

Improving Rice Water Use Efficiency

Direct Drilling of Rice and Precision Farming



A report for

By Peter Kaylock

2013 Nuffield Scholar

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Executive Summary

Water use efficiency is a driving factor for the Australian rice industry. Australian rice farmers grow rice in one of the driest continents in the world, achieving some of the world's highest yields per hectare and water use efficiency per kilogram produced (Dunn & Pal Singh, 2013). In recent years, the availability of water for agricultural production has been reduced significantly as a result of government policy. Australian rice farmers are also under constant scrutiny to justify their water usage, so need to develop new technologies and practices. Historically Australia is one of the few countries to establish a rice crop by flying rice seed into a flooded bay. The majority of the countries visited establish their crops by drilling seed into the soil and establish by flushing. In Australia, this technique could be more broadly adopted with significant savings in water use and input costs.

The Australian rice industry has signalled to its growers a need to increase production to fill prospective markets in the coming years, particularly for specialty varieties. The industry is expected to produce 825,000 tonnes of 'paddy' in the 2013/14 season, and forecasts production levels of 950,000 tonnes will be needed to meet increasing demand in the next few years.

The key limiting factor will be water. Competition for water from other irrigated crops will increase the price of tradable water and alternative ways of maintaining production levels while using less water, will have to be seriously considered.

Direct drilling (D/D) of rice is a viable system for irrigators in Australia. This technique offers substantial savings of water, chemical inputs and machinery costs over traditional methods. The addition of cover cropping and further precision agriculture technologies to this system has the potential to increase productivity, lower input costs further and reduce variability in yield.

This report reviews techniques that could be used to refine growing systems using new management skills and precision agriculture to maximise kilograms produced to water used.

While it is important that the industry showcases current water savings to its critics, it must more importantly strive to increase its productivity and competitiveness in a world market. The incentive for many farmers in many other countries to readily invest in new technology and address water-use efficiency has slowed due to subsidies and the fact most farmers overseas lease or rent the land they work.

Precision technology has many different uses in the Australian rice industry. The Australian industry presently designs, constructs and maintains irrigated cropping layouts to increase irrigation efficiency, using Global Positioning System (GPS) technology and satellites. Soil mapping and variable rate technology is currently used for soil nutrient management enabling sub metre accuracy of application.

Better understanding of the optimal timing for nitrogen application to manage leaf and canopy has potential to further improve crop yields in the future. Satellite imagery is currently available to measure crop density, enabling precise sampling of variations within a crop. These crop density maps can be used to apply nutrients, to identify soil variation and identify weed burdens. It can also highlight the importance of controlled traffic systems, measuring compaction from machinery movements.

Australian rice farmers use a wide range of Precision Farming Techniques at a far greater rate than most other rice growing countries in the world. Currently only 25% (Dunn, 2014) of the Australian rice industry establishes rice using D/D techniques. This has increased from 8% pre-drought 2003 (Ford, 2014). The adoption of direct drilling techniques in the Australian rice industry is gaining momentum, as significant savings in water use and cost savings are identified using this technique of establishment. It also has the added benefit of preventing duck and insect damage to crops.

On a gross margin analysis, D/D rice crops are competitive with conventional water sown crops. Yields per hectare (ha) can be marginally lower in a D/D crop, but total input costs are substantially less, often resulting in a better gross margin per hectare and megalitre than

conventional rice crops. Given that water is our limiting production factor, gross margins should be comparing returns by water use efficiency rather than by hectare or megalitre.

Breeding programs around the world have developed hybrid and Clearfield® rice varieties, mainly to combat weed and disease pressures, which has increased yields in those countries. They are still to match the yields of Australian varieties but the yield gap is closing. Australian varieties have superior yield and quality characteristics with the full yield potential of Australian varieties yet to be reached. Current Australian yield averages stand at 10.7 tonnes per ha.

Precision agriculture is available to most growers, as is technical support. The industry needs to better educate growers on the benefits, and use of precision agriculture systems, to encourage a wider understanding of its benefits.

The next big gains in production and yield will most likely come from varietal advances, further adoption of precision agriculture systems, and a better understanding of the limiting factors in our soil.

D/D rice will not suit everybody. Growers will need to continually refine their growing practices, and ensure attention to detail to achieve good results with D/D cropping techniques. This is particularly the case for weed control and crop establishment, for which D/D can potentially be less forgiving.

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Foreword

My family has been growing rice for over 60 years, and has always been willing to adopt new technology. We began experimenting with D/D techniques in rice during the period of low water allocations associated with the drought commencing in 2006, and soon realised the possible savings of the system without loss of yield. As with either system, aerobic or anaerobic, there are basic rules to follow to achieve best results, and these are always manipulated by the elements. It is never easy.

During a visit in 2005 to the Rice Research Station at Old Coree, near Jerilderie, NSW, I first saw the potential for D/D establishment of rice. The research farm is run by Russell Ford (Nuffield Scholar, 2000). Russell developed a system of sowing complex variety trials, using D/D techniques to stop seed drift between trials in a flooded environment. I could see the potential of this technique on a broader scale using our existing equipment. We then grew a 10 hectare trial in 2005, and have been developing the system since. The low allocation period from 2006 showed how versatile the system could be.

We have identified water savings of at least two megalitres per hectare in our soils using D/D techniques. The continual irrigating and drying process has simplified chemical usage and identified substantial input savings. The drying process between irrigations eliminates broadleaf weeds, such as Dirty Dora (*Cyperus difformis*), Starfruit (*Damansonium minus*), and insect problems, particularly bloodworm (*Chironomus tepperi*) and snails. The use of our existing machinery to carry out chemical and fertiliser applications resulted in significant savings compared to hiring an aeroplane to carry out the same procedures.

Water is pivotal to growing rice. Water supply in the Riverina is not secure, and is a tradeable commodity enabling the water resource to be moved to the highest bidder. It is also under scrutiny from community and government interests, who demand it be used efficiently and effectively.

Rice growers are gamblers in many ways, but their biggest gamble can be estimating how much water will be available for the coming season. Often a rice crop is in the ground before the season's allocation is known. With a D/D crop, there are many ways to delay expenditure on the crop until water allocations are more fully known. This cannot be done in an anaerobic crop as the most expensive inputs are applied up front.

In 2011, I joined the Rural Industries Research Development Corporation (RIRDC), Rice R&D (research & development) Committee, and have been involved in assessing and approving expenditure on research projects annually. The committee invites researchers to submit research projects associated with the rice industry. Projects that reflect industry priorities and meet program guidelines are then funded.

An important strategy for maximising the benefits of D/D is the implementation of precision agricultural techniques. In 2013, the RIRDC committee approved a four year project to assist growers in the uptake of precision farming techniques. Nine rice producers with varying data collection histories submitted data obtained from their previous cropping history. It is hoped by capturing this data some key drivers will be identified to assist production. In conjunction the rice industry is currently developing a web based portal to provide a base layer of relevant crop data and then invite growers to add their own information. Assistance will then be given to develop individual prescription maps for sowing and fertiliser applications on farms using individual's data. Both projects are designed to assist growers to collect, understand and apply their own specific data.

My Nuffield studies gave me the opportunity to visit many rice growing countries looking at the D/D of crops, cover cropping, and innovative machinery. I appreciate the opportunity given to me by the Rice Industry to contribute to its future. The rice industry needs to continue to focus on producing more with less, as water will continue to be restricted in its availability and the cost of water will continue to rise. D/D rice techniques will offer definite water efficiency savings.

Acknowledgments

I am humbled by the generous hospitality from people all over the world due to the Nuffield program. Their support and assistance was truly amazing. People would take time from their day, sometimes week, to show us their industry or businesses, and spend precious time sharing their knowledge. They often went out of their way and exceeded our expectations in providing this help.

Firstly I must thank RIRDC, and the Rice Industry for their support, particularly Russell Ford, Ian Mason and Andrew Bomm. I must also thank the following people and organisations overseas:

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My sincere thanks to my wife Liz, my three children, Laura, Grant and Aaron for their understanding. I was absent from home for sixteen weeks in total, and missed many important events in their lives. My daughter Laura, was of tremendous help in writing this report.

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Abbreviations

CHS	Cenex Harvest States
D/D	Direct Drill (Minimum Soil disturbance cropping system)
GIS	Geographical Information Systems
INIA	Institute National Investigation agriculture, Uruguay
INRA	French National Institute for Agricultural Research
IRRI	International Rice Research Institute, Philippines
kgs	Kilograms
LLS	Local Land Services
LSU	Louisiana State University
Megalitre	1,000,000 litres of water, 1 Megalitre covers an area of 10 meters*10m*10m
NDVI	Normalised Difference Vegetation Index
NIR	Near Infra-Red
PI	Panicle Initiation
RIRDC	Rural Industries Research and Development Corporation
RRAPL	Rice Research Australia Pty Ltd
SunRice	Company that mills and markets rice grown in the Riverina

Objectives

The aim of this study is to identify agronomic practices that may improve the efficiency of direct drilling systems in rice and highlight:

- What the industry can do to further increase its production from a finite water resource.
- How the industry can improve its water use efficiency to achieve this production objective.

This report will:

- Highlight the present productivity of the Australian rice industry and its willingness to adopt new technologies.
- Investigate farming systems around the world that have synergies with the rice industry to enhance the establishment and development of rice crops.
- Identify technology that may be of assistance to further enhance present agronomic systems in the rice industry.
- Identify and quantify the potential cost savings of D/D systems in rice.

Introduction

The Australian rice industry is unique by world standards. We are the most water constrained and least subsidised growing region in the world. Australian rice growers surpassed the international average production of 5.4 tonnes per hectare 45 years ago (About Rice, 2013). There are very few countries in the world that can match the Australian rice industry for productivity, technology, quality, and genetic development.

Australian growers are quick to adapt new practices and varieties. Traditionally the rice industry has had access to outstanding extension and research. Unfortunately in recent years, this changed, and as in many countries around the world, extension has shifted to a 'user pay' system. Growers continue to adopt precision farming techniques, resulting in Australia furthering our ability to record the highest rice yields annually in the world.

