide bioenergy solutions require significant industry capital and feasibility study, and at this stage are considered likely to be implemented in the longer term using rice hulls rather than straw. The industry-wide approach is limited by the in-field

handling and transport costs and seasonal and annual variability.

For example, since the cost of straw removal from the field is up to about \$90/tonne within a 100 km radius, the value of extracted products needs to compensate for this. If the rice industry was to accept approximately half of the straw yielded from an average production cycle (say 300,000 tonnes), it would have to pay about \$27 million to compensate the growers for removal. A preferred model may be to have government incentives and policy initiating and assisting bioenergy implementation through infrastructure grants with an economically sustainable model for ongoing operations.

Research in northern Australia is ongoing using pilot-scale integrated bio-refineries that involve residues from the sugar, sorghum and other industries, being transported to a central facility to create power or specialised high-value chemicals (furfural, butyric acid, bioplastics) and the testing of advanced fermentation or biotechnology processes. The production of high-value chemicals from waste residues is a big growth area with estimates in excess of a \$4 billion industry in Australia.

The general consensus is that to be most successful, a cross-sectoral approach is required whereby a number of different industries (e.g. wine, paper or cotton) may supply a bio-refinery type facility. Output products (e.g. energy, specialised siliceous products or chemicals) should ideally be able to supply local industries that have high specific demand, such as intensive energy use, bottles, recyclable packaging, to enable a closed-loop situation to be developed within the region.

In the case of rice, the silica component may present a unique aspect for opportunity. State of the art research is examining the characteristics of silica nanoparticles that are formed naturally in rice straw and husks and how they may be isolated easily and at scale. Research includes:

- enhanced energy storage capacity of lithium batteries
- use in solar power panels
- nanotechnology applications for controlled drug delivery and food additives
- use in the construction industry for high-strength concrete and glass manufacture which may have local markets.

### 2) On-farm solutions

There are a number of potential ways that rice straw can be managed on farm, other than burning. Although these solutions may only be appropriate on a case by case basis,

best-bet options for farmers in the short term may include:

- farm system rotational management, especially in single cropping businesses (may be possible on a case by case basis)
- integrated management with intensive livestock production (e.g. piggeries) followed by returning straw-manure piles and amendment to paddocks
- on-farm densification technologies that manufacture straw extrusion products such as briquettes or pellets that feed on-farm gasifiers to power pumps and domestic energy needs.

## Potential market opportunities

There is a range of potential market opportunities although to date these have not been properly developed or are unavailable.

Garden mulch products for domestic markets offer high mark-ups that can overcome handling and transport costs. Rice straw offers advantages over other straw mulches such as wheat, oat, sugar cane and pea straw as it is weed free and is attractive in gardens as it can be evenly spread. National advertising campaigns, supported at the industry level may increase the size of this market.

Fibreboard could be produced from rice straw but the process requires the feasibility of production at scale to be tested and implementation of straw transport and handling logistics.

Straw could be exported to Japan for inclusion in Wagyu beef diets. To obtain the specialised wagyu beef that has high value and demand in Japan and elsewhere, cattle are fed a finisher ration that includes rice straw which has high fibre and contains no vitamin A.

Although there is a large number of potential alternative uses for rice straw, thorough business case development is required to ensure sustainability for individuals and the industry.

## Future research

The following research and commercialisation activities are considered critical to capture the potential economic benefits of rice straw in Australia:

- demonstration of continuous processing of rice straw in combination with other industry residues (cotton, wine) through pilot scale or demonstration bio-refineries
- detailed assessment of rice straw product and market opportunities with a focus on Australian and Asian markets. For example, building products, livestock

- fodder, garden mulch products
- detailed cost benefit and life cycle analysis of small scale on-farm gasification technologies for single enterprise energy production and how to overcome impediments to investment because of rapidly evolving overseas technologies, possibly through state government initiatives
- understanding the sustainability of continued straw removal versus burning and its impacts on productivity and the additional nutrient inputs that may be required to offset this removal
- understanding agronomic and carbon sequestration benefits of rice straw derived soil amendments
- development of rice varieties that may offer enhanced amorphous silicon nanoparticles
- development of specific technologies that allow the easy culturing of microorganisms that produce high value omega oils.

## Conclusion

Despite research endeavours across a multitude of stakeholders, practical solutions that are economically viable for the management of rice straw at a level that accommodates the majority of farm businesses, other than burning, is not yet available for Australian rice growers.

A co-ordinated effort between several closely-located industries that may reduce investment risk and overcome issues of scale and variations in feedstock quantity and composition is required.

### RIRDC Project PRJ-009170

*Alternative management of rice straw*

### Acknowledgments

Funding from RIRDC, CSIRO Sustainable Agriculture Flagship and Deakin University is gratefully acknowledged. Dr John De Majnik is thanked for his support throughout and especially in the final stages. Thank you to Andrew Bomm and Neil Bull (Australian Ricegrowers' Association) and Russell Ford and Antony Vagg (Rice Research Australia) for providing industry information.

### Further information

Wendy Quayle  
M: 0417 436 775  
E: w.quayle@deakin.edu.au



● At times, even responsible burning can present problems, consequently there is a need for the rice industry to explore alternative ways of managing rice straw. Photo: MALCOLM TAYLOR

## Burning compared with removal and retention

**A**n important aspect of straw management for farmers is how it impacts on soil nutrient balance and longer-term soil fertility, as well as weed, pest and disease control. The chemical composition of rice straw and ash gives an indication of the nutrients and trace elements that are lost or remain, according to whether straw is removed completely from the field or burnt (Table 1).

There have been claims that burning causes almost complete loss of nitrogen, about 25% of phosphorus, about 20% of potassium and 5–60% of sulphur. If straw is continually transported off farm on an annual basis then greater amounts of potassium may need to be applied.

Generally, however, if the straw is burnt rapidly *in situ*, phosphorus, potassium, sulphur, calcium, magnesium and silicon losses may be relatively low since these elements tend to remain in the ash and will be retained in the soil. However, these elements may be in a different chemical form with potential changes in availability to plants. Burning versus straw removal also causes changes in soil moisture and hydraulic conductivity through heat and compaction.

**Table 1. Nutrient removal by rice grain, rice straw and burning rice straw**

Nutrient removal (kg nutrient/tonne)						
	Nitrogen	Phosphorus	Potassium	Magnesium	Calcium	Silicon
Rice grain	10.5	4.6	3.0	1.5	0.5	2.1
Rice straw	7.0	2.3	17.5	2.0	3.5	11.0
Burning	7.0	0.6	3.5	1.0	2.9	0.2

Source: Dobermann and Fairhurst, Best Crops International, 2002



● Rice field harvested with Shelbourne Reynolds stripper front — typically, there may be 12–15 t/ha of straw remaining after harvest.

# SEEDING FORAGE LEGUMES AFTER RICE

## QUICK TAKE

- A new project will investigate what advantages there are by growing forage legumes in rice stubbles.
- Demonstrations and replicated trials at *Old Coree, Tongaboo and Cobram* in 2015 compared the establishment and growth of five forage legumes (subterranean clover, balansa clover, Persian clover, arrowleaf clover and vetch).
- In the 2016 autumn–winter three replicated studies were established to compare the production of a range of eight forage legumes when sown into rice stubbles.

**Upon completion of rice harvesting each autumn, each hectare of land has a full profile of moisture and is covered with 12–15 tonnes of straw.**

### Malcolm Taylor

Agroparaisals Pty Ltd, Cobram, Vic

**T**RADITIONALLY rice stubbles are looked upon as a liability. The straw impedes passage of most seeding equipment, encouraging many growers to burn the stubble with an inevitable loss of nutrients and organic matter. Stubbles are commonly of little value as market returns for rice straw mostly barely cover the costs of baling and transport.

Yet rice stubbles represent a most unusual ecological niche in the normally arid Riverina landscape. After harvest of dryland winter crops, most dryland fields

retain minimal standing stubble or grass and have negligible soil moisture until breaking rains arrive, typically late in May or June.

Can growers take advantage of the soil moisture beneath rice stubble to establish a profitable following crop, and yet retain the nutrients and organic matter contained in the straw?

### Incorporation

Attempts to incorporate rice stubble into moist ground in Australia have largely failed. Implements such as offset discs, PTO-powered discs and rotary hoes all require high energy inputs; incorporation operations

are inherently slow at a time when farm labour is directed to establishing winter crops; and fields can be difficult to traffic with heavy machinery due to wet ground. Stubble incorporation is rarely achieved in a single working and the resultant soil surface is usually left in a rough state that will require subsequent grading.

## PTO-driven disc ploughs

Powered discs (i.e. driven by the tractor PTO to give a positive drive relative to ground speed) are used commercially in many parts of Asia to incorporate stubbles between rice crops.

Indian researchers reported on the design and performance optimisation of PTO-driven discs when incorporating stubbles:

- increasing forward speeds and decreasing depth of tillage reduced fuel consumption from 4.4 to 2.9 L/ha.
- increasing forward speed and increasing depth of tillage increased the percentage of stubble inverted from 86 to 97%.

In early 2015, Agopraisals imported two PTO-driven linkage disc ploughs to determine if they would offer improved incorporation of rice stubble immediately after harvest, as an alternative to burning.

The experience with this equipment proved disappointing as a consistent pattern of disc blockage occurred at all sites where testing occurred. Variations in PTO speed, forward speed or operational depth did not appear to influence the propensity of the plough to block with straw and mud. An exception to this failure was when operating the equipment in a fully inundated field where the plough did not block; however the tractor required steel narrow track wheels to avoid excessive rolling resistance and bogging.

By June 2015 it was concluded that incorporation of freshly harvested rice stubbles into moist soil was both impractical and undesirable, given the rough surface that resulted required subsequent levelling.

## Broadcast seeding

Whilst testing the PTO-driven plough in 2015, seed for a range of forage legume species was broadcast onto cultivated (stubble incorporated) and undisturbed (stubble standing) plots. Intriguingly, it was noted that establishment of the legumes was improved where the stubble was retained and the ground left undisturbed. In what proved to be a relatively dry autumn, the retained moisture beneath the rice stubble, enhanced germination and establishment of five different legumes (subterranean, balansa, Persian and

**Table 1. Ground cover (%) ratings, on two dates, of five forage legumes broadcast seeded into rice stubble, Cobram, 2015**

Legume	Seeding rate (kg/ha)	Ground cover rating*	23 Aug 15	9 Oct 15
Fallow		0 c	0 d	
Subterranean clover	10	8 c	45 c	
Balansa clover (Viper)	5	6 c	48 bc	
Persian clover (Shaftal)	10	30 b	65 b	
Arrowleaf clover	5	9 c	51 bc	
Vetch (Rasina)	30	57 a	90 a	
LSD ( $P=0.05$ )	12.6	18.3		
Standard Deviation	9.6	13.9		
CV	42%	28%		

\* Treatment means with the same letter do not differ significantly



● Trafficability is limited by the wettest spot in the field.



● Blocking of PTO-driven plough after cultivating a rice stubble, Jerilderie, April 2015.



● Vetch established by broadcast seeding after rice harvest, May 2015.



● Vetch broadcast seeded after harvest into a rice stubble, August 2015.

arrowleaf clovers and common vetch).

Seeding subterranean clover into rice stubbles using aircraft or drop seeders has been practiced successfully since the 1950s. The technique largely lapsed as livestock returns plummeted during the late 1980s. Forage legume options have broadened since this period, thus it is timely now to re-examine the suitability and productivity of forage legumes given improved returns for livestock enterprises relative to grain production.

How do forage legumes perform when sown into standing rice stubbles? Early seeding around rice harvest produced some spectacular results in the 2015 season.

Demonstrations and replicated trials at

Old Coree, Tongaboo and Cobram in 2015 compared the establishment and growth of five forage legumes (subterranean clover, balansa clover, Persian clover, arrowleaf clover and vetch).

Early spring growth was outstanding with Rasina vetch and Shaftal Persian clover. Late spring rain produced an additional flush of growth in Viper balansa clover and arrowleaf clover.

Quadrat cuts from demonstration plots at Old Coree in early September produced fresh weight equivalents of between 21 and 29 t/ha of silage at 15–19% protein. Subterranean clover performance was poor and insufficient to harvest, whilst vetch,



● Straw spreaders can reduce excessive concentration of straw.



● Prolonged waterlogging in wet seasons will kill many forage legume species.



● Shaftal Persian clover broadcast seeded after rice harvest, August 2015.

arrowleaf, balansa and Persian clovers all developed substantial and productive swards.

## Harvest management

Crop harvesting techniques produce dramatic contrasts in the density and architecture of rice stubbles.

Conventional open front headers leave 20–60 cm of straw standing (less in a lodged crop), with the balance threshed and spread over a lesser width behind the machine. This can result in straw loads of in excess of 40 t/ha in header trails, proving a major challenge to the growth of any plant that may attempt to establish in this zone. Straw spreaders at the back of the header can alleviate this concentration of rice straw.

Stripper fronts will leave straw intact to a height of 80–110 cm with a lesser load of flag leaf, stems and empty florets in the header trails. Straw loads across the field tend to be more even, however shading of the ground is increased due to the increased height of standing stubble. Traffic lines will of course be flattened by the passage of wheels.

Some Asian-built rice harvesters are fitted with a second knife in order to cut stubbles closer to the ground and reduce straw length for ease of incorporation.

Leaving rice stubble undisturbed, then either burning it or incorporating it dry in late spring represents a major lost opportunity for crop production through the winter-growing season. Thus establishing forage legumes for livestock production or as a green manure crop prior to re-cropping rice is desirable and potentially profitable.

## Wet or dry seasons?

In dry autumns rice stubbles offer moist soils and protection from desiccating winds for newly planted forage legumes, and other crops. In wet autumns, rice stubbles are commonly severely waterlogged and hostile to the establishment and productivity of most forage legumes. How often do wet autumns deleteriously affect these crops?

Deniliquin has over 150 years of complete rainfall records. Table 2 shows that averaged over the total record, less than

one in four autumns is likely to become wet enough to challenge forage legumes with waterlogging; even less frequent (less than one in seven years) when focusing on the last 50 years of data.

Most growers would take a punt on these odds to grow a successful forage crop. We do not understand the relative tolerance of many forage legumes to waterlogging, so observations in the 2016–17 season across our demonstration sites should improve our understanding of this issue.

When establishing crops after rice, one has little information with which to confidently predict if the winter season will be wet or dry. In wet years crops may become waterlogged and a complete loss. Field layout, slope and drainage can be considered and steps taken to improve drainage to prevent prolonged waterlogging by connecting drains and toe furrows.

## Inoculation and sowing

Inoculants ought to be applied to forage legume seeds, immediately prior to broadcasting to maximise the potential for nitrogen fixation by the crop.

Experience with irrigated pastures shows that optimum growth of annual legumes occurs when the field is watered in February to commence germination. This timing coincides with draining of rice, thus it follows that aerial broadcasting of forage legumes just after water has been removed is likely to result in the best potential production.

## Costs and techniques

Opportunities for ground-based seeding exist using air booms mounted on tractors,

however wet areas in fields are likely to prove challenging. Alternatively seed could be distributed beneath the auger table or stripper front of a header using a small air seeded mounted on the harvester. Marking of the field is assured using this method. Systems for achieving this technique were marketed in France during the 1990s using a drive wheel operating on the top of the header main tyres. Contemporary systems could obtain a signal from the ground radar used to measure harvester speed.

Aerial seeding can be a cost effective means of establishing forage legumes after rice. Seeding can occur irrespective of ground conditions (wet or dry), is rapid and usually facilitated with an agricultural aviation contractor for under \$30/ha. Adding a seed cost of perhaps \$50 leaves change out of \$100/ha; a price that pales into insignificance compared with the multiple thousands required to grow summer crops such as rice, cotton on maize.

## A business case for legumes after rice?

One cannot determine if a business case exists for growing forage legumes without an understanding of the yield and quality of the forage produced, coupled with knowledge of the value of this production to an enterprise. Will the fodder be grazed (and if so when) or conserved as hay or silage?

Forage legumes have the capacity to fix nitrogen for subsequent crops. How much nitrogen fixed will be dependent upon the success of inoculation and the manner in which the legumes are used (grazed versus silage versus hay versus incorporation as green manure). Typical inputs of fixed

**Table 2. Summary of autumn rain events that could have resulted in waterlogging of a rice stubble at Deniliquin, NSW.**

Rainfall recording period	Number of years with more than 75 mm rain April–June ('wet' autumns)	'Wet' autumns as a percentage of total years
1858–2014	34	22%
1966–2016	6	12%

**Table 3. Forage legumes under evaluation in 2016**

Common name	Species	Variety	Seeding rate kg/ha	Characteristics*	Uses
Subterranean clover	<i>Trifolium subterraneum</i>	Trikkala	10	Shallow rooted annual clover Winter dominant growth	Grazing
Balansa clover	<i>Trifolium michelianum</i>	Viper	5	Semi erect annual clover High tolerance to waterlogging Rapid growth in warm moist conditions	Grazing, hay
Persian clover	<i>Trifolium resupinatum</i>	Shaftal	5	Semi erect annual clover Waterlogging tolerance High palatability Spring recovery from cutting	Grazing, hay, silage
Arrowleaf clover	<i>Trifolium vesiculosum</i>	Zulu II	5	Semi erect annual clover Tolerant of waterlogging Spring growth late maturity	Hay, silage, grazing
Bladder clover	<i>Trifolium spumosum</i>	Bartolo	5	Semi erect annual clover Intolerant of waterlogging	Grazing
Common vetch	<i>Vicia sativa</i>	Rasina	30	Semi-erect climbing/decumbent annual Intolerant of prolonged waterlogging	Grazing, hay, silage
Lucerne	<i>Medicago</i>	Aurora	5	Deep rooted perennial Intolerant of waterlogging	Hay, grazing
Field peas	<i>Pisum sativa</i>	Morgan	30	Semi-leafless annual pea Excellent early vigour	Grazing, hay, silage

\*Descriptions from Pasture Legumes for Temperate Farming Systems The Ute Guide, PIRSA, 2004

nitrogen from forage legumes are 20–25 kg N/tonne of dry matter produced.

Will forage legumes assist to sustain the yields of the rice farming system through better conservation of soil nutrients?

Burning a 12 tonne rice stubble can result in losses of approximately 80 kg of nitrogen, 7 kg of phosphorous, 4 kg of potassium and 3 kg of sulphur in addition to large quantities of organic carbon. Growing a forage legume after rice may enable these nutrients to be conserved and enhanced with additional nitrogen fixation.

What is the opportunity cost of using a full profile of soil moisture for forage legumes versus a cereal crop?

All the factors described need to be considered when deciding whether to seed forage legumes into rice stubbles. Species selection and fertilisation requirements for forage legumes sown after rice are not well understood, however the technique holds promise for contributing to the profitability and sustainability of the rice-farming system.

## 2016 season

Rice growers are skilled at discerning results relevant to their enterprises and replicated research trials are costly to conduct, especially when located far from base. In the 2016 autumn–winter three replicated studies were established to compare the production of eight forage

legumes when sown into rice stubbles. To supplement these results and to obtain broad feedback on the potential for forage legumes after rice, 36 kits of pre-weighed and inoculated seed were distributed amongst agronomists and growers for the establishment of demonstration sites. Opportunities should arise in all districts to inspect these sites. Contact your local rice extension officer for further information.

### Useful publications

**Irrigated Winter Forages in Northern Victoria: Choosing an option**, Anon., Victorian Department of Primary Industries (2004)

**Pulses putting life into the farming system**, Armstrong, E. and Holding, D. NSW Department of Primary Industries (2015)

**Rice straw management in California**, Bird, J.A et al, California Agriculture, March–April (2002)

**Inoculating legumes, a practical guide**,

Drew, E. et al, Grains Research and Development Corporation (2012)

**Irrigated forage legumes**, Damian Jones, IREC Farmers' Newsletter 182, Autumn 2010, pp 30–31 (2010)

**Effects of irrigation timing on seedling establishment and productivity of subterranean clover pastures**, Kelly, K.B. and Mason, W.K, Australian Journal of Experimental Agriculture, 27(4), 545–549 (1987)

**Effect of rice stubble management on soil health**, Kirkby, Clive, IREC Newsletter No 162, Summer 2003 52–54 (2003)

**Establishment and early growth after rice of subterranean clover (*Trifolium subterraneum*), Persian clover (*T.resupinatum*), balansa clover (*T.michelianum*), and white clover (*T.repens*)**, Lattimore, M.E, Beecher, H.G., and O'Callaghan, K.L., Australian Journal of Experimental Agriculture, 34, 459–467 (1994)

**Design and development of a powered vertical disc plough**, Singh, T.P. and Singh, B., Indian Journal of Agricultural Engineering, 38 (1), pp 41–52, (2001)

**Pasture Legumes for Temperate Farming Systems The Ute Guide**, Wurst, Michael, PIRSA (2004),

### RIRDC Project PRJ-009224

*Improving rotational crop establishment options following rice*

This project was supported by the Rice Research and Development Committee of the Rural Industries Research and Development Corporation.