Due to quarantine policies and the clean seed program, Australian rice growers enjoy the advantage of not having to contend with the weed, insect, and disease problems of their world counterparts. Other countries have had to breed varieties to address these problems, and those varieties do not yield as well as Australian varieties, giving us a cost of production and yield advantage. Australian growers do not have the assistance of protectionist policies of many of their world counterparts.

Direct drilling rice into pastures is not a new concept. Rice traditionally is based on a one in four year rotation with pasture and sheep production. The benefit of a long pasture history gives excellent residual crop nitrogen and assists with weed control.

In the early years of rice production, pastures were sprayed or 'grazed out' and sod-seeded with disc combines but problems were experienced with irrigation management, establishment and weeds. This type of establishment was abandoned in the early 1970s by the Australian rice industry and aerial sowing techniques were developed in conjunction with new chemicals for weed control. The industry grew substantially, length of rotations

decreased as production increased and more water became available. Advancements in laser levelling gave better weed control and water management.

The Australian rice industry is coming under increased pressure to improve water use and efficiency, for both economic and wider community expectations. Rice systems need to be refined and showcased to the wider community. Direct Drilling (D/D) systems can assist the industry to further achieve water efficiencies. Aerobic rice techniques compare well with other forms of agriculture for water use efficiency.

The benefits of a Direct Drilled crop can be highlighted in the following ways:

- Direct Drilling of a rice crop will result in water savings. The amount of water saved will vary due to soil types, timing of initial irrigations, weed burdens and rainfall, but in general two to three megalitres per ha can be saved (Dunn, 2014). This can be water savings of 15% to 30% (Whitworth & Lacey, 2008).
- Chemical usage and costs can be reduced.
- There is very little need for the use of insecticides, if at all.
- Broadleaf weeds associated with conventional rice crops will not survive the 'wet- dry' process.
- No planes (or associated costs) are required to apply chemicals, as all applications can be carried out by ground rigs. The risk of drift is significantly minimised, and cost of chemical applications is significantly reduced and higher water rates can be used.
- Damage to the crop from wildlife (ducks) is not a factor.
- The economics of D/D crops are competitive with conventional aerial sown crops (Dunn & Rajinder, 2013).

Yields of D/D crops are suggested to be comparable to conventional rice crops, but water use efficiency is markedly improved.

Rice has a huge economic value to the local community, the Ricegrowers Association of Australia web page states:

“It is estimated every \$1 of rice production equates to \$4 in flow on economic activity. Rice is Australia’s third largest cereal grain export, and the ninth largest agricultural export. The industry generates around \$800 million revenue per annum, with around \$500 million of this coming from value-added exports. Australia exports to 60 major international destinations. Up to 85% of Australian rice is exported to more than 40 countries. Papua New Guinea is the biggest buyer, buying 25% of what is exported. Other major markets include Japan, Hong Kong, Turkey, The Middle East, New Zealand, Fiji and the Solomon Islands.

Most agricultural products exported from Australia are sold as a bulk commodity and value-added off-shore, yet Australian rice is milled, packed and branded in the Riverina by SunRice.

Only 25 million of the 600 million tons of world annual rice production is traded outside its country of origin. Australian rice only represents around 0.2% of world rice production, but our exports represent about 2% of world trade and 25% of medium grade trade” (RGA, 2013).

In Australia, rice is grown from October until March in rotation with other crops, mainly wheat and barley. These crops are grown utilizing residual soil moisture from the harvested rice crop, and are often completed with minimal irrigation. This gives added efficiencies in water use, and provides growers with two crops from the one application of water. The practice of double cropping after rice is unique to Australia.

The Australian Rice Industry

The Australian rice industry is a world leader in production efficiency, water use efficiency and environmental management. These efficiencies have come about from the development of more sophisticated drainage and recycling systems, improved irrigation layouts, the development of new short season and higher yielding varieties, and improved crop nitrogen application.

Australia's climate is unique but very favourable to rice production in Southern NSW. Long cloudless days, with high sunlight intensity, help to maximise the yield potential of summer crops.

Water supply is the main constraint on rice production. Australian rice growing areas are largely rain fed from storages in the mountains on the Murray and Murrumbidgee River systems. Most farmers are supplied from private irrigation systems that divert water from these rivers. Some pump water from river systems and ground bores but all have a yearly allocation of water based on annual resource availability. Most commonly, growers hold low security licenses that have a variable yield and are dependent on rainfall filling the dams to ensure their requirements are met. Traditionally, allocation announcements are made as the season progresses so growers almost never know the full extent of their water availability until well after a crop is planted. License holders can also market their water to the highest bidder, or use their allocation to produce another commodity.

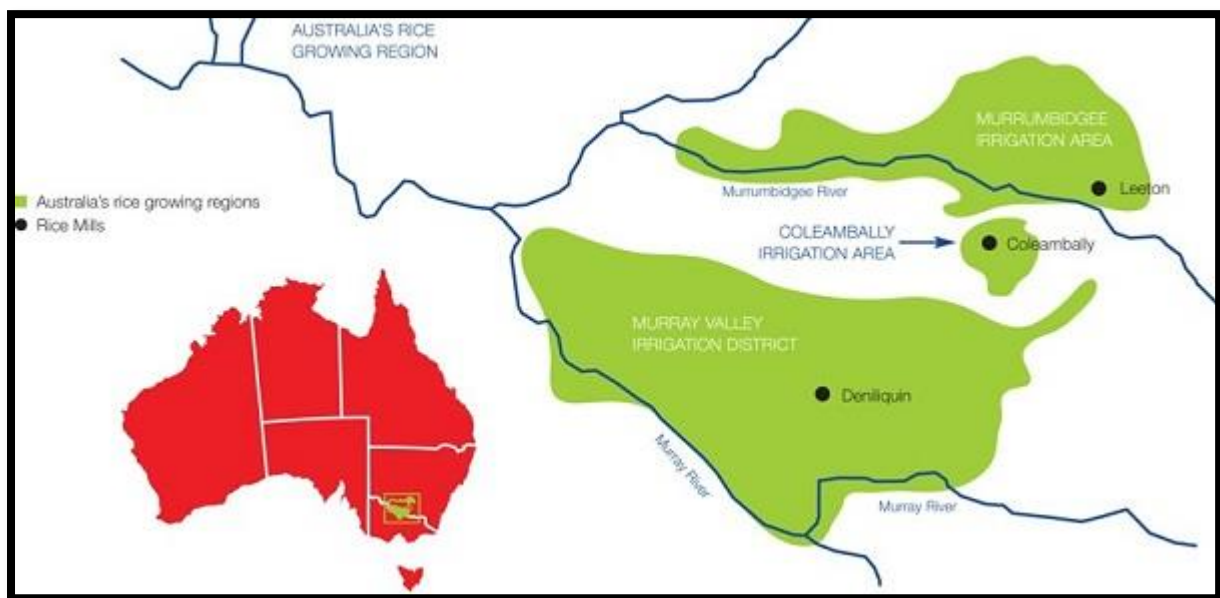


Figure 1, Map of Australia' Rice growing region (RGA, 2013)

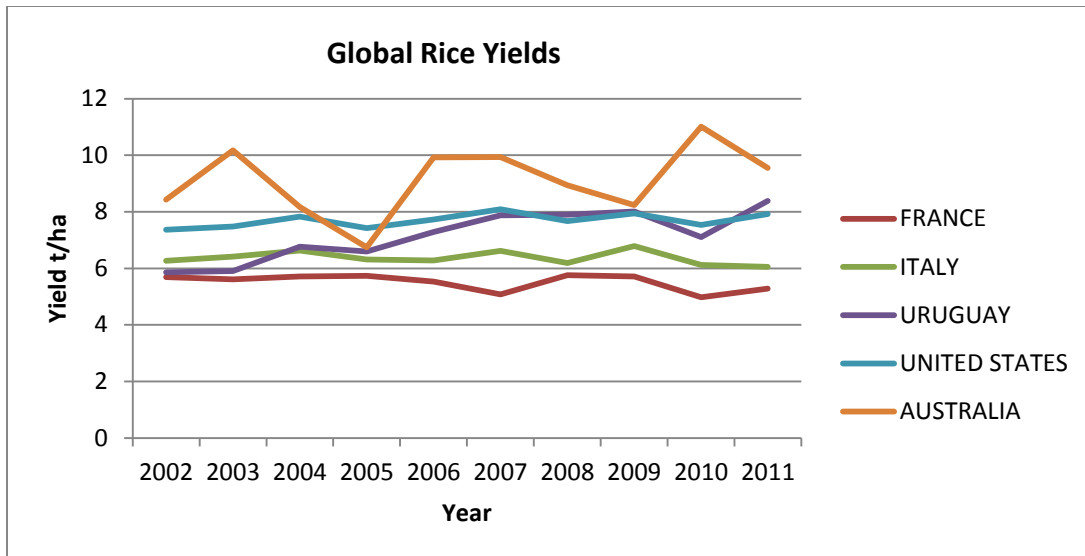


Figure 2, World Rice Yields (IRRI, 2014)

This graph (figure 2) shows Australia's yield advantage, but also highlights the susceptibility of the Australian crop to cold damage compared to the even climates of other countries.

Growers find that direct drilling of rice has many advantages relating to water use and availability. The D/D technique allows growers to plant their desired area of crop before assessing the likely water allocation. The rice crop can be prepared and sown with minimal inputs compared to a conventional aerial sown crop. With a D/D crop, the main input expense is mid-season compared to a conventional crop being up front. A grower with a D/D crop can shut down a proportion of the planted crop with minimal loss of inputs.

The combination of a well lasered (even) layout, with excellent drainage, recycling capabilities and high water flow is critical for success. The adoption of laser guided land forming ensures the most efficient use of water and allows farmers precise control over the flow of water on and off their land, aiding the quick establishment of crops. The application of water allows the soil to settle, requiring layouts to be re-lasered constantly. Rice growers in America and Italy were observed to laser level their country before rice planting annually, to achieve the perfect levelled layout, aiding establishment.

A D/D crop requires up to three flushes of water for the crop to emerge. If at any stage water is allowed to pond on an emerging crop, plant numbers will be reduced in those areas. Water quality (turbidity) is not an issue in the establishment stage of D/D crops, where it is critical with a conventional crop. Once the crop has emerged it is quite hardy, and can be stressed to the point of wilting and leaf loss without incurring yield penalties. Flushing (drying and wetting of the soil) eliminates the usual broadleaf weeds that are a problem in conventional crops, but will encourage the germination of grass weeds which compete aggressively.