### More information

Malcolm Taylor

T: 03 5872 2892

M: 0427 722 892

E: malcolmc.taylor@bigpond.com

- Growers in northern Australia are keen to establish a commercially viable rice industry to provide speciality rices for niche markets.



# PROFITABLE RICE FOR NORTHERN AUSTRALIA

## QUICK TAKE

- Several rice varieties suitable for aerobic and flooded production in northern Australia have been identified.
- Varietal performance for grain yield and quality under critical environmental factors, such as cold, heat, water stress and blast disease, have been assessed.
- The research will provide basic information for the introduction of new varieties to northern Australia targeting the domestic and international markets.
- The research will also help growers in the region to adopt best practice for both economic and environmental sustainability of rice production systems in northern Australia.

**Suitable soils, warm climate and availability of water make the Ord River Irrigation Area and parts of the Northern Territory ideal for growing rice.**

### Siva Sivapalan

Development Officer, Department of Agriculture and Food, Western Australia, Kununurra

**T**HE Australian rice industry, which is based predominantly in southern New South Wales, is looking for opportunities to produce quality rice in northern Australia. In northern Australia, local industry groups are keen to establish a commercially viable rice industry to provide speciality rices for niche markets.

Despite keen interest, there is a lack of information about tropical rice growing in Australia on which to base sound decisions when starting a new enterprise. Rice has been grown in the region previously but many issues regarding suitable varieties, planting date, establishment technique, sowing rate, and fertiliser and irrigation requirements remained unresolved.

### Key findings

The project *Agronomic options for profitable rice-based farming system in northern Australia*, which ran from 2012 to 2015, carried out a series of experiments evaluating the best agronomic options for a profitable rice-based farming system in the tropical north of Western Australia and the Northern Territory. The field work was necessary to gain information in order to establish a viable industry based on high quality exportable produce and production systems that are efficient, environmentally sustainable and responsive to market needs. The results of this project will provide information about growing rice in Australia's north by:

- demonstrating the most appropriate production system
- determining the most suitable varieties
- ensuring that grain quality standards are maintained in different climate regions.

## Growing system

Rice growing under aerobic conditions is the most suitable system for the high rainfall areas of northern Australia, as it better fits existing crop rotations, requires less irrigation water and minimises bird pests, compared with flooded systems.

A split fertiliser application strategy was tested, with different rates of basal fertiliser (several nutrients) at seeding followed by different rates of nitrogen at different growth stages. High rates of basal fertiliser did not achieve significant yield increases over low basal rates. Grain yield data indicated significant differences between the top-dressed nitrogen rates but the response to was not specific for varieties or irrigation systems. The highest grain yield was achieved when nitrogen was applied at the panicle initiation stage.

## Minimising cold damage

Minimum air temperatures of less than 15°C had the biggest impact on varietal performance. Potential cold damage during the months of June and July warrants selection of varieties with cold tolerance for this environment, especially for production in an aerobic rice system. Ponded water provides a 4–8°C temperature buffer against ambient air temperature, thus providing some protection against cold. In the project, this resulted in higher yields under the flooded system.

Planting dates, varying from late February to late May, were found to play a crucial role for plants to avoid low temperature damage at critical growth stages. The results also indicated that late planting ensured high yields (Figure 1), but the grain quality suffered due to extreme weather conditions prior to harvest. The maturing grain experienced high fluctuations in diurnal temperatures which caused cracking of the grains, and hence low whole grain millout and high chalk content in grains. High percentage whole grain millout was achieved by harvesting at high grain moisture levels, for example, greater than 19.4, 19.5 and 20.0 per cent, for varieties NTR 426, NTR 587, and Yunlu 29, respectively. However, high chalk in harvested grains remained an issue.

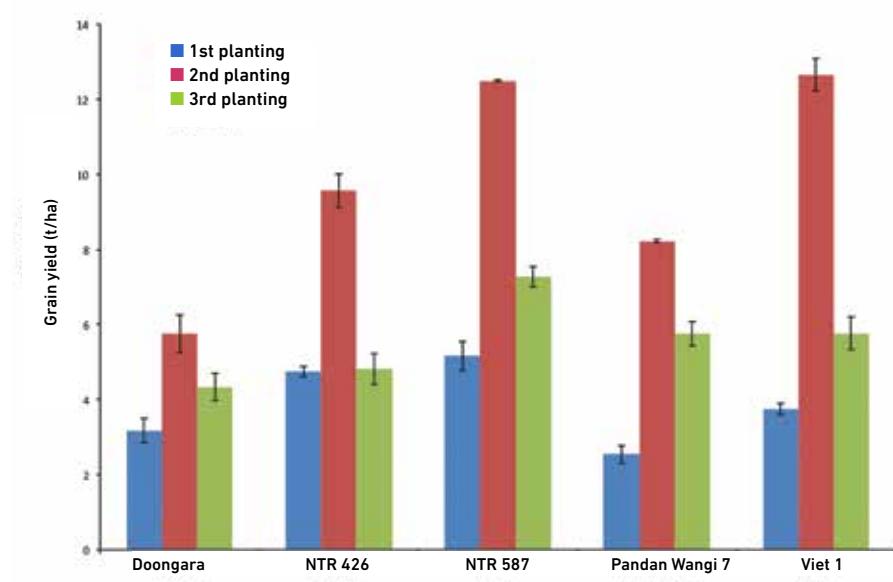
## Best varieties

Seven temperate and 20 tropical rice varieties, sourced from nine countries (Australia, USA, Korea, Indonesia, Japan, India, Philippines, China and Vietnam), were evaluated in field trials for their yield performance in the Ord River Irrigation Area, during the dry seasons between 2009 and 2014.

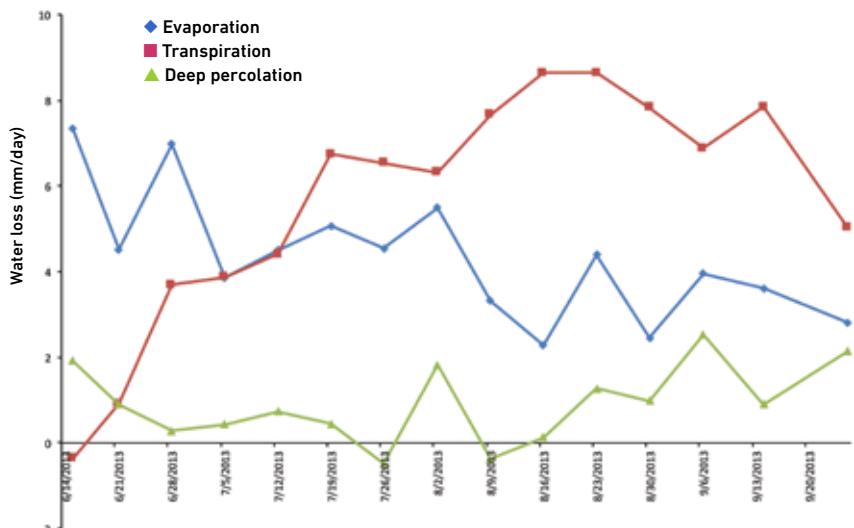
A similar set of varieties was also tested



● There is a need for more information about tropical rice growing in northern Australia.



● Figure 1. Grain yield of five varieties planted on 22 April (1st planting), 8 May (2nd planting) and 21 May (3rd planting) in 2013



● Figure 2. Rates of evaporation, transpiration and deep percolation under flooded system.



#### ● Strip harvesting of rice in the field experiments for yield estimates and quality assessment.

at three other sites in the Northern Territory — Katherine Research Station, Tortilla Flats and Coastal Plains Research Station. Among the varieties tested, selected tropical varieties yielded higher than the temperate varieties. Variety Yunlu 29 was identified as the best variety adapted for aerobic rice systems. NTR 426 and NTR 587 were found to out-perform all other tested varieties under the flooded system.

#### Water management

Rice is a semi-aquatic plant and considered a heavy user of water. Thus, for the aerobic system, it was necessary to maintain the soil moisture level closer to the drained upper limit to avoid water stress. The results of this project suggested that irrigation scheduling based on a seven-day irrigation interval achieved the best results for the aerobic system in Cununurra Clay soil in the tropical environment.

Leakage measurements in the flooded system (Figure 2) revealed that the deep percolation losses in Cununurra Clay soil were either negligible or less than 1 mm/day, which is within acceptable limits of groundwater recharge. The results also indicated that the total water use varied from 9.7 ML/ha for NTR 587 in 2014 to 13 ML/ha for IR 72 in 2013, which is efficient for a rice production system in the tropical environment.

#### Implications

The yield performance of temperate and tropical rice varieties tested in this study was influenced by the environmental conditions imposed by factors such as growing season, water management, date of planting and basal and top dressing.

The response of different rice varieties to an aerobic rice growing system was completely different compared with the response to a flooded system. For economic reasons, it was concluded that varieties could not be broadly adapted to both production systems.

Varieties with specific adaptation to each system have been identified for the Ord River Irrigation Area. Overall, varieties originating from tropical regions might be better suited to north western Australia compared with varieties from the temperate regions.

Cold air temperatures during the night appeared to be a major issue which will influence the selection of appropriate varieties with cold tolerance.

The variety Yunlu 29, from Yunnan Province in China, has red coloured grain and is adapted to aerobic conditions. It has good cold tolerance and remarkable recovery after cold temperature events. It is high yielding (10–12 t/ha) under favourable conditions. It is also believed that rice from this variety could attract premium prices by targeting speciality markets, locally or internationally.

Originating from IRRI in the Philippines, the long grain varieties NTR 426 and NTR 587 are believed to have resistance to blast disease. Both varieties have produced good yields up to 10.7–12.5 t/ha in trials under flooded systems. These varieties are very sensitive to cold temperatures and therefore not suited for the aerobic production system.

Understanding the amount of leakage under flooded rice fields is becoming more important in the Ord River Irrigation Area as natural resources continue to be developed. An estimation of evaporation, transpiration and deep percolation losses for a flooded

rice crop in Cununurra Clay soil was made using a range of measurement systems. The results showed that deep percolation losses were less than 1 mm/day. The estimated total water usage of flooded rice for variety NTR 587 in 2014 was 9.7 ML/ha. Hence undertaking the cultivation of flooded rice systems in similar soil types of Cununurra Clay soil is considered safe and within manageable limits of groundwater recharge rates in the Ord River Irrigation Area.

#### Recommendations

Minimum air temperatures of less than 15°C had the biggest impact on varietal performance. Potential cold damage during June and July warrants selection of varieties with cold tolerance for this environment, especially for aerobic growing systems.

The flooded rice system is recommended where cold damage is expected and cold sensitive varieties such as NTR 426 and NTR 587 may be grown for their yield advantage. Given ponded water is generally 4–8°C warmer than the air temperature, this system provides some protection against cold damage.

Planting dates, varying from late February to late May, were found to play a crucial role for plants to escape potential low temperature damage at critical growth stages. For the flooded system, it appears that a planting date during the second week of May might enable very high yields to be achieved. However, the high amounts (greater than 5%) of chalk in harvested grain due to greater diurnal temperature range during the ripening stages of the crop could be avoided by planting early so that the crop would mature during mild weather.

Among the varieties tested, tropical varieties yielded higher than temperate ones. Yunlu 29 was identified as the best variety for an aerobic rice production system in the Ord and Katherine regions. NTR 426 was found to outperform all other tested varieties under the flooded production in the Ord, compared to NTR 587 in Tortilla Flats in the Adelaide River region.

Future work is needed with a greater focus on the quality of harvested grain from this region.

#### RIRDC Project No PRJ-00749

*Agronomic options for profitable rice-based farming system in northern Australia*

#### Further information

Dr Siva Sivapalan

T: 08 9166 4060

M: 0413 412 937

W: agric.wa.gov.au

- Little is known about how and why particular technologies are adopted by growers, and the challenges that growers face in making technologies workable on farm. Photo: SUNRICE



# SOCIAL FACTORS INFLUENCING TECHNOLOGY ADOPTION

## QUICK TAKE

- Little is known about how and why particular technologies are adopted by growers, and the challenges faced to make technologies workable on farm.
- Several factors were important in influencing growers to adopt new technologies but of most significance was the cost effectiveness of new technology.
- Growers use a range of strategies to work around the perceived risks associated with technology adoption, including informal learning from other growers and early adopters.
- Adoption by rice growers relied on information from trusted sources such as local agronomists, rice industry organisations, the NSW Department of Primary Industries and other growers.

**Adopting new technology to improve on-farm productivity and water efficiency is common practice amongst Australian rice growers.**

### Vaughan Higgins

Charles Sturt University, Albury

### Melanie Bryant

Swinburne University of Technology,  
Melbourne

**W**HILE it is widely recognised that there are high rates of technology adoption in the rice industry, little is known about how and why particular technologies are adopted by growers, and the challenges that growers face in making technologies workable on the farm.

Research in Australia and overseas shows that *social factors*, ranging from farmers' personal goals, knowledge and networks, to the broader cultural, environmental and economic context in which they make decisions, have a significant impact on why and how technologies are adopted.

This research project reported in this article aimed to investigate such factors in the irrigation areas of the Murray Valley (Murray), and the Murrumbidgee (MIA) and Coleambally (CIA) irrigation areas to develop knowledge about what growers are already doing in response to market and environmental changes, and how the industry can work better with growers to maintain sustainable and competitive rice production in Australia.

To investigate the social factors influencing technology adoption, 59 interviews were conducted with rice growers from each of the main rice growing areas between March and September 2015. Of the total growers interviewed, 25 were from the Murray Valley, 25 from the MIA, and nine from the CIA. Twenty interviews were also conducted with rice industry

stakeholders including senior staff from SunRice, RGA and irrigation companies, private consultants, extension agents, public and private sector agronomists, and researchers.

In this article the focus is on the findings from the grower interviews since these provide the greatest insights into the social factors influencing growers' adoption practices. Three key themes emerged from the grower interviews which are outlined below.

## 1. Constraints to adoption of technology

Growers viewed several factors as important in restricting their capacity to adopt new technologies (Table 1). Of most significance was the *cost effectiveness* (cost versus expected financial returns) of new technology. Growers also expressed concerns about the challenges in adopting precision agriculture technologies due to the lack of demonstrated and proven benefits, the lack of time to trial and interpret the information generated by the technology, problems with compatibility between the platforms of different technology/machinery manufacturers, and fear over loss of flexibility and lock-in to a particular manufacturer's platform.

The age of rice growers was also identified as a potential challenge in technology adoption. Older growers were perceived as slow adopters but not necessarily less likely than younger growers to adopt new technology.

## 2. Strategies for adopting technology

Despite the reported constraints and challenges, growers were generally interested in and amenable to adopting new technology. Growers use a range of strategies to reduce, or work around, the perceived risks — particularly lack of demonstrated benefit, cost vs return, time and cost involved in trialling new technology, and technological compatibility — associated with technology adoption. These strategies include informal learning about technology from other growers and particularly early adopters, adaptation of new technology to work with existing equipment, and the use of technology/equipment owned by contractors or neighbours (Table 2).

**Table 1: Constraints to technology adoption**

Constraint	Example from data
<b>Cost of technology versus expected returns</b>	I look at new technologies as is it going to make the job easier, is it going to make it more cost effective, those sort of things. And will it return us a decent amount of money to warrant spending money on it in the long term. (Murray, Grower 23)
<b>Lack of demonstrated benefits</b>	...at this stage there's not many of our neighbours or people that we work for that are using variable rate technology directly. [Grower's neighbour] is one that is, but with his work it's a little bit limited success.... And they're not really seeing the benefits for the money that you're outlaying. (MIA, Grower 13)
<b>Time involved to trial or interpret information from new technology</b>	We use all these technologies [but] we haven't actually got time to sit down and read the results. I think the technology is speeding up our lives. Consumption of your time and ... knowing how to deal with it is a challenge in adopting new technologies. (Murray, Grower 19)
<b>Technology compatibility and lock-in</b>	Retailers, a lot of them will tell you we'll do this and do that and like we bought another tractor that had a GPS in it last year and it won't talk to our boom spray but the system we've got will talk to our boom spray and this other one's meant to be a new flash modern technology but it won't talk to our boom spray, whereas our old one will. Just simple things like that [are frustrating]. (CIA, Grower 6)
<b>Age of the grower</b>	I'm a slow adopter; I mean some of it's to do with my age.... I think when you're 25 ... you have a much different view of risk and how you analyse things, and what you adopt. But I suppose I'm fortunate enough, or unfortunate enough to have been through the cycle a couple of times now, of ups and downs, and it changes your view of how you assess that [risk]. (Murray, Grower 4)

**Table 2: Adoption and adaptation strategies**

Strategies	Example from data
<b>Learning from other growers</b>	If I know someone who's got a machine with something in it I'll ring them and have a yarn to them and ask them whether they've had trouble with this or that and they'll say yes or no. And then you ring the bloke up the road who's got the same machine and he might tell you something different and then you can fit somewhere in between, that's the main way I work. (MIA, Grower 21)
<b>Learning from early adopters</b>	The main challenges [in adopting technology] are just making that initial decision I suppose. [I'm] fearful of going down the wrong path. And being an early adopter you'd have to wear that. [So] you just wait for the early adopters to make the mistakes. I'm happy doing that. (MIA, Grower 24)
<b>Adaptation of technology</b>	...it doesn't really matter whether it's IT type technology, precision ag stuff, or whether it's the hard physical stuff — shift the dirt, move the water stuff — the same rules apply. You fiddle with it for a while, you bend it to suit yourself. (Murray, Grower 11)
<b>Use of contractors' or neighbours' resources</b>	As much as I'd love to have a lot of that stuff it's not financially practical for me to adopt a lot of it. We find that in a lot of regards there's always a contractor or there's someone that's going to hire a bit of gear or there's a neighbour that's got it that you can actually get your hands on it to do the job. (MIA, Grower 18)

### 3. Trusted sources influencing decisions

For rice growers, the adoption process is based first and foremost on trust. If a technology is being promoted by an individual or organisation that they trust, growers will be more likely to consider using that technology. Growers identified four key trusted sources: local agronomists, the rice industry (including SunRice, RGA, RRAPL, and RIRDC Rice R&D Committee), the NSW Department of Primary Industries, and other growers (Table 3).

## Conclusions

Our findings suggest overall that there is no single 'driver' or 'barrier' to grower uptake of technology. While growers are keen on engaging with new technology, they experience a range of constraints and challenges, many of which are outside of their direct control. Growers seek to overcome or work around these challenges in different and often innovative ways. However, their capacity to adopt and adapt is dependent on support from a range of trusted agents and institutions.

Our research shows that improving technology adoption in the rice industry is more complex than trying to change individual grower practices. It requires a broader approach that *works with* what growers are already doing to implement technology, and *works through* networks of trusted agents and institutions. Specifically, such an approach should:

- use locally credible, trusted, change champions/early adopters to demonstrate the financial and agronomic benefits of new technology (especially precision agriculture technology)
- encourage the use of paddock-level learning about new technology
- emphasise the options and shortcuts for growers in adapting existing technologies and systems
- work more closely with local agronomists and farm advisors in promoting new technology and encouraging farm-level adoption.