Most Australian growers collect GIS (Geographical Information Systems) data, but rely on service providers to collate information to create variable rate and nitrogen top-dressing maps. Yield maps, cut and fill maps, NDVI maps are just some of the layers that can be further added to create prescription maps.

Before a field is lasered it is usually grid surveyed, and the height contours of a field mapped. The high areas of a field are physically moved to the lower areas to level the field, creating an even gradient across the field. The area soil was moved from is referred to as a cut, the area the soil is deposited in is referred to as fill, hence a cut and fill map can be drawn. Often a cut area will have low fertility, as topsoil has been removed, and a fill area will have increased fertility. When a variable rate application map of fertiliser is produced, cut and fill maps are taken into consideration in an effort to address soil fertility as a result of lasering.

Topsoiling is the practice of stockpiling soil from a cut area before lasering, and replaced on completion of paddock preparation, with great effect.

The D/D of rice for establishment is practiced in many parts of the world, often exclusively, with excellent results. 35% of the Australian Rice industry in 2013-14 established their crops using D/D techniques and this establishment method continues to create a lot of interest as growers look for further ways to reduce their input costs and water use. Growers need to fully understand how to implement the technique, as missing a key driver can be costly at harvest.

Ricecheck

Ricecheck was developed in Australia by John Lacy, Department of Agriculture, in the early 1990's to improve rice yields for the Australian rice industry. It is a comprehensive list of agronomic checks developed to aid farmers to achieve best practice.

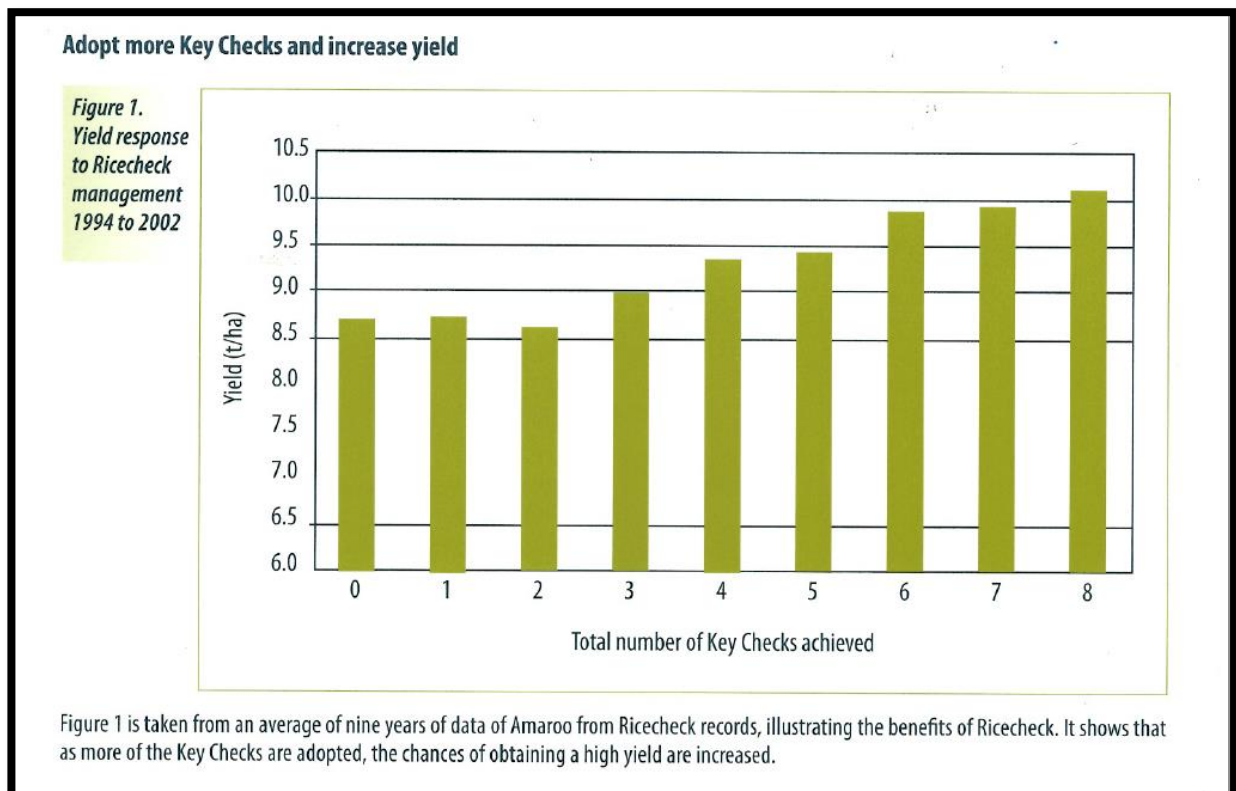


Figure 3, Yield responses to Ricecheck management (NSW DPI, 2012)

Ricecheck recommendations are based on current rice technology developed from field experience, rice trial results and research. Each year recommendations are reviewed and revised based on seasonal experiences, research, extension and farmer results.

The present *Ricecheck* recommendations for D/D establishment are based around a trash-free cultivated seedbed using pre-emergent chemicals, not for seed placement into a cover crop using minimal disturbance. *Ricecheck* should be developed further to suit D/D cropping systems.

In Uruguay all rice is established using direct drilling techniques and industry yields have improved markedly since the introduction of the Australian Ricecheck management system.

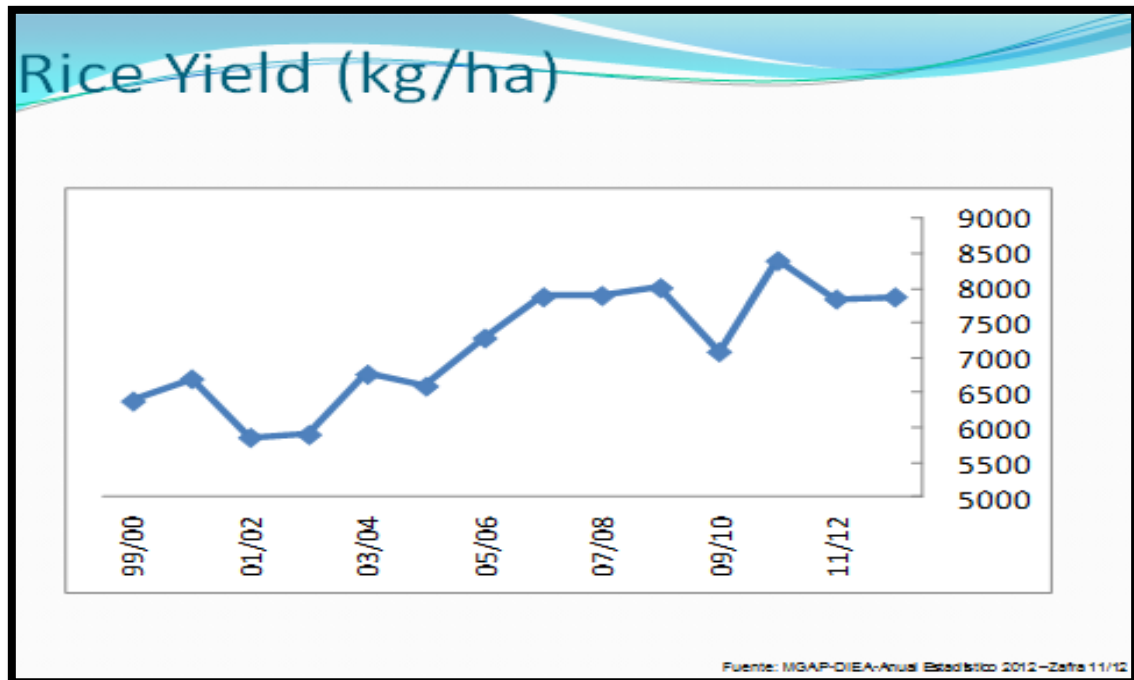


Figure 4, Rice yields in Uruguay after the introduction of Ricecheck (Carracelas & Riccetto, 2012)

For the Australian rice industry to increase its water use efficiency the establishment of rice using D/D systems needs to be further developed. The industry should continue research into developing cover crop systems, complete further research into seed dressings, introduce new and existing genetics into its breeding program, introduce or develop other chemicals for weed control, and continue to encourage the use of precision agriculture systems on farm.

Cover Cropping

Cover cropping should be considered in the preparation of a D/D crop to aid in weed suppression, moisture retention and to add organic matter to the soil.

Cover cropping is an interesting concept, one that is normally practiced in locations of high rainfall or snow cover, but is well suited to irrigated cropping rotations. Cover cropping aims to keep the soil covered and active at all times. Cover cropping is the establishment of another crop in the residue of the previous crop, or a new crop sown into a mature crop, without removing the initial crop residue. In a rice rotation, rice could be established into wheat stubble or the remains of a pasture. Medic pastures fit our rotations well and could be an ideal cover crop to establish a crop into. With some planning and thought, other cover crops could be considered. Traditionally Australian farmers have operated a rice-pasture rotation, particularly in years when livestock were an economic option. As the value of wool and livestock fell, cereals have taken their place in rotations.

Cover Crops grown around the world include:

- Brassicas, radish, canola and mustard are deep rooted crops that can aerate and fumigate the soil, they can break hard pans and are claimed to reduce the incidence of root pathogens. Deep rooted brassicas are also claimed to bring nutrients to the surface, aid in storing nutrients for coming crops, and improve water penetration.
- Clovers and legumes provide nitrogen for the subsequent crop, and create a soft ground cover that will decompose readily.
- Corn provides organic matter and soil cover. Roots break hardpans and allow water infiltration. Corn is often not grown as a crop to harvest, but for desiccation on stem hardening to increase soil organic matter

The principle is simple. Achieving it is not. Keep your soil active. Grow a beneficial crop rather than weeds or a fallow. Grow a crop that will give dense soil cover to exclude sunlight. Time the planting of a cover crop to achieve maximum bulk as the sowing window approaches. Use a knockdown herbicide to kill the cover crop, either before or after sowing

the target crop. It is often easier to sow into a growing standing crop rather than a desiccated crop. Consideration should be given to the growth window available before the target crop, the available moisture, time of year and the timing of the target crop. Cover crops can be mixes of crops, and different mixes are known to complement each other as they grow.

Machinery to plant into high trash conditions will need to be considered. Disc or tyned machines with a disc opener are often used. A tyre roller or similar can be used to lay the cover crop on the ground. The sowing pass will leave minimal soil uncovered and aid germination leaving a dense weed mat in place which can hold weed emergence.

Desiccation of the cover crop can often be delayed until the target crop is about to emerge, enhancing weed control. Thought should be given to what weeds are present, or when they may occur in the growing crop.

Added benefits of D/D are:

- Drilling into pastures maintains a firm seed bed, allowing traffic at an earlier point than a conventionally prepared paddock. There are also harvest benefits with a firm base for harvest activities.
- It allows a layout to drain quickly, and reduces ponding.
- Soils remain warmer and seed germinates more quickly aiding establishment.

Ricecheck recommendations for Direct Drilling techniques in rice are based upon a dry seed bed, free of organic matter. It is suggested to drill rice seed into the soil, apply knockdown and pre-emergent chemicals, and commence irrigation. Presently, pre-emergent chemicals cannot be used with a cover crop as they are designed to have direct contact with the soil.

Under the present recommended system, because there is no organic matter on or in the soil, soils dry quickly and crust, making seedling emergence difficult. Organic matter is needed to

conserve moisture, but it ties up chemicals. Weed control relies on knockdown sprays being applied as late as possible before the rice seedling emerges.

Cover cropping around the world is gaining interest but is not a new concept. It is, however, generally associated with high rainfall situations. Our Australian rainfall patterns are vastly different so careful consideration will need to be taken to choose cover crops suited to our climate and rotations.

Cover Cropping Examples

Dave Brandt, Southern Ohio, USA



Figure 5, Dave Brandt in a Radish crop after the snow thaw

Dave crops 506 ha of corn, soybeans and wheat, in a 900 ml rainfall zone. He has been practicing ‘No-Till’ since 1971, and cover cropping since 1978. By keeping the soil covered and a growing crop in the ground as often as possible, he now achieves good corn yields without chemicals or fertiliser.

Thirty years ago Dave had 10cm of topsoil, with yellow subsoil, now he has 36cm of topsoil, full of humus, and black in colour. The organic carbon levels of his soils have increased from

1% to 7%. Dave demonstrated the advantages of his cropping system, by pushing a one metre 12mm steel rod easily into his fields. In his neighbour's field, he could not achieve half this depth of penetration.

He advocates a mix of deep rooted plants such as legumes and brassicas. Deep rooted plants, particularly radish, fumigate the soil, pull nutrients from the deeper profiles and as they decompose leaving nutrients and sugars, available for the next corn crop. The tap root of a radish plant can penetrate 50cm. Radish plants decompose quickly, leaving a deep hole, allowing moisture to access the deeper profile. Dave is trialling companion crops, corn with soybean planted closely. The soybeans add nitrogen to the growing corn, and are shaded out as the corn crop grows.

He advised us in our drier Australian conditions to grow our cover crops as early as possible, and sow into them. He disputed that dry conditions will limit cover crop success, saying that “fertility brings moisture, bulk of crop brings fertility” (Brandt, 2014). Cover cropping is not limited to high rainfall locations, and with planning can be used in any rainfall situation.

Dave stated, “Cover cropping reduces weed competition, improves organic levels in the soil, and conserves ground moisture” (Brandt, 2014).

Fredric Thomas, Dhuizon, France



Figure 6, Fredric Thomas

Frederic produces the French No-Till magazine TCS, www.agriculture-de-conservation.com, operates his family farm when time allows and is a keen cover cropper.

He grows corn with eight tonne/ha yields, on deep sandy soils, a metre deep, with a clay base in a 650mm rainfall zone.

Frederic uses minimal chemicals, and rotates subsequent crops of corn, followed by wheat. He grows companion crops of canola and vetch, separating the two grains after harvest, resulting in a 25% overall better paddock yield.



Figure 7, Cover crop seed mix

Frederic uses a huge mix of different seeds but not grasses as they compete strongly and can be hard to manage. He does not expect all the plants in his mix to survive, as every year is different.

He bases his rotations on green manure and corn crops. Corn is the highest biomass crop he can grow. His sandy soils have low organic matter, and low water holding capacity. Building organic matter and creating biomass in his soils is important to hold moisture and nitrogen.

Frederic states “if you grow nothing, you grow weeds, if you grow cover crops, you have cover crops.” (Thomas, 2014).

Sandrine Gallion, Arles, France

Sandrine and Allaine farm 100 ha in the south of France, where the annual rainfall is 650 ml. They have irrigation available, but have not accessed it for 10 years. The monthly rainfall in Arles is consistent most of the year, but less in June-July. Temperatures are mild in summer and cold in winter months, but have no snow fall.

Sandrine grows canola, wheat, corn, lucerne and soybeans. Rice is grown when it is economic and she intends to grow her next rice crop as a trial, without the use of irrigation.

Sandrine traditionally grows corn sown directly into thick cover crops but also sows corn into established lucerne, after applying a growth regulant. A cover crop of sorghum and millet are often sown into corn stubble after harvest.



Figure 8, Sandrine discussing corn in her rotation

Sandrine works hard to keep her soils active with either a cover crop or her main crop. She says. “It is important to identify the timing of cover crops for maximum bulk to sow the target crop into and to use crops that will produce a high organic mass” (Gallion, 2014). The key is to grow enough cover crop, that when pushed to the ground, will provide a dense cover excluding sunlight from reaching the underlying soil, preventing the germination of weeds and conserving moisture.

Personal Cover Cropping Experience

In 2004, the author planted rice into a layout with dense clover pasture. The clover was sprayed with a desiccant (glyphosate), but actively grew on. Rice was drilled in ten days later, and then flushed. No other pre-emergent chemicals were applied. The rice established itself well, and no weeds were experienced due to the thickness of the clover stand. Fertilizer was broadcast and permanent water applied. The clover mass gradually disappeared as water levels were raised, and created no slime issues.

In 2012, a Shaftal clover pasture was established in late April and rice direct drilled into the pasture early October. No knockdown was applied at time of drilling. Once again, rice establishment was excellent due to the soil maintaining good moisture levels. As the rice emerged the clover was silaged, and a post emergent herbicide applied to the crop after removal of silage. Both instances have shown that practicing cover cropping principles, while not possible in the same way as seen overseas, are important to soil health, fertility, weed suppression and moisture retention. The dense cover crop helped to maintain the moisture in the soil, assisting the rice plant to emerge, with less reliance on post emergent chemicals.



Figure 9, Rice established into Shaftal clover, 2013

Soil Health

Australian rice soils have a shallow layer of topsoil. The variation of soil types and structure has been well documented over the last 50 years by many different researchers (Dunn & Beecher, 2012).

Lasering removes topsoil and exposes the raw sub soil beneath. This can be remedied by topsoil replacement on cut areas, but this is an expensive process. Large amounts of nitrogen, phosphorous, zinc and some gypsum are then added to assist the slow process of soil renovation.

Rice soils are often very sodic, and highly dispersive under flooded situations resulting in turbidity. Turbidity of water keeps the sunlight from reaching the germinating plant and stops the water from warming during the day. Gypsum has long been known to have a softening effect on soils, and will help to settle turbidity of water on sodic soils. Unfortunately, gypsum also has the effect of opening the soils structure increasing water infiltration, therefore it is not widely used.

Soil Analysis

The soil test shown is taken from the Western Murray Valley district and tested by the APAL soil testing lab, South Australia, using the Albrecht system. Test results show low calcium (Ca) levels and very high concentrations of Magnesium (Mg). This will result in a hard-setting impervious soil.

APAL recommended applying 7 tonnes/hectare of lime, 1.5 tonnes/hectare of gypsum over two years in an effort to reduce the effect of high Mg levels. Soil pH will be high due to the high levels of Mg and Sodium (Na).

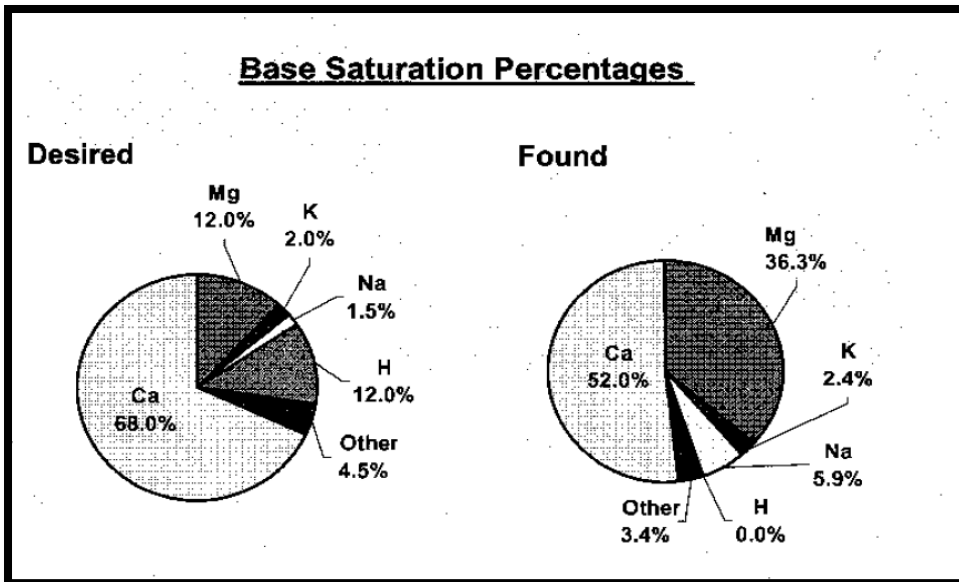


Figure 10, A soil test showing the imbalance of element ratios in Western Murray Valley rice soils

The results of the soil tests describe the soils accurately, but industry researchers are sceptical that this treatment will achieve the desired result. They suggest that treatment of soils in the above way is uneconomic, unlikely to reduce Ca and Mg levels to the point of a good 'cation exchange'. The best way to combat sodicity levels is to build organic matter. Rice rotation is a good option as the soils are well suited to rice production (Conyers, 2014).