#### RIRDC Project PRJ-009181

*Social factors influencing technology adoption in the rice industry*

#### Further information

Assoc Prof Vaughan Higgins  
T: 02 6051 9623  
E: vhiggins@csu.edu.au

Table 3: Trusted information sources

Information source	Example from data
<b>Local agronomists</b>	These blokes, because I know them, because I'm from here and grown up with these guys. I trust them, like the agronomist to give me an honest opinion. And also because they've got no interest, they don't sell the technology, so they're not going to give you a bias there. (MIA, Grower 20)
<b>Rice industry</b>	The people that do our R&D in the industry, they've got their finger on the pulse of all those things.... You've got to trust the people doing the research that they're giving us the stuff that they think is the best, and I suppose that's us choosing the right people to do our research and whether people are competent that are doing the job. (MIA, Grower 8)
<b>NSW DPI</b>	[I trust the] DPI because they're the most impartial. I mean you don't trust your neighbours because they just want to brag about how good their crop is and it's always been like that so you don't take any notice of your neighbours. (CIA, Grower 8)
<b>Other growers</b>	I trust a lot of farmers actually more than I will the people that sell [technology]. Your best point of reference is someone that's already involved in it.... Other people in the district that have got new technologies, it's always handy to talk to those and others that have started it. You gain a lot from that because they're hands on, they're using it, they can see, they come up with the pitfalls and whether it works or doesn't. (Murray, Grower 23)



● Growers find the adoption of precision agriculture technologies challenging due to the lack of demonstrated and proven benefits. Photo: SUNRICE



● While growers are keen on engaging with new technology, they experience a range of constraints and challenges, many of which are outside of their direct control. Photo: SUNRICE



● Craig Dawe and Tina Dunn collecting rice canopy spectra (remotely-sensed data) using a hyperspectral scanner mounted on a four-wheel drive motorbike.

# REMOTE SENSING PI NITROGEN UPTAKE IN RICE

## QUICK TAKE

- Nitrogen uptake maps of rice crops at panicle initiation (PI), derived from remote sensing, would reduce the need for physical sampling and provide a greater understanding of crop variability.
- The high-resolution satellite-based Worldview 3 has shown potential for predicting PI nitrogen uptake but another season's data is required to be confident it can work across seasons.
- The new micaSense RedEdge camera, which can be mounted on a drone, looks promising from one season's results and will be further tested in the 2016–17 season.
- The success of a remotely sensed option to measure PI nitrogen uptake is dependent on accuracy of predictions and affordability.

Researchers have been investigating the use of remote sensing to predict nitrogen uptake at panicle initiation (PI) and the results are encouraging.

**Brian Dunn, Tina Dunn, Iain Hume and Beverly Orchard**

NSW Department of Primary Industries,  
Yanco Agricultural Institute

**Remy Dehaan**

Charles Sturt University

**Andrew Robson**

University of New England

efficient and reliable as the crop's growth already takes into account some of the unknown variables at sowing such as early seasonal temperatures and available soil nitrogen. The NIR tissue test has been the industry standard for measuring crop growth and nitrogen at PI since the mid-1980s. Unfortunately many growers and agronomists do not take advantage of this technology but rely on estimating the rice crop's nitrogen requirements. One of the main reasons growers do not use the test is difficulty in sampling the rice crop in the water.

Four years of research has been conducted to investigate how accurately nitrogen uptake of rice at PI can be predicted using remote sensing from drones, aircraft and satellites. This was part of an ongoing Rural Industries Research & Development Corporation (RIRDC) research project.

**C**URRENTLY, the NIR tissue test is the recommended method for determining nitrogen requirement for rice at PI, however less than 30% of growers are currently using this system.

Remote sensing would reduce the need to physically sample the rice crop and the derived maps of nitrogen uptake at PI would provide a greater understanding of nitrogen variability throughout the crop, which would be an added bonus.

Applying nitrogen to a rice crop at PI is

## Remote measurement

For each year of the project, a series of experiments was setup with several commercial rice varieties. Across the varieties, a range of nitrogen rates was applied to create rice plots with a large range of nitrogen uptake levels at PI.

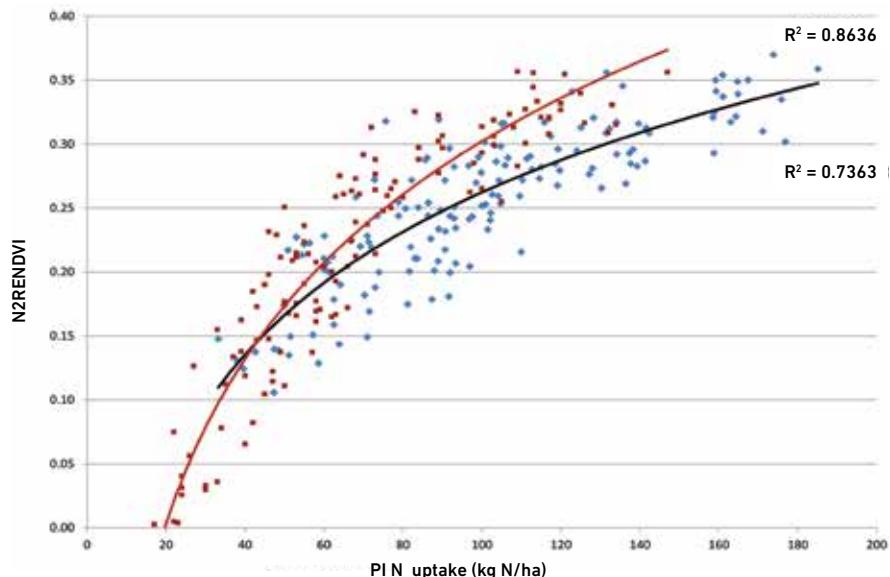
These plots were measured at PI using several remote sensing instruments and physical plant samples were also collected. The relationships between the remotely sensed data and the physically measured nitrogen uptake at PI were investigated. Multi-season correlations have been developed between the data and measured nitrogen uptake at PI for several multispectral and hyperspectral systems (Table 1).

The PI nitrogen uptake prediction obtained from three years of hyperspectral data was very encouraging (see article in IREC Farmers' Newsletter No. 194) but no hyperspectral sensors are available that are commercially viable. The four wavelengths that were most significant in the full hyperspectral prediction have been determined with the aim of testing if they alone can accurately predict PI nitrogen uptake in an aircraft-mounted filter camera. If a camera using these wavelengths can be sourced it will be used to scan plots in the coming season.

We have also been evaluating the Worldview 3 satellite and the newly released micaSense RedEdge camera for their abilities to predict PI nitrogen uptake. Both of the sensors measure the red edge, which is a narrow band of reflectance (710–740 nm) that corresponds to the rapid change from low red reflectance to high near infrared (NIR) reflectance. This band is very sensitive to plant stress and provides information on the chlorophyll and nutrient status of plants.

**Table 1.** The range of instruments used in four years' of research to collect remotely sensed data from 'rice variety x nitrogen' experiments.

Remote sensing instrument	Collection method	Bands	Data collected
SVC 1024	Ground	Hyperspectral (330–2500 nm)	3 seasons
Greenseeker	Ground	NDVI	2 seasons
Aerial NDVI	Aerial	6 bands (490–900 nm)	3 seasons
micaSense	Aerial	4 bands with red edge	1 season
HyVista Hymap	Aerial	Hyperspectral (430–2450 nm)	1 season
Worldview 3	Satellite	8 bands (400–1040 nm)	2 seasons

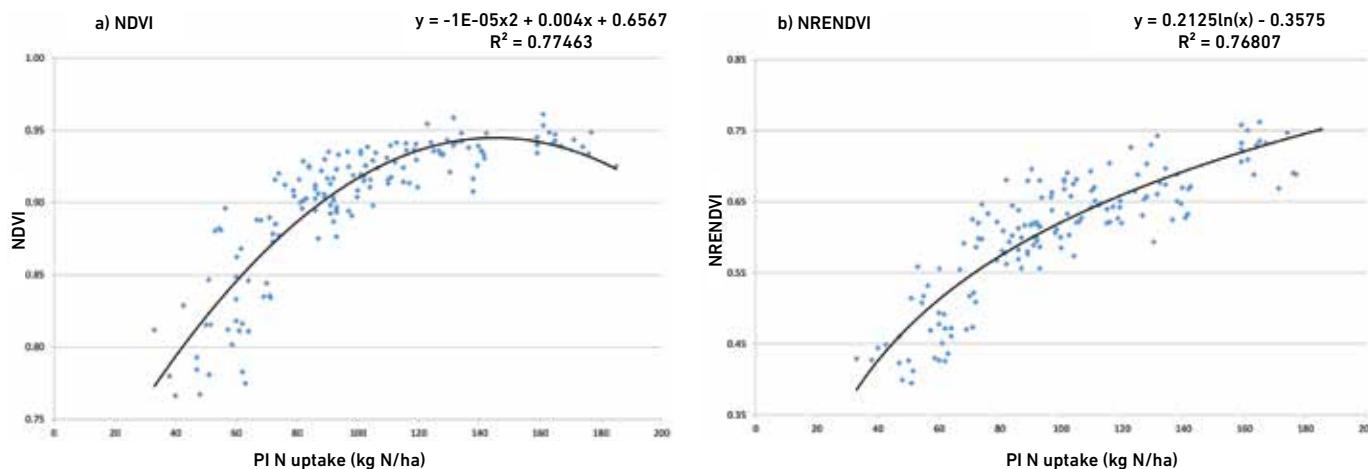


**Figure 1.** Measured PI nitrogen uptake (kg N/ha) versus N2RENDVI for data collected from the Worldview 3 satellite for two seasons.

### Worldview 3

Two season's data has been collected with the very high resolution Worldview 3 satellite. The first season of the Worldview 3 satellite data showed considerable potential but when the second season's data was analysed it showed a different relationship between PI nitrogen uptake and N2RENDVI (a normalised difference vegetation index based on the near infrared

and red edge wavelengths)(Figure 1). The indice N2RENDVI calculated by  $((\text{NIR2}-\text{red edge})/(\text{NIR2}+\text{red edge}))$  was shown to have the best relationship with PI nitrogen uptake. It is common for spectral data to be different across seasons and is the reason multi-season data is required when developing robust calibrations. A third season's data will be collected in 2016–17 to determine how accurate a prediction using



**Figure 2.** Measured PI nitrogen uptake (kg N/ha) versus the indices a) NDVI and b) NRENDVI collected from the micaSense RedEdge camera mounted on a drone.

this instrument across seasons and varieties can be achieved.

#### micaSense RedEdge

Recently the compact micaSense RedEdge camera was released, which scans the red edge as well as the traditional red, blue, green and NIR wavelengths, and it is small enough to be mounted on a drone. One season's data has been collected with the micaSense RedEdge camera and the relationship between NDVI (normalised difference vegetation index) and PI nitrogen uptake is shown in Figure 2a. The normal problem with NDVI when used for measuring rice PI nitrogen uptake, as shown by the figure, is that as the PI nitrogen uptake goes above 90 to 100 kg N/ha the NDVI saturates and no difference in the NDVI reading occurs. When the red edge wavelength is used with a different indice, NRENDVI = ((NIR-red edge)/(NIR+red edge)) the relationship with PI nitrogen uptake is greatly improved (Figure 2b). A second season's data is required to see how accurately the instrument performs across years.

### How accurate does the prediction need to be?

A significant question in this research is how accurate does the prediction need to be? Especially when 70% of growers currently are not using the NIR tissue test. There are also sampling errors that can occur with the current physical sampling for the NIR tissue test and a remotely sensed option has the advantage of showing the spatial variability that is present across the field. Ideally the remotely sensed option would be accurate enough that no physical sampling would be required, but if this cannot be achieved will farmers and agronomists accept a remotely sensed test that still requires a reduced level of sampling?

### Where to now?

In the 2016–17 rice season the Worldview 3, micaSense RedEdge and the new Parrot Sequoia camera will all be tested across a range of nitrogen experiments and in several commercial fields. Once analysis of that data is completed the sensing technology that

provides the best prediction accuracy of PI nitrogen uptake at an affordable price will be identified. The opportunity for development of a semi-commercial system for determining nitrogen uptake of rice at PI will be assessed after results from the coming seasons experiments have been collated. The project team will also monitor and test new technology as it becomes available as technology in this area is evolving rapidly.

#### RIRDC Project PRJ-009772

*Moving forward with NIR and remote sensing*

#### Acknowledgements

This research was co-funded by the NSW Department of Primary Industries and the Rural Industries Research & Development Corporation. Excellent technical support from Chris Dawe and Craig Hodges has contributed significantly to this project.

#### Further information

Brian Dunn  
T: 02 6951 2621  
E: brian.dunn@dpi.nsw.gov.au



**It's time to get serious about your rice crop agronomy.**

**Don't take your rice crop and water investment lightly.**

**Yield, grain quality, water use, precision ag, nutrition, weed and pest management**



**Rawlinson and Brown Pty Ltd**  
60 plus years of rice agronomy  
**Coleambally   Griffith   Hillston**  
6954 4176   6964 1933   6967 2523  
[www.rawbrown.com.au](http://www.rawbrown.com.au)



- 
- The short-grain breeding line YRK5 (left) flowers 14 days earlier than Opus (right) in a mid-November sowing.

# OVERVIEW OF NEW SHORT SEASON BREEDING LINES YRM70 AND YRK5

## QUICK TAKE

- A shorter growing season is a key feature of two lines in the final stages of testing in the rice breeding program.
- YRM70 and YRK5 have maturity comparable to Jarrah and potentially offer about a 10% increase in water productivity.
- Both lines include cold tolerant parents and have tolerance to low temperatures at the reproductive stage equivalent to Sherpa.
- Low GI medium-grain and long-grain breeding lines are showing promise in the rice breeding program and will be priorities for future variety releases.

**Two lines in the final stages of testing in the rice breeding program potentially offer efficiency gains of around 10% in terms of rice produced per megalitre.**

**Ben Ovenden, Peter Snell and Laura Pallas**

NSW Department of Primary Industries,  
Yanco Agricultural Institute

**Russell Ford**

Rice Research Australia P/L, Jerilderie

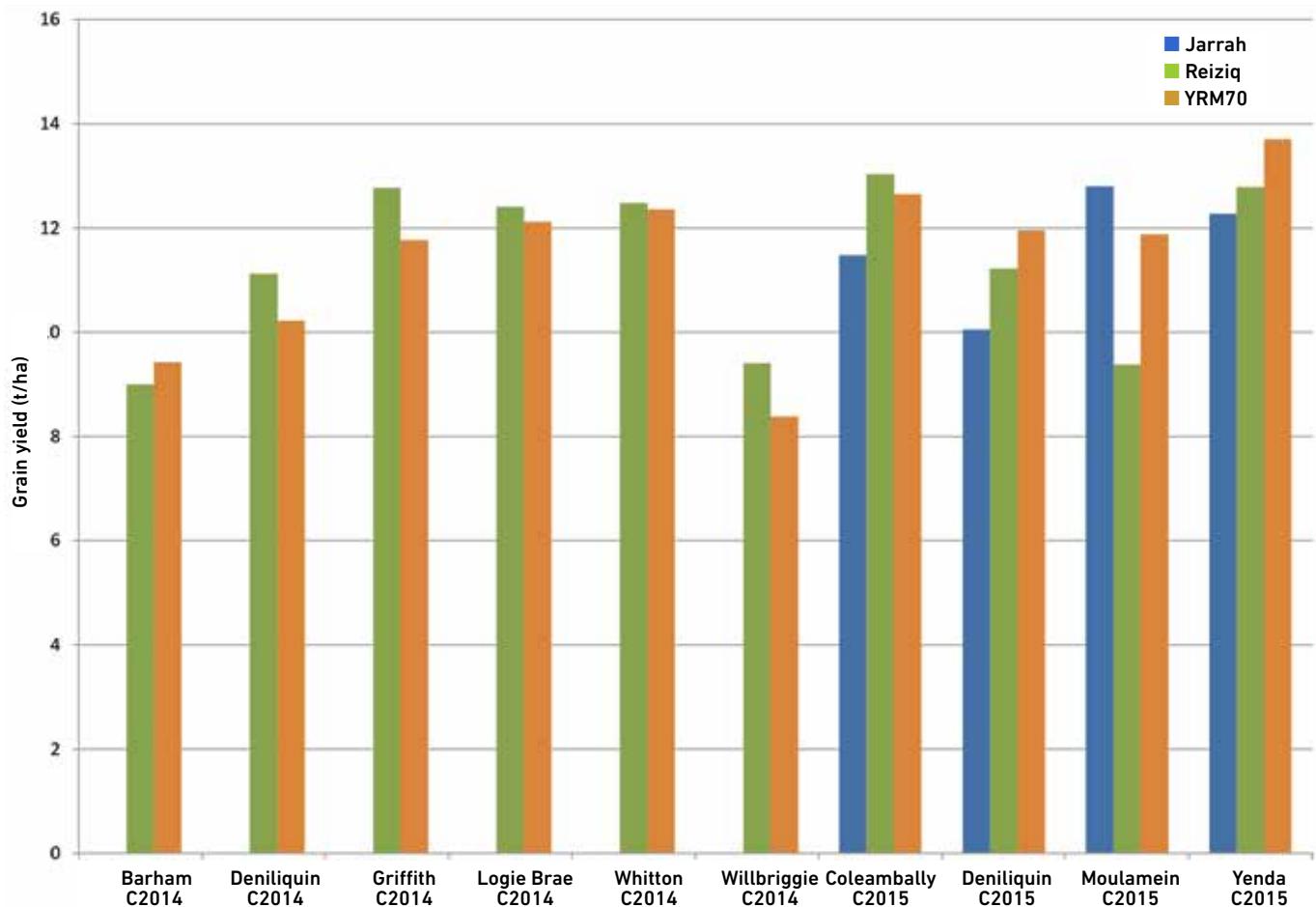
**Y**RM70 is a medium-grain rice with similar quality characteristics to the variety Reiziq and YRK5 is a short-grain rice with quality characteristics matching the variety Opus. The key feature of both new varieties is a short growing season, the same as or shorter than the outclassed variety Jarrah that was grown between 1993 and 2012.

Both breeding lines originate from the cold tolerance screening nurseries in the breeding program and were identified

through panicle sterility measurements.

The lines include cold tolerant parents in their pedigree that were sourced from high latitude regions overseas, where rice is grown between snow events. The lines both have tolerance to low temperatures at the reproductive stage, equivalent to Sherpa.

Both lines have been evaluated in district trials after progressing through the breeding program. Results show that Reiziq performs better than YRM70 in full season trials, while YRM70 outperforms Reiziq in late sown trials (Figure 1). Trial performance across similar performing trial groups over three years show YRM70 grain yield is predicted to be 96% of Reiziq in full season sowing dates, and 107% of Reiziq in late sowing dates.



● **Figure 1. District trial results for predicted grain yield in 2014 (full-season planting dates) and 2015 (late-season planting dates)** district trials show the yield advantage of YRM70 over Reiziq in later planting dates (i.e. 2015).

As these new breeding lines are very different in maturity from the standard full season varieties, comparison in full season trials does not give a true indication of performance, so these lines have been grown in breeding trials with early, mid and late planting dates. Figure 2 compares Reiziq and YRM70 grain yield from four seasons of breeding trials at Leeton and Jerilderie by time of sowing. Earlier sowing times favour Reiziq over YRM70, while in later sowing times YRM70 performs better than Reiziq. However sowing time does not give a complete picture of varietal performance, as random weather events encountered during the growing season mean lines with differing maturity are encountering different (and unpredictable) environmental conditions even in the same field trial. Another way of comparing performance, particularly as cold tolerance plays such a large part in determining yield stability in the Riverina rice growing environment, is to compare grain yield with minimum temperatures encountered at the critical early microspore stage. Figure

3 illustrates the performance advantage of YRM70 over Reiziq at early microspore temperatures under the critical threshold of 15°C where reproductive cold damage can occur. A similar result can be seen in trials comparing YRK5 and Opus (Figure 4).

## Agronomic features

Establishment for these lines may be easier given the warmer temperatures likely to coincide with the later sowing dates. Additionally, the speed of emergence and seedling growth at these dates means that the pre-emergent herbicide application in a drill sown situation may be sufficient for good weed control.

Lodging is more pronounced in short season varieties due to rapid accumulation of biomass compared with full season varieties. However lodging potential for YRM70 and YRK5 is significantly less than Jarrah with the plant also supporting a higher yield potential than Jarrah.

The lines have not been evaluated for early sowing leading to early harvest situations, however this may be an option if

careful consideration is given to harvesting close to physiological maturity (at higher grain moisture). However it is anticipated that whole grain millout and other quality attributes may not be optimal with early sowing dates due to inherent warmer conditions during grain development.

Shorter-season varieties present a risk management option to rice growers in an environment of uncertainty. In conjunction with the current suite of full-season varieties, they provide a much wider sowing window for rice producers when, for example, irrigation water allocations are increased in late spring. Additionally these lines provide an over-sow option for the full season varieties Reiziq and Opus in the event of establishment problems. The growth duration of both lines is short enough for them to be planted after a canola, pasture or early cereal crop without compromising yield potential, enabling rice to be grown intensively in a double-cropping rotation. The main photo on page 51 illustrates the shorter time to flowering of YRK5 compared with Opus.

## Market acceptance

Both breeding lines are targeted at higher-value end use markets to maximise grower returns. The grain size of YRM70 is targeted at the Middle East market and YRK5 fits with Opus for the growing domestic market for sushi rice. The pure seed scheme has multiplied sufficient seed (up to 1000 tonnes) of both lines in the event of commercial release in the C2017 season. Successful release will depend on consumer acceptance surveys in key markets for each line, however initial results have been promising for both YRM70 and YRK5.

Future releases in the breeding program may include varieties with low glycaemic index (GI) eating characteristics in both long and medium-grain types. A low GI indicates prolonged uptake of carbohydrates in the digestive system with a slower release of sugars into the bloodstream after eating, which has reported health benefits particularly in the prevention of diabetes and related disorders. Low GI rice types are a growing market segment with increasing consumer focus on the health properties of staple foods and an increase in the prevalence of diabetes across important international markets for Australian rice. Promising breeding lines undergoing evaluation currently include a cold tolerant, low GI long-grain line comparable to Doongara, and a medium-grain low GI line suited to production in systems with delayed permanent water.

### RIRDC Project PRJ-009950

Australian Rice Partnership II

The breeding program is part of the *Australian Rice Partnership II* project, which also includes rice quality evaluation and the rice pure seed scheme. It is funded through a collaborative partnership between NSW DPI, SunRice and RIRDC. The *Australian Rice Partnership II* project involves the following people:

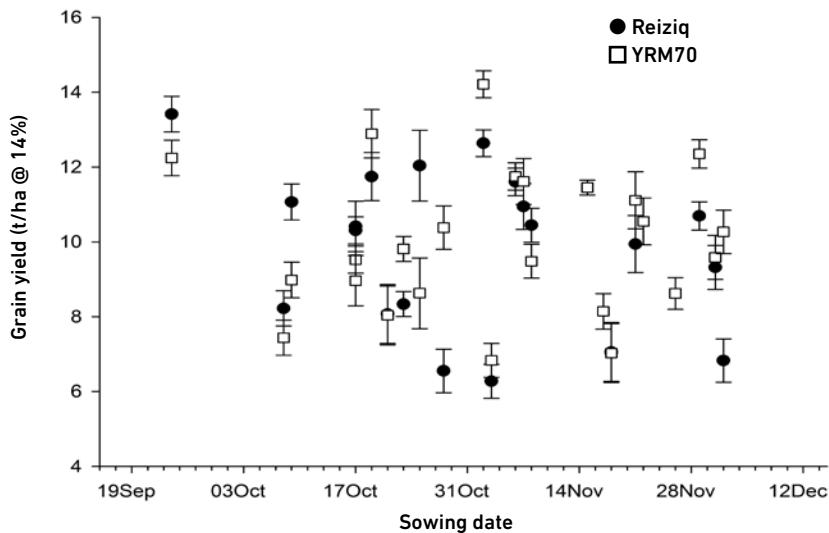
- Dr Peter Snell, Rice Breeder
- Dr Ben Ovenden, Rice Breeder
- Dr Laura Pallas, Cereal Chemist
- Russell Ford, RRAPL Manager

### More information

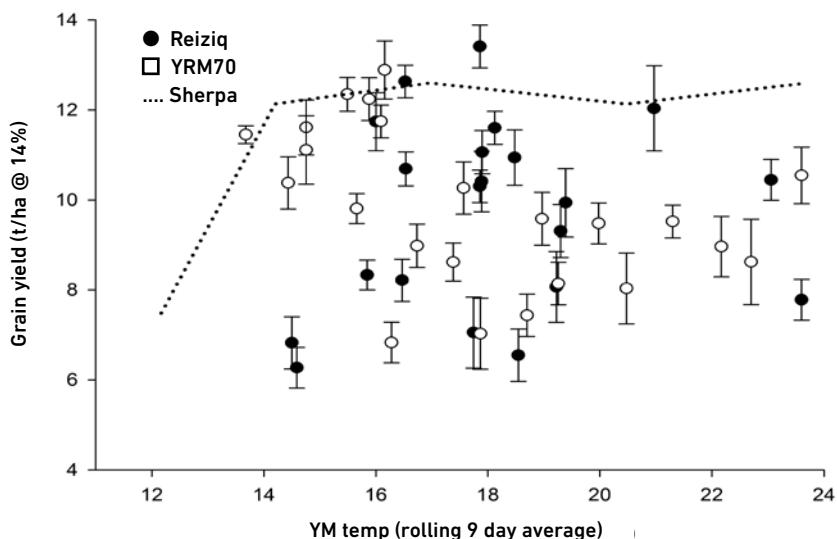
Ben Ovenden

T: 02 6951 2679

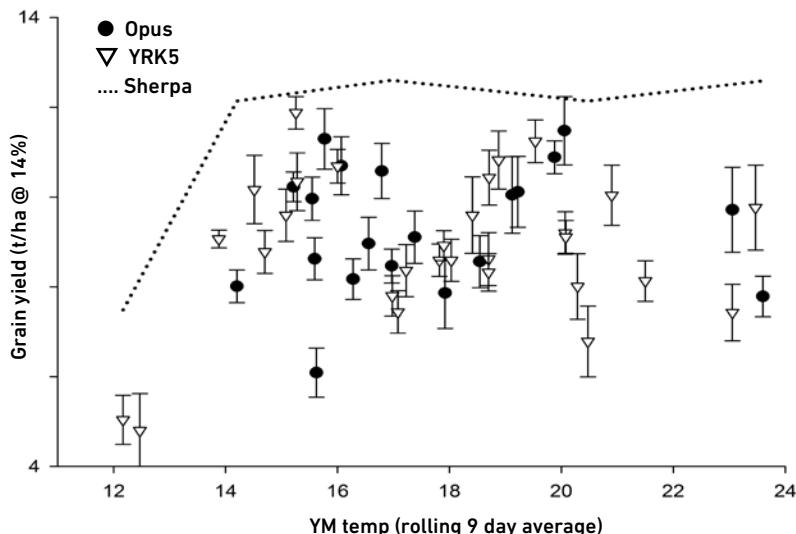
E: ben.ovenden@dpi.nsw.gov.au



● Figure 2. Grain yield performance by sowing date in breeding program trials over four years for Reiziq and YRM70. Earlier sowing times favour Reiziq over YRM70, while in later sowing times YRM70 performs better than Reiziq.



● Figure 3. Grain yield performance of YRM70 compared to Reiziq at early microspore temperatures under the critical threshold of 15°C. The response illustrates cold tolerance performance of YRM70 similar to Sherpa.



● Figure 4. Grain yield performance of YRK5 compared to Opus at early microspore temperatures under the critical threshold of 15°C. The response illustrates cold tolerance performance of YRK5 similar to Sherpa.

- UQ Masters students updating Ben Ovenden, NSW DPI rice breeder (back row and right) on their rice research in the controlled-temperature glasshouse at Gatton campus of UQ.



# NEW PROCESS ASSISTS BREEDING OF COLD TOLERANT RICE

## QUICK TAKE

- Researchers at The University of Queensland have developed a screening (phenotyping) process to identify genotypes of rice that are cold tolerant at the booting and flowering stages.
- A successful screening process will improve the efficiency of the rice breeding program in developing new varieties with imported cold tolerance.
- The screening process will also enhance the ability of plant breeders to identify the regions of the rice genome that are important for cold tolerance.

An important step in the development of new rice varieties is a pre-breeding program to identify suitable genotypes to include in a breeding program.

### Jaqie Mitchell and Shu Fukai

The University of Queensland, School of Agriculture and Food Sciences, Brisbane

### Peter Snell

NSW Department of Primary Industries, Yanco Agricultural Institute

cold-tolerant genotypes, these genotypes can be studied to identify the physiological and genetic characteristics of cold-tolerant rice varieties.

The multidisciplinary research team (i.e. agronomists, physiologists and geneticists), which is focused on improving cold tolerance in rice, is led by Professors Shu Fukai and Ian Godwin and Drs Jaquie Mitchell and Brad Campbell. The research is carried out in close collaboration with rice breeders Drs Peter Snell and Ben Ovenden from the New South Wales Department of Primary Industries.

The screening process has been developed as part of the project *Cold tolerant*

**A**T The University of Queensland (UQ), a process for screening (phenotyping) genotypes of rice for cold tolerance in a controlled-temperature glasshouse has been developed. The process is repeatable and therefore can be used in the pre-breeding stages of variety development. Further, having determined



● The phenotyping system in the controlled temperature glasshouse facility at Gatton campus, UQ. The system is based on two sets of pots for each genotype, which are planted 17 days apart. Set 1 was subjected to cold at the flowering stage and Set 2 was subjected to cold at the booting stage. LEFT: 24 August 2015, 24 days after sowing of Set 1 (at the back) and 7 days after sowing of Set 2 (at the front). RIGHT: 14 September 2015, 45 days after sowing of Set 1 (back) and 28 days after sowing of Set 2 (front).

traits and QTLs for improved efficiency of the rice breeding program (PRJ-007580). Overall, the project aims to improve breeding efficiencies for the selection of cold tolerance in rice at the booting and flowering stages through the identification of quantitative trait loci (QTLs) — sections of DNA that correlate with cold tolerance and underlying physiological mechanisms. However to ensure that this is achieved, a highly-repeatable, low-temperature screening process was needed.

This article describes the design of the screening or phenotyping system developed to enable benchmarking of genetic material (lines of rice) for the identification of improved cold tolerance at the booting and flowering stages of plant development.

## Background

Traditionally based in southern New South Wales, the Australian rice production system can suffer from severe yield reductions due to low temperature damage at any time of the growing season. Other than water availability, year to year variation in rice yield in Australia is largely due to low temperature events. Thus, low temperature is considered a major problem facing the Australian industry.

Considerable efforts have been made by various research groups in Australia over the past 20 years to develop cold tolerant rice varieties with high yield potential and acceptable grain quality. During this time, cold tolerant genotypes have been imported and crosses made with Australian-adapted germplasm. However, the inability to routinely test genotypes in a repeatable

phenotyping system within the breeding program and across the various research groups has limited the rate of improvement of cold tolerant cultivars in Australia.

Previous research in Australia and elsewhere has shown that both cool air and cold water can be used for selection, as they are equally effective in identifying cold tolerance. In Japan and Korea, cold-water facilities have played pivotal roles in cold tolerant variety development. The Australian rice breeding program has used late sowing in the field in an attempt to expose segregating material to low night temperatures. This system is particularly dependent on seasonal temperature fluctuations and the underlying maturity range of the materials being evaluated.

In a previous RIRDC project *Rice cold tolerance for yield stability and water-use efficiency* (RIC05-01), a field-based cold-water irrigation system was constructed at Rice Research Australia Pty Ltd (RRAPL) at Jerilderie, in southern NSW, for large-scale screening for cold tolerance. This RRAPL facility, in conjunction with the staggered sowing strategy, is used to validate the UQ glasshouse phenotyping system.

Low temperature stress at the reproductive stage can cause large reductions in yield of rice. The early pollen microspore stage (approximately 10–12 days before heading) is the most sensitive to cold injury. However, identification of the early pollen microspore stage (early booting) is difficult without dissection and is likely to differ among genotypes. Flowering is considered the second-most sensitive development stage for low temperature stress and this can be a problem

particularly when crops are planted late in the season in Australia.

Spikelet sterility is widely accepted as the best indicator for cold injury at the reproductive stages, and genotypes with low spikelet sterility are considered cold tolerant. Not only does this new phenotyping system enable the identification of cold tolerance at the early booting stage but it also can be simultaneously used to screen for tolerance at the flowering stage.

Introducing cold tolerance genes to Australian rice varieties is a major target for the Australian rice industry to overcome low temperature stress at booting, particularly at the early pollen microspore stage. Cold tolerant genotypes from overseas have been used to introduce cold tolerance genes into the genomes of Australian-adapted varieties.

The development of a new screening process, or technically, a phenotyping system, is an integral part of the rice breeding program. The system provides a reliable way of benchmarking advanced genotypes and varieties, providing a platform to maximise opportunity for identification of genomic regions contributing to cold tolerance at the booting and flowering stages. Once identified and validated across genetic backgrounds, genetic markers can then be used to reduce the many thousands of early generation genotypes coming through the breeding program. This will ensure that only genotypes possessing the cold tolerance genes, as well as genes for required agronomic and quality traits, are advanced through the breeding program. The system



● Undergraduate Science student Ella Wherritt (left) working with PhD student Chris Proud at UQ to investigate early vigour in relation to aerobic rice production and cold tolerance in rice.

will assist the greater goal of increasing the low-temperature threshold of new commercial rice varieties.

## A new screening process

The phenotyping system screens advanced and promising genotypes that have been progressed by the rice breeding program to the F5 or F6 stage. Plants are exposed to low temperature (21°C/15°C) for 14 days/nights at the early booting stage (Set 2) and at the flowering stage (Set 1), both conducted in a controlled-temperature glasshouse facility at UQ.

Genotypes in Set 1 (i.e. exposed to cold at the flowering stage) are sown 17 days prior to genotypes in Set 2 (i.e. exposed to cold at early booting). Both sets are managed the same way in terms of water and nutrient supply; and glasshouse conditions are managed for ideal day length. There are three replications of each line (genotype) in each set.

For Set 1 (exposed to cold at the flowering stage), each pot is moved into the cold room when the individual plant reaches the heading stage. When two out of three replications of each line in Set 1 have reached the heading stage, all three replications of the same line in Set 2 (exposed to cold at the early booting stage) are also moved into the cold room — noting that Set 2 was planted 17 days after Set 1.

All genotypes in both sets remain in the low temperature room for 14 days and then are transferred back to the warm room until maturity, when they are harvested. At maturity, spikelet sterility is determined, and in turn, tolerance to low temperature is determined for both development stages.

## Results to date

Results from the phenotyping system have identified genetic variation for cold tolerance within populations of genotypes

in development, in advanced genotypes and within previous and current commercial varieties.

For example, there was a very wide variation in spikelet sterility which ranged from 4–99% in the early booting stage among genotypes that were derived from a population (KKN) based on Kyeema crossed to a Japanese cold tolerant donor (NorinPL8).

Several cold tolerant genotypes were identified from a population that used Reiziq and Chinese cold tolerant donor Lijiangheigu, and there is work now focused on phenotyping a population that uses Millin and Lijiangheigu.

Table 1 shows the spikelet sterility, as an indicator of cold tolerance, measured by the phenotyping system for a range of current and previous commercial rice varieties. The screening process was applied to genotypes from a Japonica diversity set of

rice varieties released from NSW DPI rice breeding program (Yanco) from 1987 to 2014. Two tolerant donor genotypes used in a number of populations were also included.

Based on the solid phenotypic data that was gained from the phenotyping system, the researchers were able to use a genotyping-by-sequencing methodology to identify genetic regions of importance to cold tolerance. Subsequently, the quantitative trait loci (QTL) on chromosome 10 of the rice genome was confirmed and several genomic regions on chromosomes 5 and 7 were identified that contributed to an estimated reduction in spikelet sterility of 25% and 27%, respectively from genotypes in a cross using Lijiangheigu cold tolerant donor.

Preliminary field trials at Yanco in 2014–15 season experienced a limited degree of cold induced sterility (33%) due to relatively warm (19.5°C) temperatures at early booting. However, spikelet sterility from 30 tiller cuts from 17 KKN genotypes and parents had a relatively strong positive relationship ( $r=0.56^{**}$ ,  $n=17$ ) between field and glasshouse results, with Norin PL8, KKN9-216 and KKN11-221 having low sterility (Figure 1).

## Conclusion

The project has resulted in the development of a successful phenotyping (screening) process that enables identification of cold tolerant genotypes, which will improve the efficiency of the rice breeding program in developing new varieties.

The screening process will also enhance the ability of plant breeders to identify the regions of the rice genome that are important for cold tolerance, and therefore incorporate cold tolerance from breeding and international lines of rice into commercial rice varieties adapted to Australian conditions.

### RIRDC Project PRJ-007580

*Cold tolerant traits and QTLs for improved efficiency of rice breeding program*

### Further information

Jaqie Mitchell

T: 07 3365 1494

E: jaquie.mitchell@uq.edu.au

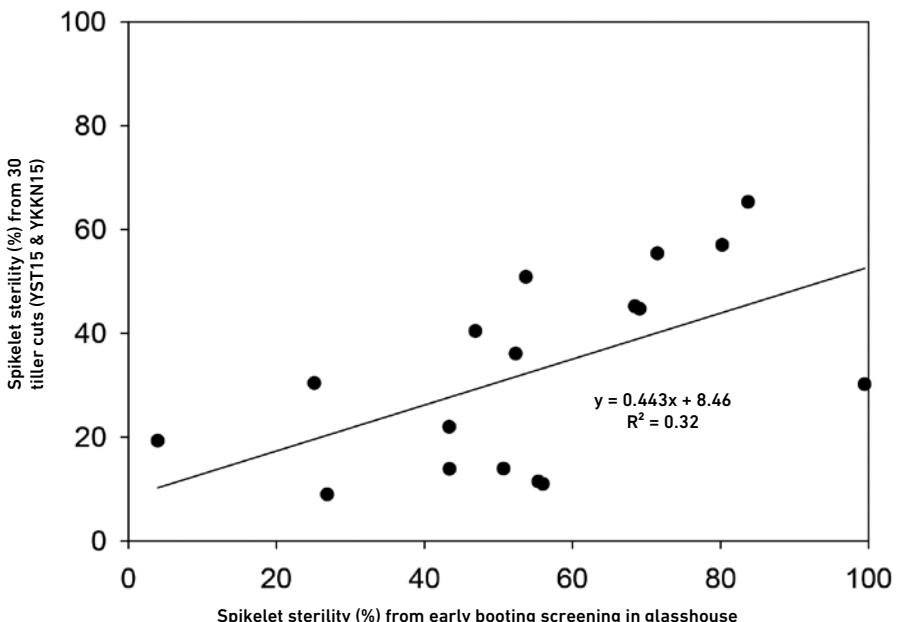
**Table 1: Cold tolerance at the early booting stage of rice varieties released by NSW DPI from 1987 to 2014. Cold tolerance was based on spikelet sterility determined at maturity.**

Variety	Release year	Grain type	Spikelet sterility (%)
Inga	1973	Long grain	31
Pelde	1982	Long grain	61
M7#	1983	Medium grain	18
Amaroo	1987	Medium grain	19
Bogan	1987	Medium grain	38
Doongara	1989	Long grain	39
Echuca	1989	Medium grain	14
Goolarah	1991	Fragrant long grain	11
Jarrahdah	1993	Medium grain	31
Kyeema	1994	Fragrant long grain	32**
Langi	1994	Long grain	40*
Millin	1995	Medium grain	26**
Opus	1999	Short grain	24
Paragon	2003	Medium grain	55
Quest(CT18)	2003	Medium grain	28
Reiziq	2005	Medium grain	61**
Sherpa	2011	Medium grain	19**
Topaz	2014	Fragrant long grain	40*
<b>Cold tolerant donor genotypes used in crosses</b>			
Norin_PL8			9**
Lijiangheigu			18**

#Released in Australia but bred in California (USA)

\* based on different experiment

\*\* average performance across (3-5) booting stage stress experiments



**Figure 1. Relationship between spikelet sterility (%) from 30 tiller cuts from field-grown rice in plots at Yanco and that from low temperature exposure at early booting in the UQ glasshouse screening of 15 KKN genotypes and parents.**



● Grain cracking is thought to be related to changes in grain moisture content. It can be a significant problem as most cracked grains break during milling, reducing payments to the grower and processor. Photo: SUNRICE

# CRACK FORMATION IN RICE GRAINS

## QUICK TAKE

- Grain cracking is a hidden risk to the acceptability of Australian-grown short-grain rice in current markets.
- 'Hanasaki' is a historical method of assessing the potential of rice grain cracking during cooking.
- The work reported in this article shows that nitrogen, variety and sowing date can influence the extent of cracking, within a season, in stored grain.
- An automated method of quantifying fissures will help future research to target areas of agronomy, variety selection and post-harvest handling to maximise grower returns.

In some growing seasons, rice grain is susceptible to forming fine cracks, mostly after the grains have matured in the field.