Rice production leaves large amounts of dry matter that take some time to break down, increasing organic matter returned to the soil, so is an ideal crop to increase organic content.

Sodicity is a soil type that is high in Na, often deposited as a result of immersion from inland seas. High Na loadings in soil create hard setting soils when dry, and soil dispersion when wet. Soils can be prone to water logging, and limiting available oxygen to plant roots, and nutrient uptake.

Gary Zimmer, Mid-Western Bio-Ag, Wisconsin, USA



Figure 11, Gary Zimmer, centre, 2013

Gary has been practicing biological farming for 30 years. His approach is to understand the makeup of a soil. His advice is based around the Albrecht soil testing system, and he believes a soil should be in “balance” where possible. It can be a long process to make soil changes, but the use of cover crops, soil tests, influencing soil microbes, applying natural fertilisers and trace elements, all play a part in developing a balanced soil. Gary suggests that “a soil in the right balance with good microbial activity will result in a soil that has better water holding capacity, requiring less fertiliser and fewer chemicals” (Zimmer, 2013) .

Robert Plumb, Lincoln, England

Robert Plumb, of Soil Fertility Services in Lincoln, England, believes in a similar approach: “Get your soils in balance and they will work for you” (Plumb, 2013). Soils that have good ‘cation exchange ratios’ will be easier managed and more productive. Robert is an advocate of microbial mixes to stimulate soils, and in soil testing with the Albrecht system.

Biological Farming

Biological farming is not a concept readily used or accepted in rice agronomy. Analyses of Australian rice soils show that there are definite imbalances of trace elements within soils. Flooding soil for long periods changes the soil from an aerobic state to an anaerobic state, changing the way our soil behaves, the nutrients it can release, and further complicating the understanding of soil reactions.

Subsoil Manuring

Work carried out by Peter Sale (Sale & Malcolm, 2014), Latrobe University, Melbourne, Vic, has shown that subsoil manuring of up to 20 t/ha of high organic manure into sodic clay soils will improve the structure, water holding capacity and microbial activity of clay soils.

This practice can improve the porosity of clays which in turn will encourage root penetration and root activity. Crops are then able to extract previously unavailable moisture in soils. Moisture is attracted and held in soil by organic matter.

The microbial action around the organic matter produces exudates which assist to improve the structure of clay by improving aeration and softening of the soil, enabling roots to proliferate. Biological aggregation is able to overcome the dispersing effect of sodic clay. This practice has in dry-land cereals given large increases in yield over a four year period (Sale & Malcolm, 2014).

Rice production produces large amounts of organic material that is often difficult to handle as it has a high lignum and silicon content making it very slow to break down. Most times it is burnt and lost to the system.

Trials on composting rice straw with manures and other waste products from local industry have proven to produce good compost materials. With a ready supply of the base materials, rice producers have a cost advantage in producing this type of manure. The advantages of changing sodic clay soil structure and increasing water holding capacity could be an enormous benefit to establishing a crop in D/D rice systems. The process is quite costly, with figures quoted at \$50 per metric ton produce composted product, plus application. The cost of production and high application rates, will limit its use.

Seed Dressings

Increased root development should aid plant emergence, drought tolerance, and increase the vigour of the developing rice plant. A greater root depth may allow improved nutrient uptake, lengthen periods between flushing, and allow chemicals to have a longer residual action (flushing reduces the longevity of chemicals). A deeper root system will allow roots to access moisture from a deeper depth, possibly allowing a crop to be drained earlier. This could result also in better grain quality, due to a slower dry down period as the crop matures.

Gibberellic Acid

Gibberellic acid is a naturally occurring hormone found in rice plants. Its function is to accelerate growth of roots and leaf matter in a plants early growth stages.



Figure 12, Maurizio Tabacchi in a Gibberellin trial, Italy, 2014

Maurizio Tabacchi , research scientist with ValOryza, Italy, is conducting trials on hybrid rice, which showed that gibberellin in seed dressings can aid root development, and reduce germination times by up to two days. Gibberellin has been trialled at Rice Research Australia PTY Ltd (RRAPL), with mixed results. Not all varieties of rice show a benefit from the application of Gibberellin. Further trials are to be conducted.

In California, Gibberellin is used as a seed dressing, with research not showing a measurable yield benefit. Growers continue to treat seed as they maintain there are benefits in crop establishment.

Zinc Seed Coatings

Trials with applications of zinc fertilisers have been carried out for many years and the advantages to crop health and emergence are well documented. Fertilisers that have zinc encapsulated within the granules, placed in reach of the plant root zone have shown improved vigour and establishment (Dunn & Beecher, 2012).

Local trials (at Morago) by RRAPL and John Fowler, Agronomist, NSW Local Land Services (LLS), with zinc coated directly on the seed compared to conventional treatments, have shown a marked response, and more dedicated trials are to be implemented in 2014 (Dunn, 2014).

Treatment	Estab.	PI	DM	PI Tillers	PI	PI N
Seeding rate	(No/m ²)	(g/m ²)		(No/m ²)	N%	uptake (kg N/ha)
25 kg/ha	40	552		1006	2.54	140
75 kg/ha	54	572		1051	2.33	132
150 kg/ha	100	711		1183	1.85	130
150 kg/ha (Zn seed)	104	730		1409	2.09	154
300 kg/ha	123	764		1342	1.99	152

Figure 13, Morago trial showing establishment and panicle initiation (PI) results, 2014

By coating rice seed directly with a zinc coating, this trial shows marginally better plant establishment numbers, higher dry matter production, tillers, and nitrogen uptake, suggesting a better potential yield. Trials in cereal varieties also show zinc seed coatings to be beneficial to plant establishment and yields.

During the 2013 season, RRAPL trialled several commercial zinc seed treatments, with a yield increase of 6% documented. Unfortunately yield benefits were not seen across all rice varieties trialled. Further evaluation work will be done this season.

Rice Genetics and Breeding

Traditionally rice research and extension has been carried out by state government departments. Of recent years, Rice Research Australia Pty Ltd (RRAPL), a subsidiary of SunRice, has undertaken rice varietal trials, agronomic research and development in partnership with the NSW Department of Primary Industries under direction from RIRDC. RRAPL also conducts breeding trials, cold tolerance research projects and participates in seed build up programs.

Australian rice varieties have their origins from Californian medium grain type Japonica varieties. Our rice is of high quality and sought after by overseas markets. The industry has a very active and progressive breeding team, reacting to market needs.

Australian rice breeders have been very successful in developing high yielding varieties with good grain quality to suit our climatic conditions. Australian rice varieties have been screened for drought tolerance (or water deficiency stress) for many years. The International Rice Research Institute (IRRI), Philippines, has a huge rice research program. Research of interest has been to develop drought tolerant varieties, focusing on survival, rather than water use efficiency. IRRI is also working to introduce the C4 gene (found in corn) to rice varieties, in the hope of increasing plant metabolism. The advantages of this infusion should result in increased vigour, yield and water efficiencies.

Golden rice, Vitamin A enriched varieties, have been developed, which if released, could be beneficial to many poorer countries. World markets and public attitude towards genetically modified plants will need to be addressed before these types of breeding advances will be accepted and released commercially.

RIRDC have recently funded research into Marker Assisted Selection (MAS) in rice varieties within the breeding program. MAS will assist greatly in selection of desirable traits within

varieties. MAS technology has the potential to decrease the time taken to release new varieties, and could see new varieties developed in half the time now taken.

Hybrids

The Australian industry has no hybrid varieties available at present. Hybrid varieties were developed in the USA by Rice Tec Ltd, which are now grown the world over and have exceptional plant vigour. This vigour has resulted in resistance to plant disease (rice blast), improved cold, heat and drought tolerance. This seed is very expensive, as new seed has to be grown from parent stock every year. Due to the vigour of hybrids and exceptional tillering capacity (up to 40 tillers per plant), sowing rates are very low, usually 30 to 40 kilograms/hectare. Unfortunately, yield and grain quality are traditionally lower than conventional varieties. Hybrids are typically long grain varieties. Uruguay and Italy are producing 12 t/hectare yields, achieving whole grain mill-outs of 60% with hybrid varieties. Australian whole grain mill-outs are comparable. Whole grain mill out is the percentage of whole grain recovered after the milling process, typically 50 to 60% in rice. Rice starts the milling process as brown rice, the outer coating (bran) is removed to produce white rice.

Hybrids have a more vigorous root system than conventional varieties, giving them access to deeper moisture in drought conditions, and better ability to handle pre-emergent herbicides, particularly the pre-emergent herbicide Clomazone®.

Hybrid rice varieties could have a place in the Australian rice industry. To date, hybrid varieties in general have shown lesser grain quality and yield potential than the varieties the Australian industry has developed, but their vigour is a desirable trait that Australian breeders should not ignore. Australian rice varieties have been bred to suit the southern Riverina, and are not particularly suited to other areas of Australia. Hybrids will suit the northern areas of Australia and could be of great benefit in developing a rice industry in the north.

Clearfield®

Clearfield® varieties (resistant to Imidazoline chemicals) are available around the world. These varieties were developed to control native red rice. Red rice is now a problem in many countries but can be effectively controlled in crop with Clearfield® technology.



Figure 14, Clearfield® seed rice in Louisiana

In California, USA, barnyard grass (*Echinochloa* spp) resistance to the chemical Propanol® has been documented and the development of Clearfield® varieties amongst other techniques has assisted its control. Clearfield® varieties tolerate imidazoline chemicals from Group B chemical family. Group B chemicals and crop rotations must be well managed to reduce the risk of herbicide resistance. Most countries have strict protocols applied to the use of Clearfield® varieties and in some areas, the technology is the only commercial option for rice production.

In Australia, the chemical Molinate® is registered for the control of grasses in rice, but due to safety concerns for applicators, the chemical Molinate® is no longer registered for use in rice in many countries. If Molinate® is deregistered in Australia, Clearfield® technology may give another method of controlling barnyard grass.

The main grass weed problem of D/D rice in Australia is barnyard grass, and Clearfield® technology could simplify crop establishment. Clearfield® technology allows rice to be

established without the use of any pre-emergent chemical, and if available in Australia, would open the way to control grass weeds in crop, reducing overall chemical use. Present Australian recommended D/D chemicals can retard emerging rice plants, and are not very effective in drought conditions.