**Mark Talbot, Laura Pallas and Peter Snell**  
NSW Department of Primary Industries,  
Yanco Agricultural Institute

**G**RAIN cracking (also known as 'suncracking' or 'fissuring') is thought to be related to changes in grain moisture content, particularly cycles of grain drying and wetting. For example, hot sunny days followed by humid or dewy nights, or rain falling on dry grain, can lead to cracks. Downed or lodged crops are also prone to moisture fluctuation as they generate their own micro-environment due to the proximity of the grain to the ground.

Cracks can also form after harvest, during storage, milling and transportation, dependent on grain moisture content, rate of grain drying and fluctuations in temperature, and humidity levels at the

various stages. The susceptibility of grains to cracking increases as the grain is processed from paddy to brown to white.

## Why look at grain cracking?

Cracking can be a significant problem as most cracked grains break up during milling, reducing payments to the grower and processor. A high content of broken grain also results in mushy cooked rice due to the leaching of starch from the exposed crack surfaces during cooking. Such grain breakage can be exacerbated by storage time leading to some clientele opting out of Australian grown rice (generally older than six months in storage) and sourcing northern hemisphere markets for 'fresher' raw product between rice seasons.

## How is cracking measured?

The extent of cracking is usually measured on dry grains after milling and can be used to determine the likelihood of grains breaking in storage. However, there are different types of cracks and not all cracks will result in a broken grain during cooking.

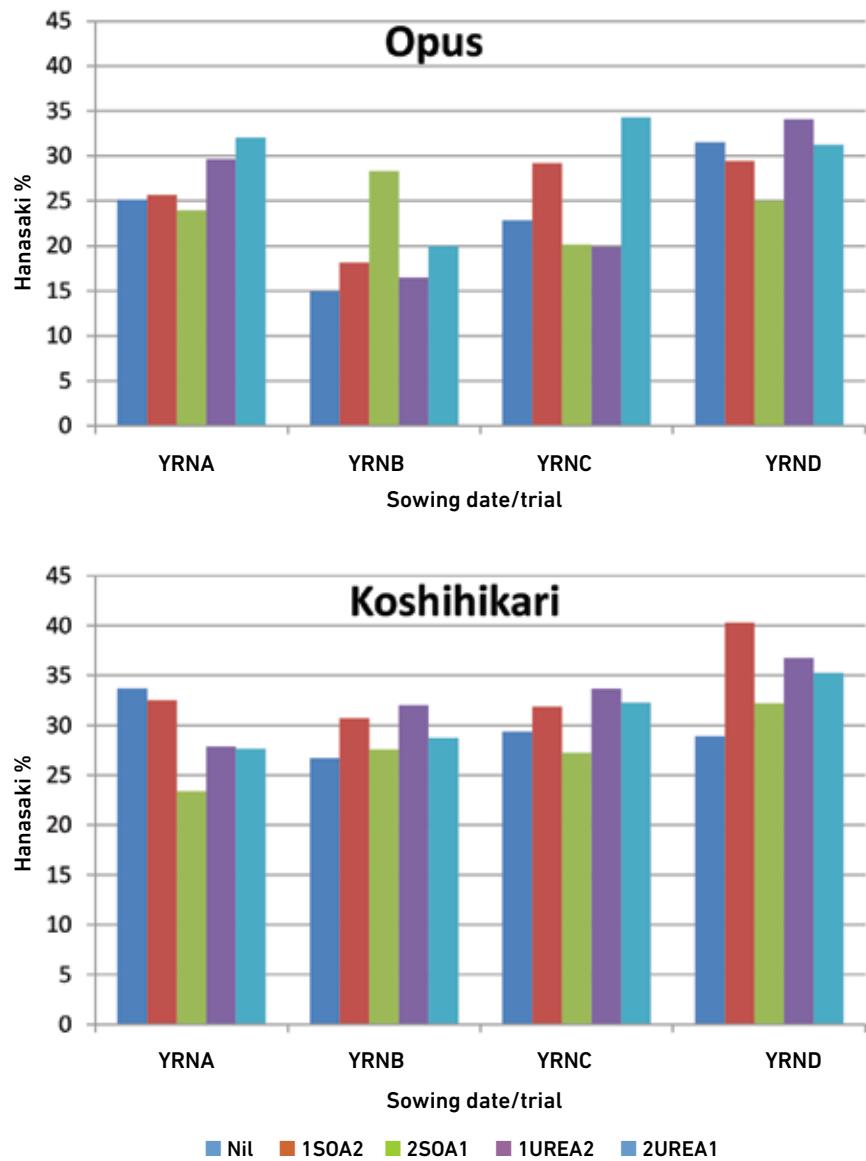
Most research into cracking has been done on dry grains and determining the extent of cracking relies on specialised equipment. However, the 'Hanasaki' method is a better indicator of how grain cracking affects the quality of cooked rice using the absorption method commonly used in sushi production. 'Hanasaki' is a Japanese term for 'fissures, fractures or cracks' that occur in rice during submersion in water, and is determined by soaking grains in water for a defined time period and determining the percentage of cracked grains. If the rice cracks during this period of soaking, it will likely crack during the cooking process (SunRice, pers. comm.). Assessment of the Hanasaki procedure has found that it is a good measure of predicting cooking performance in milled grain (SunRice, pers. comm.) with a threshold of less than 35% generally deemed acceptable.

## Hanasaki measurement

The Hanasaki measurement was used on grain harvested from nitrogen trials in 2014 to assess the method and investigate the effects of nitrogen regimes on crack formation. Opus and Koshihikari were the subset of varieties used to compare different forms of nitrogen fertiliser (urea and sulfate of ammonia at 150 kg N/ha), split applications (two-thirds upfront and one-third at panicle initiation) and four sowing dates (YRNA, YRNB, YRNC, YRND). Staggered sowing dates were instigated at the one location to ensure the full range of temperature extremes were encountered during grain formation and ripening (summer/autumn).

### Method

Hanasaki was determined by submerging approximately 100 milled rice grains in tap water at room temperature ( $22 \pm 1^\circ\text{C}$ ) for one hour. Images were captured with a digital SLR camera and assessed visually and by automatic image analysis. Up to 30 minutes soaking time has been used in the past (SunRice, pers. comm.), however one hour was chosen since after this time it is easier to identify cracks and it is in alignment with commercial practices in which rice is left in rice-cookers overnight on timers.



● **Figure 1. Average cracking percentage utilising the Hanasaki method for Opus and Koshihikari under different forms and rates of nitrogen over four sowing dates in CY2014 (I.s.d. ( $P < 0.05$ ) = 11.1%).**

Visual assessment is time-consuming and labour-intensive but it can be the most accurate method if done by a skilled worker. However, having a dedicated worker to assess samples is not always possible and it remains a subjective method, especially if different workers are used in rotation. With the aim of overcoming this inherent error, an automatic analysis method was developed in the freeware program 'ImageJ'. The method is automatic, objective and can be calibrated against manual measurement. The image analysis software code, once written, can then be modified and updated if needed.

### Results

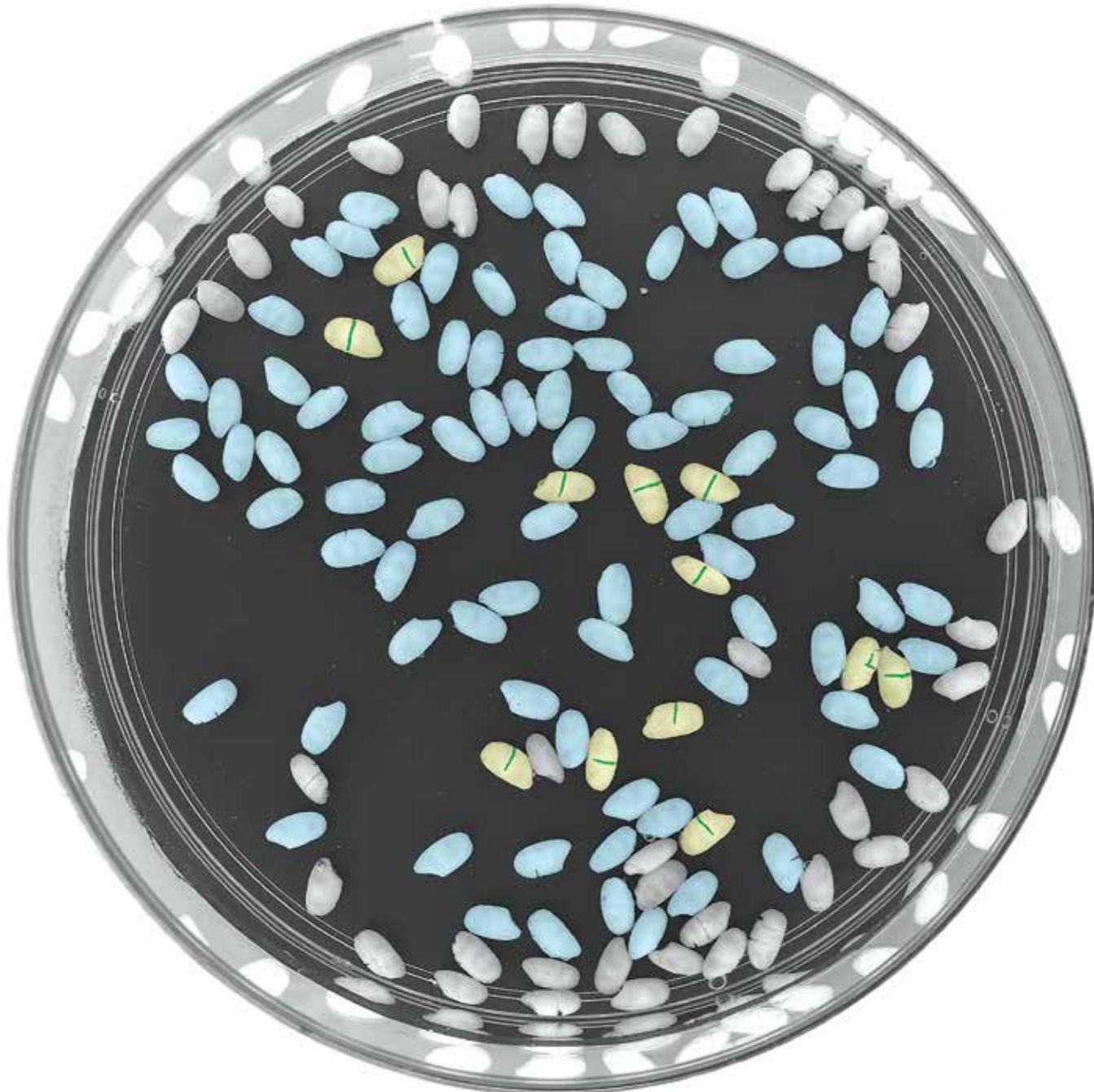
Opus (25.4%) had significantly less cracked grains than Koshihikari (31.8%)

across all sowing date and nitrogen combinations, and generally its Hanasaki ratings were inside the desirable range (Figure 1).

No single nitrogen source or rate was significantly better than others across sowing dates and varieties.

Sizeable interactions were generally the result of differing maturities within sowing dates leading to an eclectic mix of thermal loads being experienced during grain fill. The final sowing date (YRND) saw the highest Hanasaki rating for most treatment combinations, reflecting the warmer mean temperatures experienced during grain fill.

The manual Hanasaki and automatic image analysis results were also compared for the 2014 trial. Although the two methods are significantly correlated,



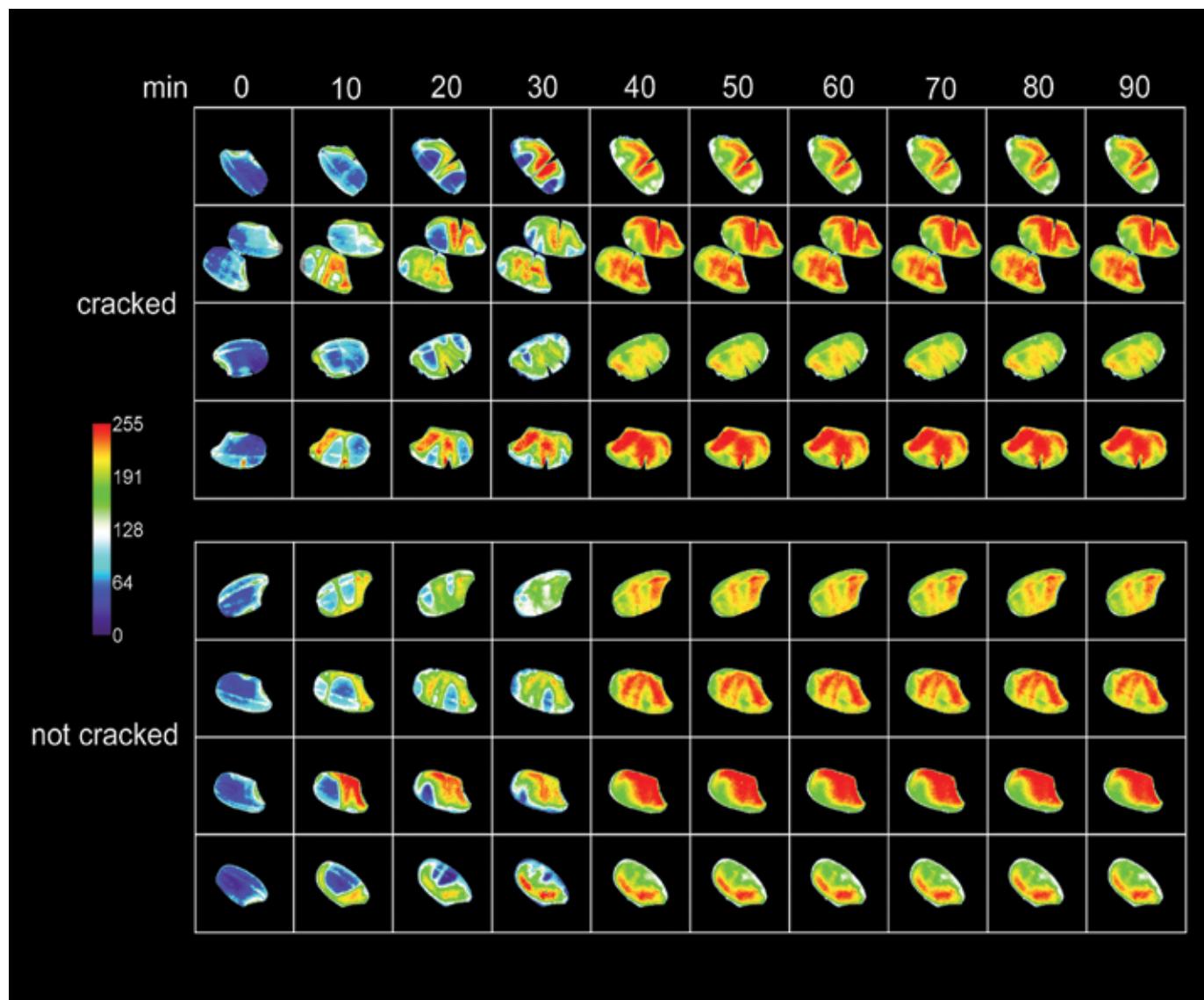
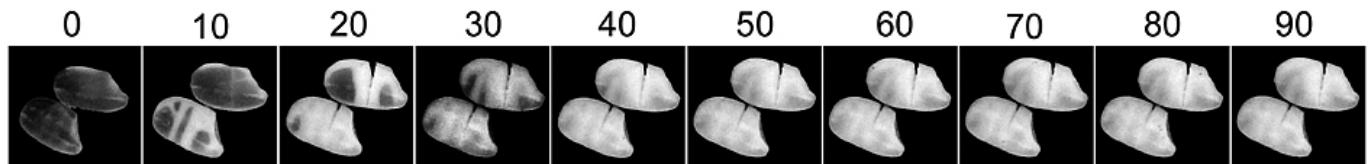
● Figure 2. Example image of the automatic image analysis script. The original image of 100 grains soaking in water in a plastic petri dish has been overlaid with colours that indicate grains without cracks or with small cracks (blue) and cracked grains (yellow) with identified cracks (green). Not all grains are counted due to difficulties with grains touching the edge of the plate and separating some touching grains. Grains that are already broken are not counted (there are none in this image).

manual visual assessment was slightly more accurate than the automated method. This might be a function of having just the one operator doing manual Hanasaki in this instance, which would be highly unlikely in a commercial setting. Although the automatic method is less accurate it is much quicker — once the images are acquired they can be processed without any human input, which saves time and salary. An example image processed

through the analysis software is shown in Figure 2, labelled for cracked and non-cracked grains. The procedure also outputs the numbers of cracked grains. In this experiment, the manual Hanasaki required approximately 50 hours of a technician's time in counting fissured grain. Although requiring the same preparation time, automatic analysis didn't require any human input once the analysis procedure was started (about five minutes).

## Where to from here?

The methodologies developed here will be routinely used in the quality evaluation program of the *Australian Rice Partnership II* to extend the knowledge on future varieties and their cracking potential in storage. These same techniques can also follow water absorption with time (Figure 3) of cracked and non-cracked grain, as surface fissures can actually be beneficial since



● **Figure 3.** Top: Time series of soaked grains showing changes over 90 minutes. Bottom: Time-series of individual grains colour-coded for greyscale value (from black to white) to highlight water absorption and crack formation. The scale on the left shows how the greyscale values are colour coded from black (0, purple colour) to white (255, red colour). Green to red colours show where water has entered the grain.

they expedite the transition of rice to the opaque stage, a feature of correctly aged sushi rice.

Agronomically, the field work supports the mantra that 'less is more' for short grain production in temperate Australia. For Koshihikari, lower nitrogen rates will actually reduce the chance of lodging, govern the maturity of the variety to the desired cooler window of grain development and result in less protein in the grain which is desirable for storage integrity and the end-users. This, and other

recently completed work, will be used to tailor the current agronomic package that accompanies short-grain production to ensure it remains a cost competitive (on a gross-margin basis) option that satisfies markets that usually avoid Australian-grown rice between seasons.

#### RIRDC Project PRJ-009950

*Australian Rice Partnership II*

The project involves the following members of the *Australian Rice Partnership II*

based at NSW Department of Primary Industries, Yanco Agricultural Institute:

- Dr Mark Talbot, Plant Cell Biologist and Microscopist
- Dr Laura Pallas, Cereal Chemist
- Dr Peter Snell, Rice Breeder

#### Further information

Mark Talbot

T: 02 6951 2674

E: mark.talbot@dpi.nsw.gov.au



- Rice plants growing in a temperature-controlled glasshouse, where water temperature is also controlled, using large heating elements. This enables trials to be run year round. Lights can be used to stimulate flowering in winter.

# DEVELOPING COLD TOLERANT AUSTRALIAN RICE VARIETIES

## QUICK TAKE

- Cold-induced sterility still presents the greatest barrier to gains in production efficiency of rice in the Riverina.
- Breeding for cold tolerance at the pollen microspore stage is second only to selection for yield as a breeding objective in the rice breeding program.
- Current sterility screening methods are being optimised to account for 'blowing up' — the combined negative effect of nitrogen and cold on successful grain set.
- Understanding changes in the fertilisation process under cold temperatures is a prerequisite to developing a rice variety for future production of rice in aerobic conditions.

**Understanding the effect of cold stress on the rice plant during its reproductive stages is the key to developing cold tolerant Australian rice varieties.**

**Kim Philpot, Mark Talbot and Peter Snell**  
NSW Department of Primary Industries,  
Yanco Agricultural Institute

**R**ICE production in southern New South Wales and northern Victoria is a challenging enterprise made more difficult by the susceptibility of rice to low temperature stress during its reproductive stage.

Cool mid-season temperatures tend to coincide with the reproductive stage of rice plant development, often leading to little or no grain filling at crop maturity.

Sterility causes annual yield losses of around 5–10%, which equates to more than \$40 million of farm gate production. Extreme or prolonged cold snaps, which occur every 3–4 years, can lead to yield

losses of around 20–40%. Currently, the only method available to reduce the effects of cold damage is to maintain deep water in fields during the most sensitive stage of reproductive development, 'pollen microspore'.

Deep water provides a thermal blanket around the developing panicle and pollen, keeping them approximately 2°C warmer on average than the surrounding air temperature. However, the extra water required to protect the developing pollen adds to financial costs for the farmer, and there is no guarantee the air temperature will not drop so low as to render the 2°C water temperature difference ineffective.

Even with adequate water coverage at the threshold minimum temperature of 15°C, high levels of spikelet sterility can also occur with excessive nitrogen use.



**Figure 1. Cold treated rice plants in a glasshouse cold tolerance trial. After treatment, panicles were tagged at emergence. Samples from those panicles were taken for pollen viability counts and *in vivo* and *in vitro* germination observations. The tagged panicles were harvested at maturity and assessed for sterility.**

This phenomenon, colloquially described as 'blowing up' a crop, indicates that an excessive amount of nitrogen at panicle initiation can exacerbate cold damage.

The major financial losses incurred with cold susceptible rice varieties means that breeding for cold tolerance at pollen microspore has become a high priority objective in the breeding program, second only to selection for yield. Reliable screening methods to assist the selection of cold tolerant rice varieties are therefore paramount to the breeding program.

## Why investigate new screening methods?

Examining mechanisms of cold-induced sterility and selection methods for determining cold tolerant rice varieties has been a major focus of the rice breeding program for many years. Currently, the program uses whole panicle sterility observations, where one panicle from each plant is tagged at emergence (after a naturally occurring cold event) and harvested at maturity. Spikelets are removed from the panicle and the empty (sterile) and full spikelets are counted as a means to identify genotypes with tolerance to low temperatures.

While this process gives accurate data on the level of sterility occurring at crop maturity, it does little to explain the effects

**Table 1: Observed % panicle fertility and observed % pollen viability from Reiziq samples with or without cold treatment.**

Cold treated		No cold treatment	
% panicle fertility^	% pollen viability*	% panicle fertility^	% panicle viability*
42	87	83	87
80	73	87	86
62	66	81	85
15	14	73	83
68	82	95	91
58	49	81	81
69	83	87	89
2	54	85	88
81	89	84	87
76	74	93	88
31	52	87	92
80	88	84	89
35	60	92	88
68	89	81	85

\* Pollen viability is the average % from five anthers per panicle

^ Panicle fertility is the percent of filled spikelets out of the total number of spikelets on the panicle

at early stages of reproductive development, and therefore alternative screening methods may be more informative. The rice breeding program continues to research improved methods for screening reproductive cold tolerance in Australian rice and the practical application of these methods to select new cold tolerant varieties.

## More efficient measures of cold tolerance

A range of experiments was conducted as part of the cold tolerance research program. The experiment reported in this article investigated pollen germination and pollen viability under cold stress conditions.

The variety Reiziq was grown under glasshouse conditions with four treatments consisting of a combination of nitrogen, cold exposure or both. Panicles were tagged (Figure 1) and samples from those panicles were taken for pollen viability counts and *in vivo* germination (natural within the flower) and *in vitro* germination (on artificial growth medium). The tagged panicles were harvested at maturity and assessed for sterility.

Pollen viability and pollen germination results were compared to observed panicle sterility at maturity. The methods were assessed for possible application to field trials as screening tools for cold tolerance.

## Pollen viability counts

Pollen viability results were obtained by staining pollen grains with iodine, which turns the starch content of pollen black. Pollen grains use starch as 'fuel' to grow a pollen tube, the structure that carries sperm cells from the stigma (Figure 2) to the micropyle opening of the ovary for fertilisation, as indicated in Figure 4. Pollen grains that turn black are considered viable/fertile; grains that turn pale grey or do not change colour are considered infertile, as they contain little or no starch.

Cold treated Reiziq showed some correlation between reduced viable pollen numbers and observed panicle sterility and exhibited greater variability between pollen viability and observed panicle sterility than untreated Reiziq (Table 1). However, the numbers of supposedly viable pollen grains appeared adequate for fertilisation to occur in 96% of the cold treated panicles, yet 93.7% showed panicle sterility. Therefore, total viable pollen number does not appear to relate directly to observed panicle sterility.

## In vitro germination

*In vitro* germination involves collecting pollen grains from mature anthers at the time of flowering and germinating the pollen on artificial growth medium. Pollen grains are considered germinated when their pollen tube length is greater than or equal to pollen diameter.

A number of complications were encountered with this particular screening method. For example, once rice pollen is separated from the anther, pollen viability quickly declines to almost 0% within 10 minutes, leaving a very small window of opportunity to achieve optimum pollen tube growth for each sample collected. Another problem is that rice pollen maintains a high water content after flowering, which makes it highly sensitive to slight changes in temperature and humidity, especially outside of the floral environment. Furthermore, rice pollen is very difficult to germinate after freezing due to its high water content, which makes transporting viable pollen from field trials (often hundreds of kilometres away) a challenging task.

Such complications in sampling pollen make germination studies difficult, which is illustrated in Figure 3. When rice pollen was taken from two different flowers on the same plant on the same day, and incubated under similar conditions, they showed very different pollen germination rates, as illustrated in Figure 3. There were no obvious differences between the two flowers to explain such differences in germination.

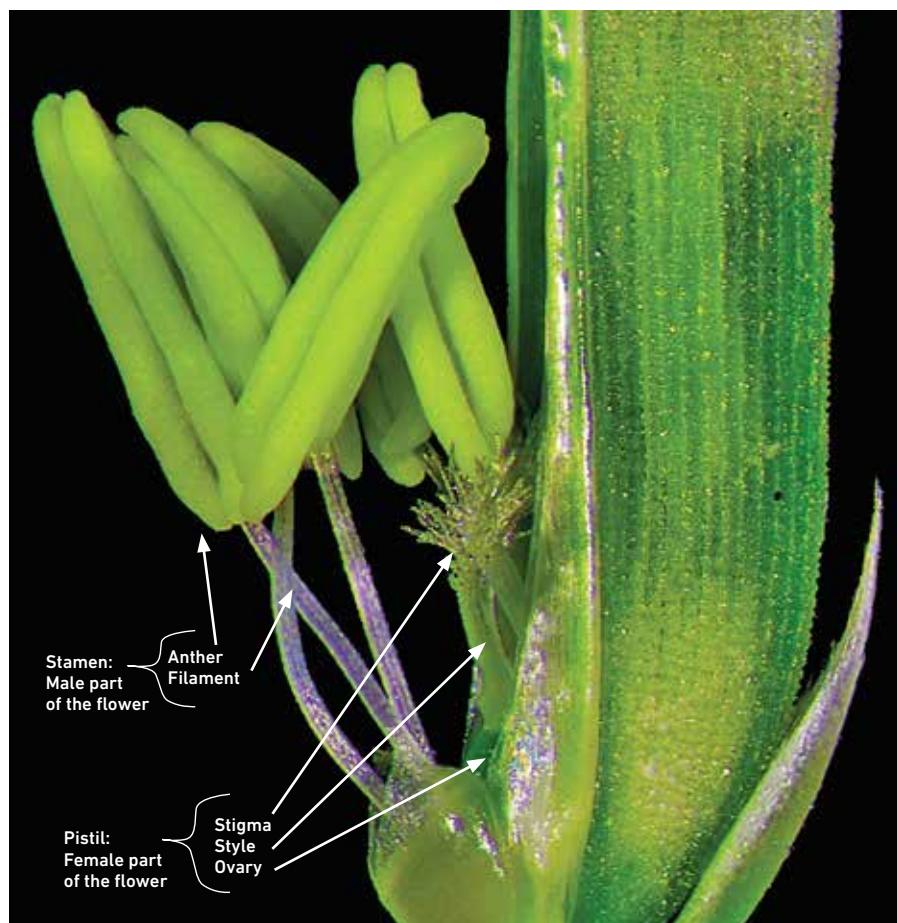
Due to the complications described, *in vitro* germination of rice pollen on artificial growth medium is therefore an impractical tool for determining pollen viability in field-based experiments.

### In vivo germination

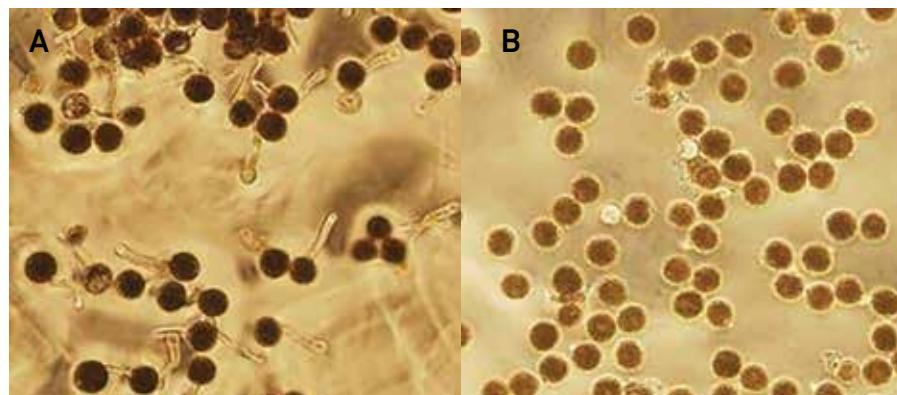
This screening process appears to be more suitable for assessing pollen viability in pollen samples collected from field trials. After pollination occurs naturally, whole flowers can be collected up to 24 hours after anthesis (flowering) and preserved in a fixative for easy transport and storage.

Pollen viability is assessed by removing the pistil (female reproductive part) from the flowers and staining the germinated pollen on the pistil with a fluorescent dye. Images of pollen tube growth are then obtained using a fluorescence microscope. Fertilisation is considered successful when pollen tubes can be seen at, or entering, the micropyle opening of the ovary.

Preliminary results on *in vivo* pollen tube observations are promising. Untreated Reiziq from the glasshouse experiment showed excellent pollen germination on the stigma and pollen tube growth reaching all the way to the base of the ovary (Figure 4), while in the majority of cold treated Reiziq plants, pollen tubes seldom reached the embryo sac or micropyle opening to complete fertilisation (Figure 5).



● Figure 2. A whole rice flower showing the male and female parts of the flower, i.e. the stamen and pistil, respectively.



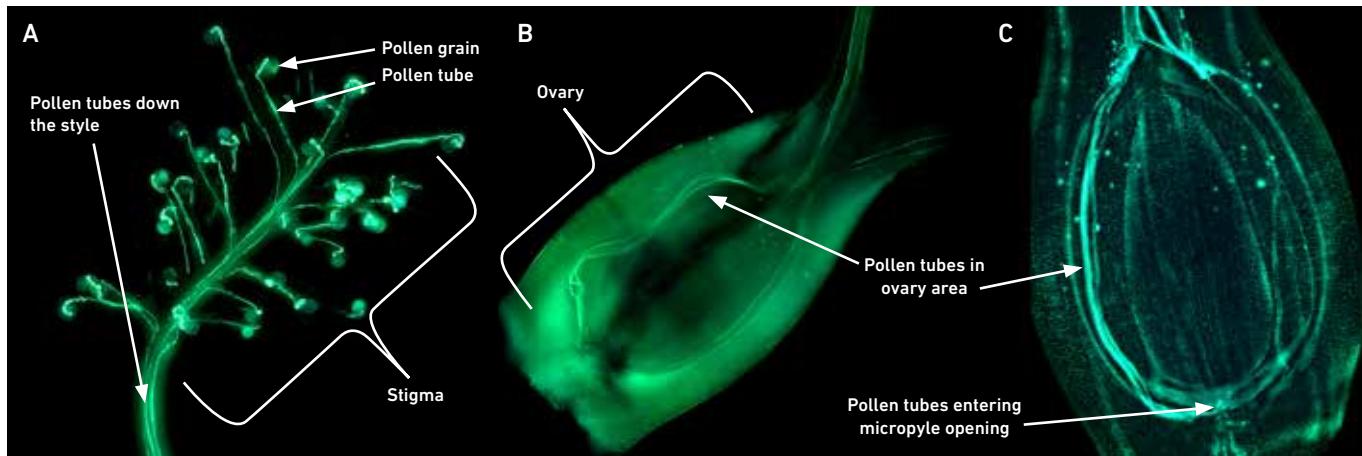
● Figure 3. *In vitro* germination of rice pollen taken from different flowers of the same Reiziq rice plant on the same day. Image A shows good pollen germination and image B shows no germination but there appears to be no apparent reason for differences between the two samples.

### Where to from here?

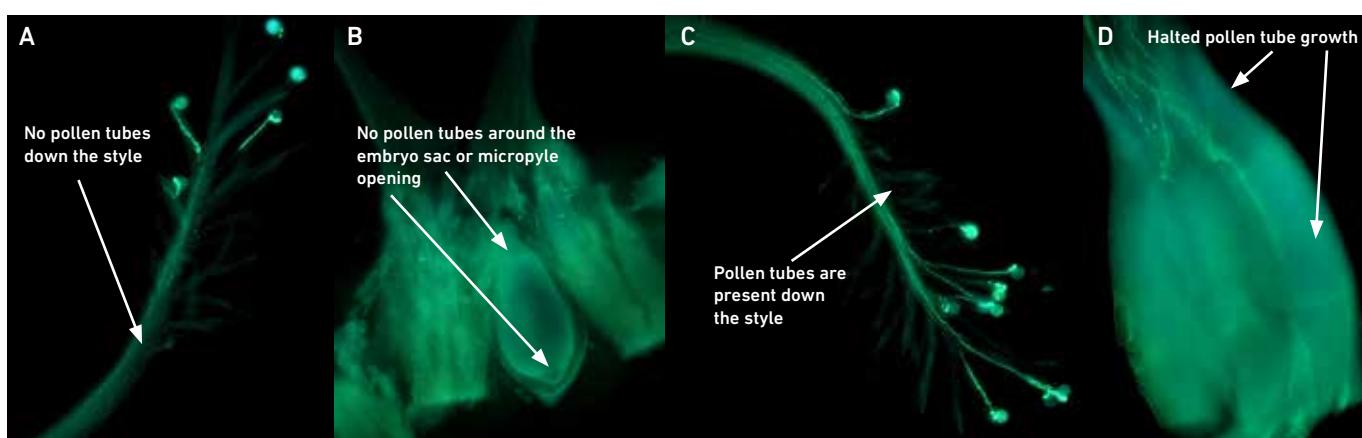
Current methods for assessing cold tolerance, although reliable, only supply information about the effects on harvested rice panicles at crop maturity. The above results clearly show that pollen viability counts and *in vitro* germination are not practical methods to use as screening tools in the breeding program. This leaves

the very promising method of *in vivo* germination and observation as a screening tool.

The method is practical and useful as pistils can be preserved in fixative for transport and storage, and are easily stained with fluorescent dye for observations of pollen tube growth. The next phase of our investigation is to look at the combined effect of excessive nitrogen and



● Figure 4. Pollen germination, 24 hours after anthesis, of Reiziq plants **not exposed** to cold treatment at pollen microspore.  
A: Germinated pollen on rice flower stigma showing pollen tube growth down the style. B: Pollen tubes have entered the ovary area and continued down to the micropyle opening at the base of the ovary. C: Pollen tubes entering the micropyle opening where they will release sperm cells completing the fertilisation process



● Figure 5. Pollen germination, 24 hours after anthesis, of Reiziq plants **exposed** to cold treatment at pollen microspore.  
Images A and B are from one rice flower and C and D are from a different flower.  
A: Very little pollen is on the stigma and no pollen tubes can be seen down the style.  
B: The exposed embryo sac with no visible pollen tubes in the ovary area or at the micropyle opening.  
C: Germinated pollen with good pollen tube growth down the style.  
D: Pollen tube growth has halted at the top of the ovary area with no pollen tubes reaching the micropyle opening.

cold ('blowing up') on *in vivo* germination on pollen collected from field trials.

## How does this research benefit rice growers?

Developing cold tolerant rice varieties will not only reduce yield loss and year-to-year yield variability caused by cold damage, it also will increase water productivity by eliminating the need for deep water. Eventually this work will lead to the development of new aerobic rice varieties that can be grown without flooded field conditions for the entire season. These varieties will be specifically adapted for performance in well-drained, non-ponded and unsaturated soils. Aerobic rice will require irrigation to bring the soil in the root zone to field capacity but ponding will not

be needed, resulting in significant water savings.

It is possible that a new cropping system with intermittent irrigation will reveal a whole new dynamic of nitrogen nutrition and water productivity that will affect successful fertilisation of rice due to both cold temperatures at early microspore and high temperatures at flowering. Such concerns have driven this and the associated RIRDC project, *Cold tolerant traits and QTLs for improved efficiency of rice breeding program* (page 61) to understand what components of the reproductive process influence successful seed set under extreme thermal weather conditions.

**RIRDC Project PRJ-00950**  
*Australian Rice Partnership II*

This project involves the following members of the *Australian Rice Partnership II*:

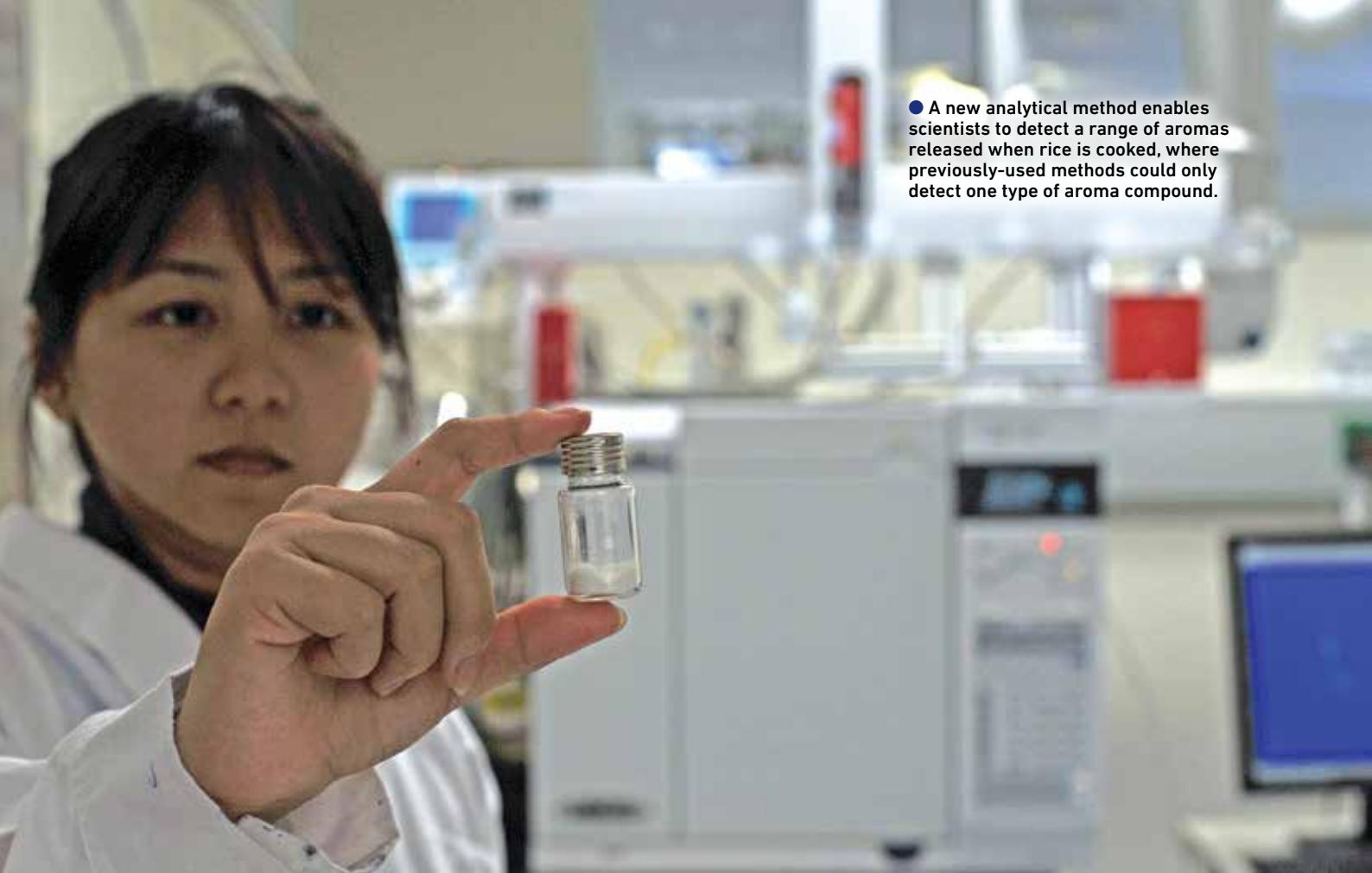
- Kim Philpot, Senior Technical Officer
- Dr Mark Talbot, Plant Cell Biologist and Microscopist
- Dr Peter Snell, Senior Plant Breeder

## Acknowledgements

Thanks to technical staff Greg Napier and Minna Russell for assistance with glasshouse work and to Aleesha Turner for assistance with fluorescence microscopy and imaging, except Figure 2 (whole rice flower), which was provided by Dr Mark Talbot.