Clearfield® technology is unlikely to be accepted for use in Australia with current production practices, but its mode of action should be kept in reserve in the event grass weeds become resistant to present chemicals. Clearfield® technology has been primarily developed to manage Red Rice which was difficult to control with conventional chemicals. Red rice is not found in Australia. The use of this technology could be considered if resistance to present grass herbicides is identified.

Weed Management

Grass weeds are the main problem encountered in a D/D crop. The main weeds needing control in a D/D rice crop are barnyard grass and silvertop grass (*leptochloa fusc*).

Broadleaf and grass weeds can be sprayed out in preparation for the crop. The wet dry sequences in a D/D rice crop are unfavourable conditions for new germinations of broadleaf weeds, which is a huge cost saving for D/D rice over a conventional crop. The chemical needs of a D/D crop are therefore considerably less than with a conventional crop.

D/D cropping allows for a ground rig to be used to control weeds. Ground spraying, compared to aerial spraying, allows higher water rates to be applied, resulting in better application of chemicals and reducing potential for drift. It also allows for chemicals to be applied at the correct time of day and allows for variable chemical application, or spot spraying weed outbreaks.

Recommended practice in Australia for D/D Rice establishment is to apply a glyphosate treatment immediately before drilling the seed. The crop is flushed, and as the rice plant emerges, a mixed treatment of Paraquat, Clomazone, and Pendamethalin, is applied. The timing of this spray is critical and difficult to achieve. Paraquat will easily remove small barnyard grass plants up to one and a half leaf, but will also severely burn or kill emerging rice plants. The correct timing of sprays can be very difficult to achieve and control of barnyard grass post emergence can be problematical and expensive.

In Australia, Molinate® is registered to control barnyard grass escapes, and is very effective on plants up to three leaves. As Molinate® is no longer registered for use in many countries, the Australian chemical regulator has moved to deregister this chemical, which will put pressure on our remaining chemicals.

Many countries practising D/D establishment have other chemicals at their disposal. Quinclorac is widely used in Uruguay, Italy, and Louisiana, (USA). It is applied independently or can be mixed with other pre-emergent chemicals. Chemical restrictions have been brought about by European Union policy, public pressure and environmental concerns. Many effective chemicals for weed management have had registrations removed. France has only seven chemicals available for use on a rice crop, two of them being insecticides. The only practical option for weed control is cultivation and long periods of flooding. Burning stubbles is banned in many countries, which is another weed control action that is no longer available to those growers.

The Australian rice industry should continue to focus its research on developing weed control strategies and introducing chemicals for residual grass weed control. The introduction of different chemicals and Clearfield® practices from around the world could assist to reduce the number of chemicals growers presently use.

Australian growers need to be very careful in the use of herbicides, to ensure their longevity and effectiveness. Australian growers currently have access to effective chemicals, allowing a rotation of chemicals, and reducing the chance of resistance developing. Growers should actively work to control barnyard grass from all summer crops in an effort to reduce seed build up. A clean seedbed will assist the effectiveness of existing chemicals.

Precision Agriculture

Most Australian growers collect Geographical Information Systems (GIS) data, but rely on service providers to collate information to create variable rate and nitrogen top-dressing maps. Yield maps, cut and fill maps and Normalised Difference Vegetation Index (NDVI) maps are just some of the layers that can be further added to create prescription sowing maps.

Progressive growers in the Australian rice industry have adopted new technologies, such as satellite imagery, global positioning systems and variable rate application of seed and fertiliser. These technologies allow the gathering of crop data, soil types, EM38 soil surveys, and many other types of information with pin point accuracy. EM38 soil mapping measures the apparent electrical conductivity (ECa) of soil. Factors such as soil moisture content, salt levels and soil texture affect the concentration of conductive materials and influence this measure.

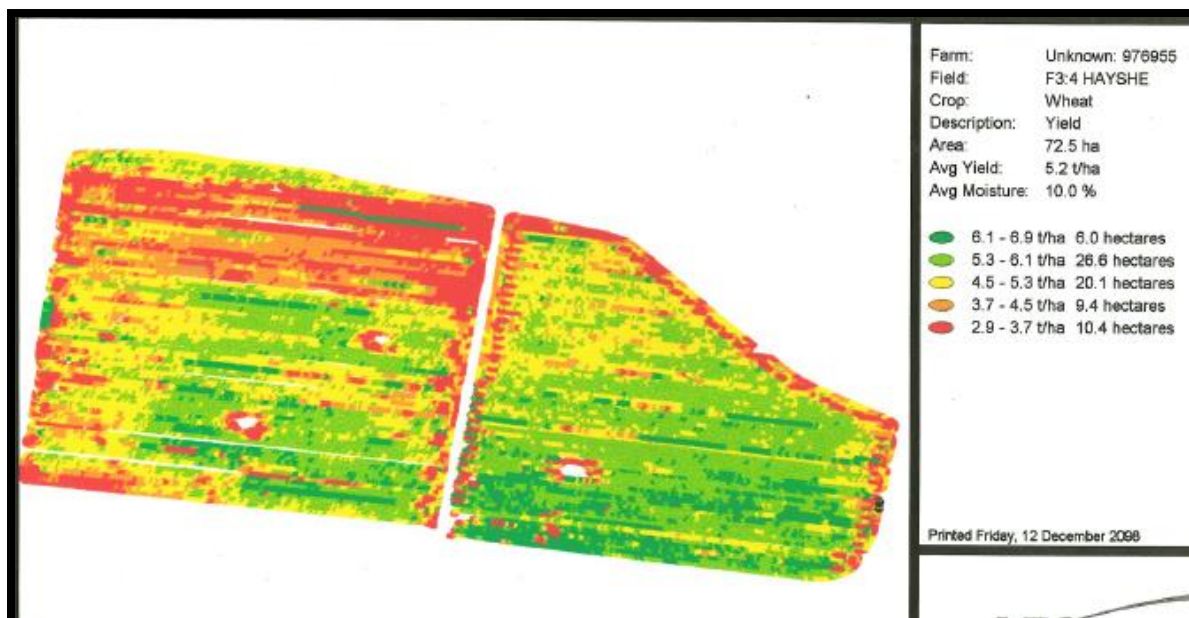


Figure 15. Rice yield map showing variation of yield from 3.7 t/ha to 6.9 t/ha

Computer software collates these layers of data to create a map that is geo referenced, often with 2cm accuracy, of the variations within a paddock. Decisions in regard to crop management can then be made to manage crop inputs.

Interpreting and proofing this data can be problematic, often with no clear direction in managing paddock variations to maximise yields. A rice yield map can show large variations in yield of four to 16 tonnes per hectare within a short distance. It is not understood fully what causes these rapid variations in paddock yields, and the industry continues to research these variations.

In 2012 RIRDC commissioned a four year study with Andrew Whitlock, Precision Agriculture, to conduct research into understanding the yield variability of Australian rice fields. Nine growers selected rice fields for the study and made available data they have collected. Data such as previous yield maps, EM38 soil surveys, soil maps, elevation maps, grid soil samples, Near Infra-Red (NIR) maps, cut and fill maps, have all been compared and analysed for correlations. After two years of project analysis, field levelling and water depth have been identified as factors thought to play a major role in variation of rice yields.

In Italy and California growers concentrate annually on layout preparation and drainage, as it can greatly influence crop establishment, weed control and resulting yields. Growers in Italy commented that a variation in water depth at establishment of 5ml was enough to reduce tiller numbers in rice. This is particularly important to those using hybrid varieties, which are sown at 30 kgs per hectare producing 60 plants per square metre, and requiring 15 to 20 tillers per plant to achieve the desired yields

Satellite Imagery

Satellite Imagery, producing a Normalised Difference Vegetation Index (NDVI) image is used to measure vegetation indexes and gives excellent data. Passing satellites photograph the earth's surface with cameras that measure the reflectance of different vegetation, soil, and water to give an image that can easily show variations in crop density. The variation in crop biomass can be used to forecast yield potential, estimate nitrogen fertiliser requirements and irrigation scheduling for other crops. This technology was previously expensive and could be unreliable due to weather conditions at the time of image capture. This has changed markedly in recent years and images are now readily available with many new satellites in orbit. The

Landsat satellites currently produce an image every eight days and are freely available through Google Earth (Hornbuckle, 2014).

High resolution cameras mounted on aeroplanes are being trialled with encouraging results. Cameras mounted under light planes (or crop dusters) appear to be cost effective, and could be used to measure biomass progressively with every pass of a crop duster plane. Gathering biomass data with successive passes as the crop evolves has proven to provide accurate biomass maps for use in late nitrogen applications.

Drones with high resolution under-mounted cameras are being developed. Drones fly lower and slower than light aircraft and cameras give excellent pixel resolution. The flying systems required to control planes has been simplified to allow the relatively unskilled to operate drones. Google Earth maps are used to locate fields, flight paths are gridded over fields for GPS guidance and once airborne, the drone is computer controlled, minimising the risk of crashing. Unfortunately, drones can be very expensive, won't cover big areas quickly, require operator training, and can have flight restrictions imposed on them. Often data captured by drones is difficult to interpret or convert into a usable map/format. Until these issues are resolved, the average grower cannot afford this technology.

Infra-red imagery

High resolution photographs can be taken to identify crop density and nitrogen uptake. These images are gaining popularity. Using maps or images produced from these photographs or satellite images, crop samples can be taken from 'zones' and analysed using NIR tissue testing to establish the nitrogen content of those zones. Recommendations are then made to growers for nitrogen top dressing of crops within specific zones to achieve target yields.

Infra-red technology has improved the use of NIR crop testing by growers, but unfortunately only 29.5% (Dunn, 2014) of growers in 2011/12 were using NIR testing to assess nitrogen requirements of their crops. Most crop sampling is carried out by service providers, not by growers. The NIR test is a proven way to improve the yield of a crop at PI and is provided

free to growers by the rice industry, yet relatively few growers chose to use the service (Lewin, 2006).

High resolution imagery will develop quickly to form the base of nitrogen application maps for maximising yield potential in the future. New technologies will soon enable the rice industry to develop a cost effective system, capable of measuring and creating zones for the application of nitrogen to crops, maximising yield potential, with minimal input from the grower. This will take the guess work out of assessing crop nutrient requirements, and give some scientific basis for nitrogen applications.