## More information

Kim Philpot  
T: 02 6951 2610  
E: kim.philpot@dpi.nsw.gov.au

- 
- A new analytical method enables scientists to detect a range of aromas released when rice is cooked, where previously-used methods could only detect one type of aroma compound.

# ANALYSING RICE AROMA USING FLAVOUR METABOLOMICS

## QUICK TAKE

- A new method enables aroma and flavour of rice to be analysed more effectively and efficiently than has been possible in the past.
- Using just one gram of rice flour, analysis by two dimensional gas chromatography enables a range of aroma compounds in rice to be detected in one test.
- The information gained by analysis can be linked to genetic variation in lines of fragrant rice, enabling rice breeders to target traits for aroma and flavour that reflect consumer demand.

Fragrant rices, such as jasmine and basmati, are market favourites among rice consumers and command the highest price and largest demand in global rice trade.

**Dara Dayon, Sangeeta Prakash, Jaquie Mitchell and Melissa Fitzgerald**

School of Agriculture and Food Sciences,  
The University of Queensland

**Ben Ovenden and Peter Snell**

NSW Department of Primary Industries,  
Yanco Agricultural Institute

**T**HE rice fragrance project developed a robust and objective method to determine if a rice variety would have an undesirable, good or very pleasant aroma — with just one gram of flour.

In past years, breeding and selection for aromatic rice varieties has been done by marker-assisted selection using genetic markers, and more traditionally by sensory evaluation. Screening by marker-assisted

selection is only useful for a single aroma compound and does not take into account any possible environmental effects. Sensory evaluation, on the other hand, is not sustainable in breeding programs or on an industrial scale as hundreds to thousands of samples need to be screened. Thus, these methods must be substituted by instrumental analysis.

## Flavour metabolomics

The key to understanding rice aroma lies with the volatile organic compounds that are emitted by rice during cooking.

Volatile organic compounds are small molecular weight compounds that are responsible for the odour of all foods. Until now, the presence or absence of only one volatile organic compounds, i.e.

**Table 1. Descriptors assessed by the sensory panel members, who were trained to distinguish and precisely score the intensity of rice aroma and taste.**

Sensory descriptor		
Very pleasant	Good	Bad
Pandan	Grainy	Sewer
Floral	Corn	Sour
Sweet aromatic	Grassy	Hay-like
Popcorn	Dairy	Metallic
Sweet taste		

2-acetyl-1-pyrroline or 2AP, was checked when screening for aroma in rice breeding programs. This was because 2AP is characterised by a sweet, baked-bread scent and can be detected by the human nose at very low concentration (0.06 parts per billion in air). However, consumers can easily differentiate the aroma quality of different 2AP-producing rice types and varieties (e.g. jasmine and basmati), which means that other volatile organic compounds also contribute to aroma.

The ability to comprehensively detect, identify and understand the right combinations of volatile organic compounds contributing to rice aroma — dubbed ‘flavour metabolomics’— is thus essential in analysis of aroma.

Flavour metabolomics was performed at The University of Queensland using a process called two dimensional gas chromatography (GCxGC). This process does not require lengthy chemical extractions; it simply requires heating of a sample of ground rice in a sealed container and detecting the volatile organic compounds emitted. The process enables comprehensive detection of all compounds instead of just 2AP. It is a relatively simple method of collecting volatile organic compounds, and more closely resembles the release of volatiles when consumers cook rice.

## Biomarker discovery

Sensory evaluation remains an important aspect in the rice fragrance project because ultimately, the consumers’ perception of the product is of utmost priority. Sensory evaluation was used in combination with metabolomics to determine which of the volatile organic compounds could be used as indicators of favourable or unfavourable scent or tagged as ‘biomarkers’. So when screening commercial rice samples, researchers need only look for these biomarkers to predict the flavour of that rice variety.

A group of sensory panellists was trained to distinguish and precisely score the

**Table 2. Volatile organic compounds associated with specific types of scent that can potentially be used as biomarkers for aroma.**

VOC	Odour threshold (ppm* in air or water)	Scent
2AP	0.06	sweet, pandan
2 acetyl pyrrole	170,000	baked bread
Acetophenone	65	floral
Acetoin	800	butter, cream
Limonene	10	citrus
1-hexanol	2500	fruity
1-butanol	360	fruity
2,3 butanedione	0.05	creamy butter
Decanal	0.1	sweet floral
Indole	140	faecal
1, 5, hexdien-3-ol	10	sewer
2-ethyl furan	2300	beany
2-methyl butanal	1000	musty, nutty
3-methyl butanal	1100	musty, nutty
1-pent-3-one, 2 methyl	na	sour
2 butanone	50000	sour
2 methyl 2 undecanethiol	na	sulphurous
Dimethyl trisulphide	0.005	sulphurous

\*ppm - parts per million

intensity of 13 descriptors of rice aroma and taste (Table 1). Once trained, the panellists were subjected to a series of blind tests of rice varieties with different aroma quality. The panellists reported significant variation in aroma perception for each of the rices, ranging from sweet floral to eggy sulphurous. It was confirmed that 2AP-producing rice varieties have differences in flavour and these variations are attributed to unique combinations of several volatile organic compounds.

The volatile organic compounds detected may either be unpleasant compounds, such as indole, thiols, sulphides and furans, which mask the sweet, pandan scent of 2AP, or pleasant smelling compounds, such as acetophenone, limonene and decanal, which combine with 2AP increasing palatability and consumer acceptance of rice.

Furthermore, using the intensity scores from the sensory panel and the quantitative data from metabolite profiling (the GCxGC analysis), the project team was able to draw out phenotype–metabolite associations and pick out the compounds that contribute to a specific type of scent (Table 2). There is now a range of volatile organic compounds that can be useful as biomarkers for excellent rice flavour quality. These volatile organic compounds are recommended to be considered in rice breeding programs.

## What's next?

In modern plant breeding, small segments of DNA (or molecular markers) that are linked to a desired plant trait, such as disease resistance or a specific type of grain quality, are being increasingly used for precise and efficient selection of lines in breeding programs. Therefore, the quickest way of incorporating the discovered biomarkers in breeding programs is by developing molecular markers that are linked to their production. The rice fragrance group has developed a diverse collection of rice, comprising aromatic rice varieties from twelve countries and advanced breeding lines from Australia. These lines will be used for mapping genes or genetic regions that are associated with the production of desired volatile organic compounds in rice.

## RIRDC Project PRJ-008568

*Developing superior aromatic rice germplasm for Australia*

## Acknowledgements

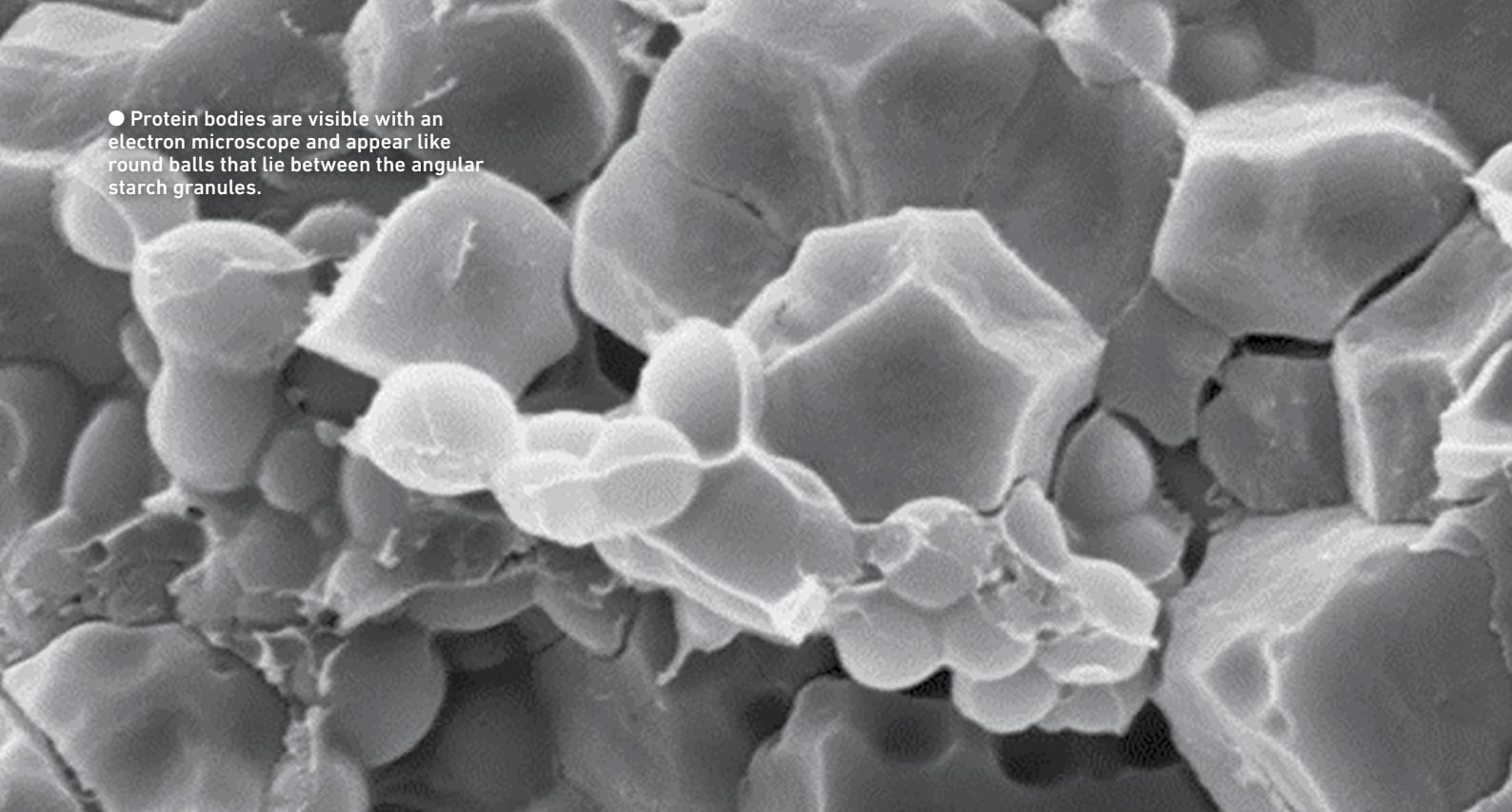
This research was funded by RIRDC, NSW Department of Primary Industries and The University of Queensland.

## Further information

Dara Daygon

T: 0413 464 158

E: v.daygon@uq.edu.au

- 
- Protein bodies are visible with an electron microscope and appear like round balls that lie between the angular starch granules.

# RICE PROTEINS

## QUICK TAKE

- A new method has been developed to analyse protein in rice grain and it shows clear differences in the protein profiles of long and medium grains, with the basmati types having the most distinctive profile.
- The levels of the protein prolamin and the prolamin/glutelin ratio plays an important role in medium grain rice quality, particularly hardness.
- Broken and unbroken grains have characteristic differences in protein composition.
- Better understanding of rice grain proteins will allow for more accurate selection of high quality and better milling rice lines.

**Rice grains are packages of energy and nutrients put in place by the rice plant to support the next generation of plants until they become self-sufficient.**

### Daniel Waters

Southern Cross Plant Science,  
Southern Cross University, Lismore

**S**TARCH, the dominant component of the rice grain, is made of only one type of building block — glucose. Research that has taken place over many years has found these glucose building blocks form chains that differ in length and amount of branching, and these differences affect rice grain quality.

Although the rice grain is mostly starch, experiments that have removed and replaced proteins from rice flour have shown proteins also affect the way the rice flour behaves. This suggests rice grain proteins affect rice grain quality, but we know very little about varietal differences in rice grain proteins and how these differences affect rice grain quality.

All cereal grain proteins, including rice, were not created equal. While starch is made of one building block (glucose), protein is made of twenty different building blocks, collectively called amino acids. These amino acids join together in different

combinations and create a vast array of different molecules and structures within all living things, including cereal grains. Proteins are remarkably variable in their properties, for example, protein is the dominant biological molecule in both fingernails and egg white, yet fingernail and egg white proteins have very different properties and water solubilities.

There are four main types of cereal grain proteins: albumin, globulin, glutelin and prolamin. The globulins, glutelins and prolamins are storage proteins that are pulled apart to build the developing seedling and are found in structures called protein bodies that lie between the starch granules.

### Solubility differences

Cereal grain proteins, including those of rice, have very different solubility properties:

- albumins dissolve in water
- globulins dissolve in salt solutions
- glutelins dissolve in weak acid or base
- prolamins dissolve in alcohol solutions.

Rice is cooked in water so the way the components of the rice grain interact with

water is very important in determining grain quality. Rice is an unusual cereal in that glutelins are the dominant grain protein, while prolamins dominate grain proteins of most other cereals including wheat.

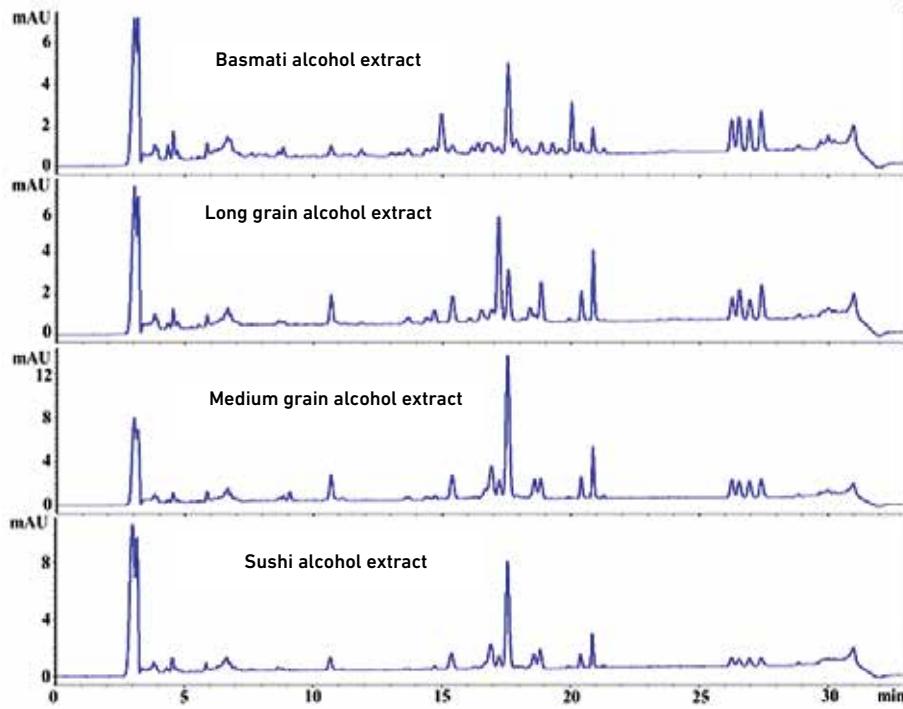
In order to understand rice grain protein, a method of grain protein analysis had to be developed. When proteins are analysed, they are extracted, separated, and then measured. Proteins can be separated on the basis of size, charge or solubility differences. The researchers chose to use a system that separates proteins on the basis of solubility because rice eating quality is related to how the rice cooks in and interacts with water. Many different extraction and separation protocols were trialled on long and medium grain samples before settling on the most efficient method. As the method was being developed, clear differences between the long and medium grains were observed, with the basmati types having the most distinctive profile.

## Quality differences

Once developed, the rice grain protein analysis method, which only needs 0.25 grams of rice flour, was applied to more than 300 long and medium-grain advanced breeding lines from the 2013 and 2014 harvests and a small sample set of sushi rice. The results were evaluated to find correlations with data derived from the Quality Evaluation Program.

The levels of the protein prolamin and the prolamin/glutelin ratio explained variation in medium grain quality, particularly hardness. The prolamins are the 'oiliest' of the proteins and are very important in wheat, sticking together to give dough much of its elasticity and allowing bread to rise. It is possible that the prolamins in medium grain rice also link together in some way and this affects grain quality.

The prolamins did not affect long grain quality to the same extent as they affected medium grain quality. Although the prolamin content of long grain rice was higher than medium grain, it was much less variable and this may explain some of the differences in grain quality between long and medium grain rice. The breeding history of long grain and medium grain rice are different and it is also possible there are differences in long grain starch structure, compared with medium grain, that are not fully understood, and these differences in starch structure may be more important in long grain quality than medium grain quality.



● Protein bodies can be pulled apart and separated using specialised equipment. When separated by solubility differences, the proteins of basmati, long and medium grains have distinctive signatures.

## Protein in broken and unbroken grains

Milling improves the shelf life and visual appearance of rice by removing the husk and oil-rich outer layers of the rice grain. A significant proportion of the grain breaks during milling and this makes milling yield an important grain quality parameter. Many factors affect the propensity of grain to break, including grain wetting and drying, the amount of chalk and the level of grain maturity.

Work by other research groups over the years suggests protein may play a role in rice grain breakage. It is known for example that broken grains have lower protein content, and that increasing grain protein content by adding nitrogen fertiliser improves milling yield of some varieties.

In this project, when the protein composition of broken and unbroken long and medium rice grains from the same breeding lines was analysed, the results showed characteristic differences in protein composition between broken and unbroken grain for each grain type, long and medium grain.

On average the medium grain prolamins were reduced by 21%, glutelins by 39% and globulins by 0.4% in the broken grains compared with unbroken grains. The corresponding long grain fractions were reduced by 27%, 69% and 16% respectively. Surprisingly, although globulins differed least between broken and unbroken grain, statistical analysis found globulins differentiated between unbroken and

broken medium grains while a combination of prolamins and globulins discriminated between unbroken and broken long grains.

Hard wheats break easily when milled and largely due to the lack of a particular protein. Although it is too early to say definitively, protein composition in combination with other factors may influence rice grain breakage. It is possible, for example, that globulins as the most water soluble of the rice grain storage proteins may play a protective role in rice grain breakage through their capacity to hold water.

## Understanding protein to develop new varieties

This project has found protein composition, particularly the prolamin/glutelin ratio, plays an important role in medium grain rice quality which will allow more accurate selection of high quality medium grain rice lines. Differences in protein composition may also play a role in grain breakage. Better understanding the component traits of grain breakage will help breed better milling rice.

### RIRDC Project PRJ-008768

*Defining the link between rice grain protein profiles and rice grain quality*

### Further information

Daniel Waters  
T: 02 6620 3443  
E: daniel.waters@scu.edu.au  
W: www.scu.edu.au/scps/

- The protein in rice bran potentially could be used to develop rice bran-based functional food and nutraceutical products, based on research by Chatchaporn Uraipong (pictured) and colleagues at the University of New South Wales.



# RICE BRAN PROTEIN – A “HEALTHY” OPPORTUNITY

## QUICK TAKE

- There is potential to value-add rice bran protein by developing high-valued bioactive ingredients for functional food and nutraceutical supplements.
- Laboratory tests have shown that rice bran proteins possess significant antioxidant activities and have the capacity to block physiologically important enzymes, which could be used to treat conditions such as diabetes and hypertension (high blood pressure).
- Developing products based on rice bran protein could add significant value to rice bran and improve the profitability of the rice industry and increase returns to rice growers.

**Rice bran protein contains peptides that exhibit significant potential antioxidant, antidiabetic and antihypertensive effects, providing an excellent opportunity for value-adding to rice.**

### Chatchaporn Uraipong and Jian Zhao

School of Chemical Engineering  
University of New South Wales

**T**HE Australian rice industry faces a number of challenges including rising production costs, fluctuating water availability, climate change and competition from low-cost production countries. To remain internationally competitive and be able to provide a reasonable return to rice farmers, the industry needs to continually innovate. Among the innovation strategies, value-adding should be given top priority as it increases the value of the crop without requiring additional farmland, water and other agricultural resources.

Rice bran makes up approximately 10–12% of the rice grain. The Australian rice industry generates around 100,000 tonnes of rice bran based on its current production

of rice (over 800,000 tonnes). Most of the bran is used as stockfeed, which provides a low return to SunRice and its shareholders. Rice bran comprises 12–16% protein with the remainder being carbohydrate, fat and ash.

Research on dairy, legume and other cereal proteins shows that controlled hydrolysis of protein can produce hydrolysates with a wide range of health-benefiting properties including antioxidant, antidiabetic, blood pressure and cholesterol-lowering and anticancer effects. Ingredients with these properties are increasingly used in an ever-expanding range of nutraceutical and functional food products for preventing many chronic diseases prevalent in modern society.

Globally, the functional food and nutraceutical market is estimated to be worth \$168 billion and is projected to

grow to \$305 billion by the year 2020. The unique composition of rice bran protein, coupled with its low allergenicity compared with many other cereal and legume proteins, represents a unique opportunity for the rice industry. Rice bran protein could be developed into high-valued bioactive ingredients for functional food and nutraceutical supplements to replace some of the standard prescription drugs for managing a range of diseases and health conditions.

## About the project

This RIRDC-funded project, with in-kind support from SunRice, was initiated with the aim of developing rice bran protein-based bioactive ingredients that can be used in functional food, nutraceutical and pharmaceutical products. The project was conducted in three phases.

In the first phase, four different types of proteins, namely albumin, globulin, prolamin and glutelin, were sequentially extracted from rice bran using a modified Osborne procedure developed in the project. The extracted proteins were hydrolysed (broken down to component molecules with water) using four commercial protease preparations, Alcalase, Neutrase, Flavourzyme and Protamex. These enzymes were selected for their hydrolytic efficiency and safety because they have been widely used in the food industry. The hydrolysates (the products resulting from hydrolysing the proteins) were analysed for their antioxidant, antidiabetic and antihypertensive activities.

In the second phase, the rice bran protein hydrolysates were separated into three fractions based on the molecular weight of the peptides: small, medium and large. The bioactivities of each fraction were measured. The fractions with the highest activities were purified and isolated and the bioactivities of the isolated fractions were also measured. Finally, the isolated fractions with the highest bioactivities were analysed to determine the peptide sequences present in them. The peptides found were then searched against the bioactivity database BIOPEP to identify peptide sequences that have been reported to have antioxidant, antidiabetic and antihypertensive activities.

In the third and final phase, the rice bran proteins went through an artificial digestion procedure that mimics the human digestion process. The proteins were first subjected to amylase digestion for five minutes, followed by pepsin digestion for two hours and pancreatic digestion for another hour under carefully controlled

conditions that mimic digestion during chewing (and passage to the stomach), in the stomach and the small intestine. The protein hydrolysates (digests) were also subjected to fractionation and isolation and characterised for their bioactivities as described previously.

## Key findings

The analysis found that the hydrolysates of rice bran proteins possess significant *in vitro* antioxidant activities as well as capacity to block the activities of physiologically important enzymes. These enzymes are closely linked with conditions such as diabetes and hypertension (high blood pressure).

Two enzymes found in digestive fluid,  $\alpha$ -amylase and  $\alpha$ -glucosidase, are responsible for the digestion of starch, with resultant release of glucose. The released glucose is rapidly absorbed by the body, leading to a sugar rush in the blood after a starchy meal, which can be dangerous for diabetic patients. Blockage of these two enzymes is a key strategy in diabetic care. In this project, the  $\alpha$ -amylase and  $\alpha$ -glucosidase inhibition capacities of albumin and glutelin hydrolysates produced by Protamex and Alcalase were found to be particularly strong (Figure 1), comparable in magnitude to those of the standard antidiabetic drug, acarbose. When the amount of the former that can be safely consumed is taken into consideration, this demonstrates that these hydrolysates have the potential to be developed into an alternative to diabetes management drugs such as acarbose in the form of dietary or nutraceutical supplements.

Angiotensin converting enzyme, or ACE, is an enzyme involved in the regulation of blood pressure. Put simply, persistently high ACE activity in the blood will lead to high blood pressure, and several blood pressure-lowering drugs, such as captopril, work because of their capacity to block ACE. The ACE-inhibition effects of rice bran protein hydrolysates are not as potent as that of captopril, but they are still quite significant (Figure 2), because we can consume thousands of times more of rice bran protein without any side effects as is the case with drugs such as captopril.

Antioxidants play a crucial role in health because they mitigate oxidative stress in our body. Oxidative stress can cause damage to body tissues and interfere with physiological functions and processes leading to various diseases. A slow, steady accumulation of oxidative "debris" in the body contributes to the development of a number of chronic diseases including

inflammation, autoimmune disorders, diabetes, cardiovascular diseases and cancer.

Antioxidants can mitigate such oxidative stress by acting as scavengers that rid the body of the toxic chemicals. Phenolic compounds in fruits and vegetables are well known antioxidants. We assessed the antioxidant activities of rice bran hydrolysates using several methods, and found the activities are very strong (Figure 3). This shows that these protein hydrolysates can provide health benefits in similar ways as phenolic compounds do.

When rice bran proteins were subjected to an *in vitro* simulated human digestion, the resultant digests (hydrolysates) are also found to exhibit significant antioxidant,  $\alpha$ -glucosidase and ACE-inhibitory activities. This means that consumption of rice bran proteins can potentially lead to generation of bioactive peptides in the digestive tract with substantial health benefits. The  $\alpha$ -glucosidase inhibitory activities of the simulated human digests of rice bran proteins, and albumin and glutelin in particular, are especially strong, comparable to that of the standard diabetic drug acarbose. This suggests that rice bran protein supplements or a diet rich in these proteins could potentially have a significant role in managing this prevalent disorder.

The bioactivities of peptides derived from rice bran proteins are strongly influenced by their molecular sizes. Peptides with smaller molecular weight have much greater activities than the larger peptides. The net charge of peptides also affects the biological activities of the hydrolysates and peptides, but the effects are not as prominent as that of molecular size. Analysis identified a large number of peptide sequences in the most active peptide fractions and subsequent search of the peptide sequences against the BIOPEP database revealed that most of them contained sequences with antioxidant,  $\alpha$ -glucosidase or ACE-inhibition activities. Several of the bioactive sequences appeared multiple times in different peptides in the hydrolysate fractions.

## Implications for the rice industry

The findings of the project have several significant implications for the rice industry, the general public, scientific community and relevant policy makers.

For the rice industry, the findings signify a significant opportunity for developing rice bran-based functional food and nutraceutical products. Such products can potentially replace or supplement

antidiabetic and antihypertensive drugs in the prevention and management of these prevalent conditions. Development of such products could add significant value to rice bran, a major and underutilised by-product of rice milling, thus improving the profitability of the industry and increasing returns to rice farmers. The findings can also be used by the industry to better market rice as a healthy food — the consumption of which may provide significant health benefits to the consumer.

For the general public, the findings could help improve their knowledge on the health benefits of rice and make a more informed choice when purchasing foods.

For the scientific community, this project points to several major directions for further research on the beneficial health properties of rice bran proteins. Chief among these is the verification of the findings by animal model and human volunteer studies because, it needs to be pointed out that, the health benefit findings of the project are obtained by *in vitro* methods and they cannot be directly extrapolated to *in vivo* conditions in the body.

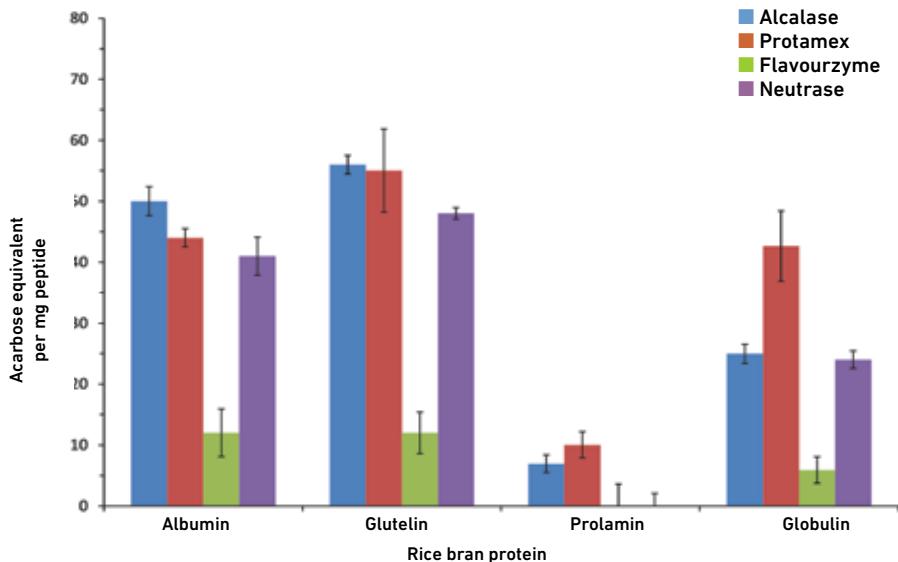
And herein lie the implications for policy makers, as well as the rice industry, i.e. further funding should be provided to researchers to conduct animal model studies to confirm the findings obtained in this project, because without such confirmation, the health benefits found in the study can only be regarded as tentative.

## RIRDC Project PRJ-008720

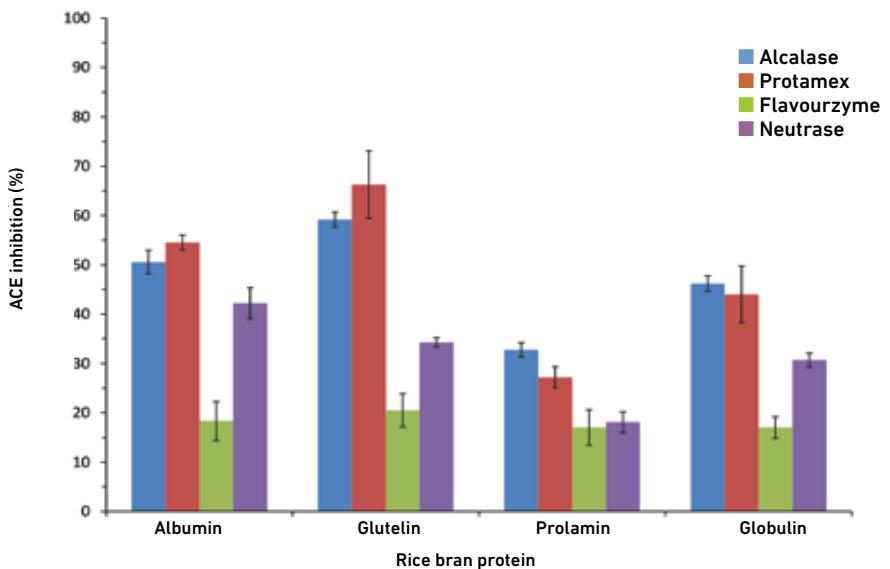
*Development of rice bran protein hydrolysate-based bioactive products*

### Further information

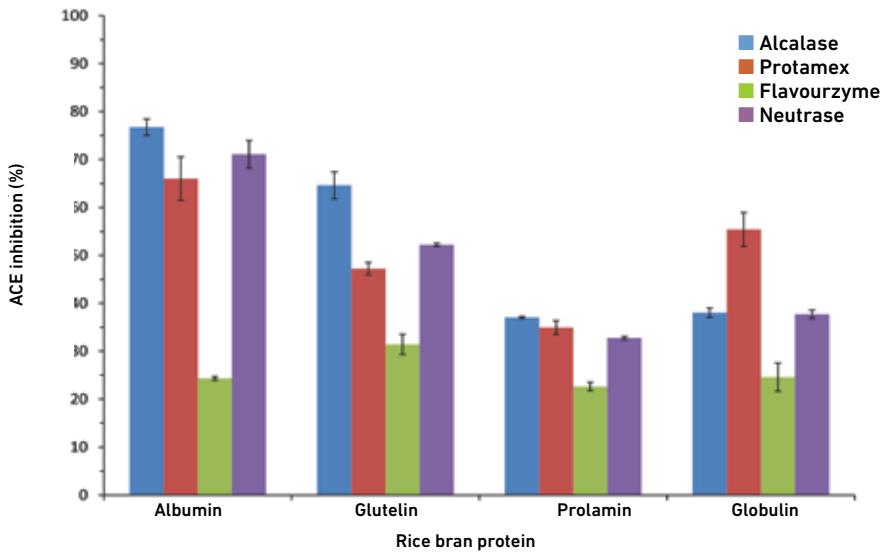
Dr Jian Zhao  
T: 02 9385 4304  
E: jian.zhao@unsw.edu.au



● **Figure 1. Alpha-amylase inhibition activity of rice bran protein hydrolysates.** The activity is a measure of the hydrolysate's capacity to block starch digestion. Albumin, glutelin, prolamin and globulin are proteins extracted from rice bran; Alcalase, Protamex, Flavourzyme and Neutrerase are enzymes used for digesting the proteins.



● **Figure 2. ACE inhibition activity of rice bran protein hydrolysates.** The activity is a measure of the hydrolysate's potential to lower blood pressure.



● **Figure 3. Antioxidant activity (ABTS inhibition) of rice bran protein hydrolysates.**



# LEADING RICE INDUSTRY EVENT RETURNS TO THE RIVERINA

## QUICK TAKE

- The Australian rice industry will play host to the International Temperate Rice Conference in Griffith in March 2017.
- The conference theme reflects the innovation and advancement of rice production in Australia in recent decades.
- A respected and knowledgeable line-up of industry experts has been organised for presentations and the conference will be an opportunity to share ideas and explore cutting-edge technology to advance rice R&D.
- The conference will also provide opportunities to visit a leading rice-growing operation near Griffith and the Rice Research Australia Pty Ltd field station at Jerilderie.

The latest information about temperate rice research, technology and innovation, from around the world, will be showcased in Griffith in 2017.

### Temperate Rice Conference Organising Committee

**T**HE International Temperate Rice Conference will be returning to Australia in March 2017, bringing delegates from around Australia and the world to the heart of the Riverina's rice-growing region — Griffith, NSW.

The four-day conference will run from Monday 6 March to Thursday 9 March, and will feature a series of dynamic presentations from local and international speakers, covering topics including rice breeding, agronomy, biotic and abiotic stress, irrigation and soils, crop protection, quality and processing, environment, precision agriculture and extension.

Relevant to all sectors of the rice industry, it will provide an international networking opportunity for rice breeders, researchers,

rice growers, agronomists, agribusiness professionals and agricultural suppliers.

### About the conference

Every few years, the International Temperate Rice Conference is hosted by a different rice-growing country with the aim of addressing the challenges and triumphs specific to temperate rice growing. Since it was first held in Yanco NSW in 1994, the conference has grown into a leading networking opportunity for rice researchers and growers from around the world, with previous conference hosts including Punta del Este, Uruguay; California, USA; and Novara, Italy.

Now returning to Australia, the conference provides an opportunity to celebrate rice growing in Australia and shine a light on the industry's success over the last 20 years, during which time Australian rice growers have become world

leaders in productivity, sustainability and water use efficiency. The industry's focus on innovation and advancement is captured in the conference theme: 'Tradition, Technology, Productivity – A Balancing Act'.

"It is fantastic to be bringing this leading conference back to Australia, and particularly to the Riverina, where it was first held over 20 years ago," said Manager of Rice Research Australia Pty Ltd (RRAPL) and head of the conference organising committee, Russell Ford.

"We are looking forward to this opportunity to recognise and celebrate the achievements of all of our rice growers, the advancements the industry has made, and to learn from and share experiences with our international peers."

## Keynote speakers

Leading the way on the conference program will be keynote speakers Dr Matthew Morrell, Director General, International Rice Research Institute (IRRI); Dr Steve Linscombe, Senior Rice Breeder, Louisiana State University Agricultural Centre; Professor Melissa Fitzgerald, Professor of Food Science, School of Agriculture and Food Sciences, The University of Queensland; and Dr Russell Reinke, Senior Scientist (Rice Breeding — Bio-fortification), IRRI.

"With such a respected and knowledgeable line-up of industry experts on board, the conference will be an invaluable experience for our delegates," said Russell Ford.

"This will be a platform for sharing fresh ideas and insights, exploring cutting-edge technology and furthering research and development in temperate rice, as the industry moves forward."

## The conference experience

Extending well beyond the auditorium, the 2017 International Temperate Rice Conference will not only showcase the latest research into temperate rice growing, it will also provide on-farm and field experiences and social events for delegates.

### Pre-Conference Tour

An optional three-day Pre-Conference Tour from Sydney to Griffith will take delegates to the best sights in regional NSW and the ACT in the lead-up to the conference.

### Day 1 – Farm Tour & Welcome Reception

Included in all Full Delegate registrations, delegates can kick off the first official day of conference with a farm tour to Benerembah, to observe cutting-edge technologies being used on the Braithwaite property.



Delegates will see how automatic flume gates are being used to maximise water use efficiency and productivity; learn about the use of precision agriculture and see high-tech machinery used for variable rate technology and laser levelling, as well as remote imagery technology; and inspect innovative rice trials taking place.

A Welcome Reception, including drinks and canapes at the Griffith Exies Club, will wrap up the day giving delegates the chance to get to know their peers in a relaxed setting.

### Day 2 — Conference sessions & Conference Dinner

Day 2 involves a full day of conference sessions, closed out with the Conference Dinner — a three-course meal showcasing the best of Riverina produce — to be held at Griffith's Bagtown Inn.

### Day 3 — Conference sessions

Day 3 will consist of a second full day of dynamic presentations and conference sessions for delegates to enjoy.

### Day 4 — Rice Field Day

The final day of conference will continue on the theme of innovation and technology, taking delegates to the Rice Field Day at *Old Coree*, Jerilderie for a day of industry seminars, field walks and business and innovation forums. With machinery exhibitions, demonstrations and a great line-up of guest speakers, the Rice Field Day will allow delegates to enjoy one final day of networking. The day includes a dinner at *Old Coree* and return bus trip to Griffith, which is included in all Full Delegate registrations.



## Registrations

Registrations are now open for the 2017 International Temperate Rice Conference.

- Full Delegate: \$880.00
- Student Delegate: \$440.00

Additional registration packages can be viewed in detail on the conference website: [www.itrconference.com](http://www.itrconference.com)

**Where:** Griffith, NSW

**When:** Monday 6 – Thursday 9 March 2017

### Further information:

Angela Wakeman  
Sauce Communications  
T: 02 6953 7382  
E: [events@saucecommunications.com.au](mailto:events@saucecommunications.com.au)  
W: [www.itrconference.com](http://www.itrconference.com)

# IREC Executive Committee

IREC Chairman	Rob Houghton	0428 559 249	roberthoughton50@hotmail.com
IREC Deputy Chairman	Kieran O'Keeffe	0427 207 406	kieran.okeeffe@cottoninfo.net.au
Executive Officer	Iva Quarisa	0402 069 643	iva@irec.org.au
Secretary	Hayley Wordsworth	02 6963 0936	irec@irec.org.au
Cropping and Water Management Subcommittee	vacant		
Horticultural Crops/Permanent Plantings Subcommittee	vacant		
Vegetable Industry	vacant		
Griffith & District Citrus Growers	Carmel La Rocca	0412 811 343	
Leeton District Citrus Growers	Sam Ciccia	02 6955 6441	
Wine Grapes Industry	Eric Berton	0427 630 175	efvberton@bigpond.com
Rice R&D Committee	Drew Braithwaite	02 6963 4204	dbraith@me.com
Ricegrowers' Association of Australia	Rachel Kelly	02 6953 0433	rkelley@rga.org.au
Ricegrowers' Ltd. (SunRice)	Alan Walsh	03 5882 4330	walsh6@ozsky.net
Maize Industry	Bernie Walsh	0427 478 227	walshfarms@bigpond.com
Cotton Industry	Kieran O'Keeffe	0427 207 406	kieran.okeeffe@cottoninfo.net.au
Murrumbidgee Irrigation	Lindsay Golsby-Smith	02 6962 0200	lindsay.golsby-smith@m灌溉ion.com.au
Coleambally Irrigation	Bernard Star	02 6950 2839	bstar@colyirr.com.au
Charles Sturt University	vacant		
Deakin University	John Hornbuckle	0429 862 920	j.hornbuckle@deakin.edu.au
NSW Department of Primary Industries	Deb Slinger	0427 026 207	deb.slinger@dpi.nsw.gov.au
Murrumbidgee Private Irrigators Inc.	Iva Quarisa	0402 069 643	ivaquarisa@gmail.com
Riverina Local Land Services	Anna Wilson	0428 964 785	anna.wilson@lls.nsw.gov.au

## Advertiser's Index

<b>AGnVET</b> .....	<b>Page 15</b>
<b>Booth Associates</b> .....	<b>Page 22</b>
<b>Bruno Altin &amp; Co Pty Ltd</b> .....	<b>Page 19</b>
<b>PHL Surveyors</b> .....	<b>Page 28</b>
<b>Rawlinson and Brown Pty Ltd</b> .....	<b>Page 50</b>
<b>Riverina Earthworks</b> .....	<b>Page 9</b>
<b>Yenda Producers</b> .....	<b>Page 9</b>



**RURAL INDUSTRIES**  
Research & Development Corporation