Yara N Tester

Yara is affiliated with a German company developing several technologies allowing nitrogen uptake in crops to be measured. The Yara N Tester is a hand held unit that tests individual leaf samples to measure nitrogen uptake. The technology has been in use for more than 12 years, in cereals grown throughout Europe, and trial work was carried out on rice at IRRI in 2004 (Balasubramanian, 2004).



Figure 16, N Tester sampling rice leaves

The chlorophyll concentration in leaves is measured using the N Tester. The youngest fully developed leaf is illuminated in two wavelength ranges using light that is absorbed in different intensities by the chlorophyll. The remaining transmitted light is captured in a photodiode and converted to a measuring value. A complete crop test can be carried out in minutes.

Presently in Australia, rice growers are not making good use of the industry NIR tissue testing service. This service is provided to growers free of charge and can assess the final nutrient needs of a crop to achieve uniformity or target yields. The NIR system has been well tested and proven. Lack of grower uptake is probably due to the time taken to physically take

samples from a paddock. If samples are collected accurately, it can take several hours per paddock to complete sampling. It then takes four to five days to have samples analysed and receive recommendations. The N Tester can carry out the same function in minutes, giving an instant crop nitrogen assessment.

In conjunction with a NIR crop image, or biomass map identifying crop density zones, the N Tester can immediately assess a crops nitrogen level. Yara have developed charts that can be referenced against the N Tester readout to assess the nutrient requirement for that zone. Further work needs to be carried out to calibrate the N Tester against Australian rice varieties. This type of technology is quick and easy to use compared to the present technology. Further proofing of this technology should be undertaken by the rice industry. The N Tester can be used on a wide range of other crops to assess nitrogen levels instantly.

Yara N Sensor

(Not to be confused with the N Tester).

The Yara N Sensor measures crop density and chlorophyll uptake in plants giving the ability to apply nitrogen by ground application any time ground conditions allow. With direct drilled rice, there are several opportunities to apply Nitrogen with this technology.

Growers growing a conventional rice crop could also use this technology. Mid-season draining has identified yield benefits (Thompson & Griffin, 2006). Water is drained from a crop at late tillering, drying the ground and stressing the plant. Research is presently being carried out on this practice by RAPPL to quantify yield gains, but this drying phase also creates an ideal opportunity to apply nitrogen with the N sensor onto dry soils before re-flooding.

These drying cycles create the opportunity for technologies such as the Yara N Sensor, Green Seeker, Topcon or Ag Leader Opt RX to monitor crop nutrient uptake and apply nitrogen to maximise yields, negating the need for satellite imagery.

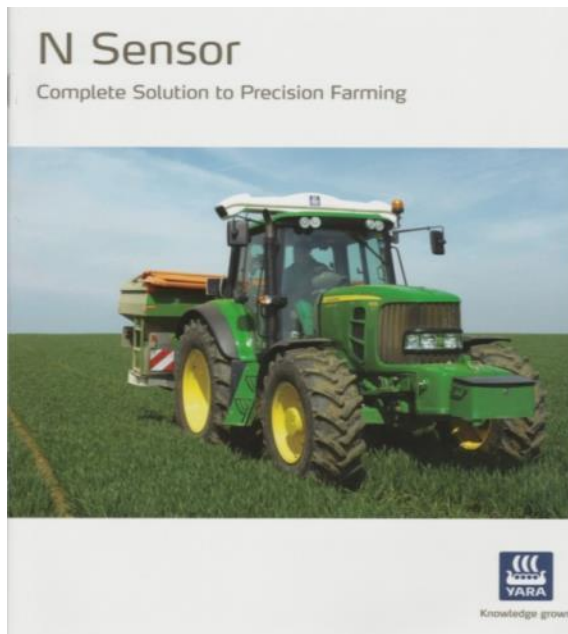


Figure 17, N Sensor, tractor mounted.

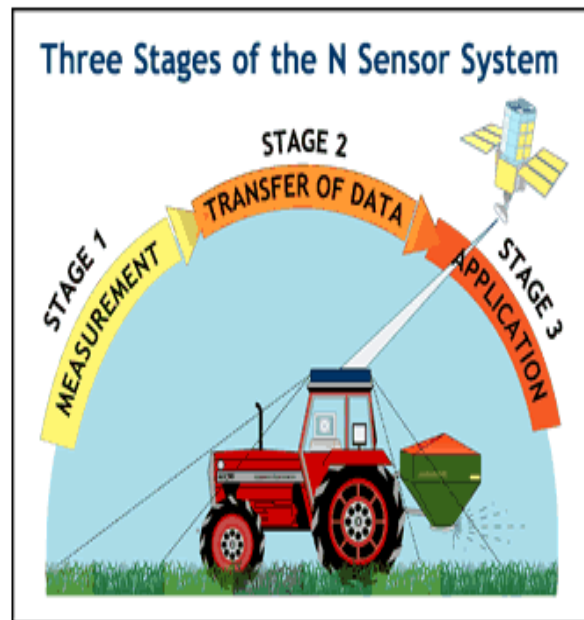


Figure 18, N Sensor delivers instant application rates

Clive Blacker (Nuffield 2004) of Precision Decisions in York, England, provides crop monitoring services to farmers and specialist precision agriculture support. His company provides worldwide support to the N Sensor, and is confident the N Sensor can play a vital part in rice crop nitrogen management. The N Sensor can manage crop density with early applications of nitrogen. Nitrogen is applied to low density areas within a crop to increase biomass, or conversely, heavy biomass areas can be excluded from applications.

The unit can be programmed in a variety of ways to react and apply nitrogen. The unit will create and record three maps: a biomass map, crop nitrogen, and applied nitrogen. Background maps (soil types, EM 38 maps) can be added to determine application rates. These maps may provide another layer data for interpretation in making maps such as variable rate maps.

A pass over the growing crop will calibrate the N Sensor before application, or a target application rate can be used as a basis for application rates. The N Sensor is mounted on the roof of the driven vehicle measuring the crop with four cameras on an oblique angle down over the crop. The crops nitrogen demand is then determined by measuring light reflectance off the passing crop. Light intensity is important, and limits the use of the N Sensor to

daylight hours. A new ALS N Sensor has been developed incorporating a strobe type light, allowing operation twenty four hours per day.

Two types of light are used to measure the crop. Ambient light is reflected off the crop, using a visible red spectra wavelength of light, giving an indication of plant chlorophyll content (colour of the crop). The second is an infrared beam relating to biomass. Using this information, the N Sensor can analyse results in micro seconds sending application rates to the spreader behind. The N Sensor can take measurements from both sides enabling the unit to variable rate applications on each side of a spreader.

The N Sensor has the potential to even out biomass within a paddock, by improving poorer areas, and limiting lodging in heavy biomass areas. Although there are other ways of reading crop density, biomass and fertility, the N Sensor will give an instantaneous application rate, making variable rate application of product much more timely, cost effective and accurate. The unit can be calibrated to many different crop types, and just recently has been calibrated to apply fertilisers to cabbages. The technology can also be fitted to sprayers to apply fungicides and growth regulants.

These Technologies are developing rapidly, particularly in Europe with cereals, but little work has been carried out in Australia to evaluate their effectiveness, or to calibrate these instruments in rice crops. They have the ability, once proven, to maximise the productivity of any crop, and as they can give instant recommendations of a crops nitrogen requirements, Australian farmers may find these units quicker and easier to use than the present NIR rice testing system.

Future Technology

Soil Sensing

In Japan, scientists are working on new technology to assist farmers in the rejuvenation of soils after the 2013 Japanese earthquake and contamination from the failure of a Nuclear power generator. The company Advanced Digital Solutions, and the Tokyo University of Agriculture and Technology, are working together to develop soil sensing technology that can map soil for nineteen different traits.

On-the-go or in situ visible and near infrared (NIR) spectroscopy has been proposed as a rapid and inexpensive tool for intensively mapping several soil parameters and soil texture for site-specific soil management.

Vis-NIR calibration models for nineteen soil parameters based on underground soil reflectance spectra are collected using a mobile real-time soil sensor with a differential global positioning system.



Figure 19, Japanese technology to analyse soil traits

The nineteen soil parameters are: moisture content, soil organic matter, pH, electrical conductivity, cation exchange capacity, total carbon, ammonium nitrogen, hot water extractable nitrogen, nitrate nitrogen, total nitrogen, exchangeable potassium, exchangeable calcium, exchangeable magnesium, boron, copper, manganese, zinc, available phosphorus, and phosphorus absorptive coefficient (Goto, 2014).

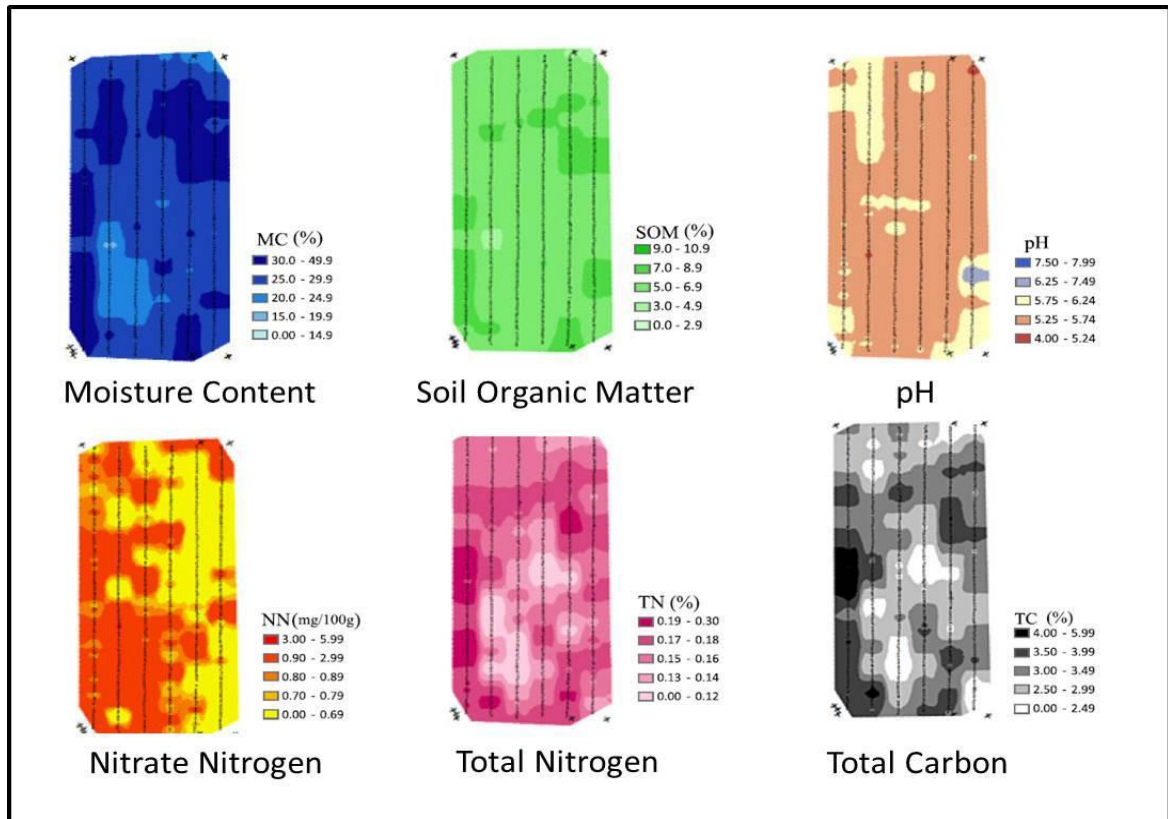


Figure 20, Maps created measuring soil variance by the ADS technology

This new technology has the capacity to identify a huge range of soil parameters in one pass.

Economic Comparison

Direct Drilling Rice compared to Conventional Sowing

Table 1. Average rice grain yield, total water use (including rainfall), water productivity and irrigation water use from four years of experiments at Yanco Agricultural Institute and Leeton Field station (Dunn & Rajinder, 2013)

Sowing/Irrigation practice	Grain Yield (t/ha)	Total water use irrigation + rain (MI/ha)	Water productivity (t/ha)	Irrigation water use (MI/ha)
Aerial	12.1	16.8	0.72	14.9
Conventional Drill	12.1	14.8	0.82	12.9
Difference	0	2	0.1	2

Sowing/Irrigation practice	Grain Yield (t/ha)	Total water use irrigation + rain (MI/ha)	Water productivity (t/ha)	Irrigation water use (MI/ha)
Conventional Drill	12.1	14.8	0.82	12.9
Delayed Permanent Water	11.6	12.2	0.95	10.3
Difference	0.5	2.6	0.13	2.6

The economic comparison (Table 1 & 2) published in the IREC Newsletter (Dunn & Rajinder pal Singh, 2013), clearly demonstrates water and input savings that can be achieved by the implementation of D/D establishment of rice.

Water savings of 2 megaliters/ha were identified, with no loss in yield and clear cost savings. D/D crops established in the last week of September, if clear of grass weeds, can be stressed for long periods until the last week of December, potentially doubling these water savings.

Table 2. Gross margin analysis of aerial, conventional drill and delayed permanent water rice growing practices (Dunn & Rajinder, 2013)

	Aerial		Conventional drill	
Income	12.1 t/ha @ \$300/t	\$/ha	12.1 t/ha @ \$300/t	\$/ha
Total income (A)		3630		3630
<i>Variable costs</i>				
Cultivation	Chisel plough, banks, roll	29	Chisel plough, level, banks	35
Sowing	150kg/ha seed + aerial	95	150kg/ha seed = drill	71
	DAP 100 kg/ha		DAP 100 kg/ha	
Fertiliser & application	Urea @PW ¹ 250kg/ha	316	Urea @PW ¹ 250kg/ha	303
	Urea @PI ² 100kg/ha		Urea @PI ² 100kg/ha	
	Molinate 1.5 L/ha		Glyphosate 1.0 L/ha	
	Tiapan [®] 2.0 L/ha		Paraquat 0.8 L/ha	
Herbicides, insecticides	Saturn [®] 3.75 L/ha	401	Magister [®] 0.4 L/ha	204
& application	Basagran M60 [®] 2.5 L/ha		Stomp [®] 2.5 L/ha	
	Chlorpyrifos 0.15 L/ha		Molinate [®] 3.75 L/ha	
	Dominex Duo 0.1L/ha			
Irrigation	14.9 ML/ha @ \$13/ML	194	12.9 ML/ha @ \$13/ML	168
Harvest	Harvesting @ \$25/t		Harvesting @ \$25/t	
	Cartage @12/t		Cartage @12/t	
Crop insurance and levels	1.73% & \$3/t	63	1.73% & \$3/t	63
Total variable costs (B)		1560		1306
Gross margin/ha (A)-(B)		2070		2324
Gross margin/ML of irrigation water		139		180
¹ PW= permanent water, ² PI= panicle initiation				

A D/D system allows different chemicals and chemical strategies to conventional rice crops, giving growers another mode of action against grass weeds. Broad leaf weeds, damaging insects, and snails will not survive the wet dry rotations, further reducing chemical applications. D/D crops use significantly less chemicals than conventional crops. The chemicals used to grow D/D crops are generic chemicals, and significantly cheaper than those used in conventional crops, resulting in less overall chemicals used, and production cost savings.

The flushing and subsequent stressing of the crop to achieve water savings results in ground conditions drying to the point of cracking, which allows chemical and fertiliser applications to be carried out by ground rig rather than as traditionally by aeroplane, so is a further

significant cost saving. It also allows for greater rates of water to be supplied on target weeds, making chemicals more effective, as aeroplanes are limited in the water rates they can apply with chemicals.

Conclusion

Travel to other rice producing countries highlighted just how progressive the Australian rice industry and its growers are. SunRice is unique in that they control the acquisition, drying, storage, milling, value adding for growers, supplying a quality product to world markets. Our growers are driving precision agriculture and utilizing new techniques at a greater rate than many other countries. Very few countries access so many pieces of the precision agricultural puzzle in the way our industry does.

Direct drilling of rice was practised in most countries visited. Soil types, climate, community pressure and small land holdings are the main reason this method was adopted. Only 25% of Australian rice farmers currently use this method of establishment. Ten years ago, virtually no Australian farmers used this technique. The need to increase water-use efficiencies will drive Australian farmers to adopt direct drill techniques in the future.

While travelling, it was observed that attention to detail, along with adoption of precision agriculture practices, was a common theme of success for farmers around the world. In Australia, precision agriculture has enabled industry yields to approach an 11 tonne average per hectare. Precision agriculture will continue to develop rapidly. Measurement of biomass on a daily basis will soon be possible. The application of nutrients with sub-metre accuracy is already upon us and mapping soils will take on a new dimension as sensors capable of measuring multiple elements within our soils help us to unravel its limiting factors. Yield maps show Australian crops are approaching theoretical yield potential of present varieties in areas, but cannot be achieved uniformly across a crop. It will be difficult to advance average yields further until growers and researchers address the limiting factors within a paddock to make further yield gains.

Cover cropping is an interesting concept. The advantages of weed suppression and moisture conservation are benefits of cover cropping that could assist the establishment of rice crops and minimise chemical usage.

Yield maps from rice crops show huge variations, much more than other irrigated crops. The cause of these variations is largely soil related, but research is identifying many other complex factors. No single aspect has the potential to increase yield, quality or profitability on its own, rather it will be a combination of agronomic factors. Developing further key Ricecheck drivers for direct drilling of rice will assist in maximising results.

It is quite evident from recent travels that nowhere in the world do farmers use precision technology to the same degree as Australian growers. Attention to detail, the adoption of precision agricultural techniques, and the ability to challenge normal production techniques are a common theme of farmers around the world, producing top crop yields

Many of the concepts described above can be used to further the potential of direct drill rice as a viable system for irrigators in Australia. This technique already offers substantial savings of water, chemical inputs and machinery costs. The addition of cover cropping, and further precision agriculture technologies to this system has the potential to increase productivity, lower input costs further and reduce variability in yield.

As Australian rice growers continue to face water availability restrictions it is timely for the rice industry to further improve water use efficiencies and practices. The rice industry needs to investigate all avenues of growing more rice with less water.

Recommendations

- Every effort must be taken by breeders to improve plant vigour and drought tolerance in new variety releases.
- The Industry should continue to focus on methods to reduce total crop water use and increase water use efficiency per kilogram of production. Growers should be encouraged to show productivity as “kilograms produced per megalitre”, to highlight crop water use efficiency.
- Hybrid varieties have increased vigour, with potential to increase yield and water use efficiency. Varieties could well be suited to the northern areas of Australia, allowing the industry quickly expand its growing area. They should be more thoroughly evaluated for the Australian industry.
- Clearfield technology should be evaluated for use in the Australian industry as a backup mode of defence. In the event of grass weed resistance to present chemicals and practices, Clearfield technology, under strict management protocols, could provide an alternative action for grass weed control in all rice systems.
- The chemical Quinclorac warrants further evaluation in an effort to provide another mode of action against grass weeds in D/D rice.
- The Ricecheck booklet should be further updated to discuss methods of Direct Drill establishment of rice in more detail. Key checks should be developed to aid the establishment of rice and specific weed control systems.
- Cover crop rotations and sowing methods should be further evaluated for D/D rice establishment.
- Growers need to be educated in ways of increasing the organic content of their soils to assist in crop establishment, retention of moisture and availability of nutrients.

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Plain English Compendium Summary

Project Title:	Improving Rice Water-use Efficiency
Nuffield Australia Project No.:	1310
Scholar:	Peter Kaylock
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Objectives	To highlight the importance of establishing rice with direct drill systems and its associated benefits to producers in improving rice water use efficiency.
Background	The Australian rice industry is under pressure to increase its production with a limited water resource. Growers need to produce more with less water and other inputs. The establishment of rice using direct drilling techniques can reduce water use of a crop and increase water use efficiency and profitability.
Research	The research aims were to: <ol style="list-style-type: none">1. Visit countries establishing rice using direct drill systems and evaluate their methodology and productivity.2. Assess where the Australian Industry can improve its grower support for direct drill systems and the likely gains to be made.3. Research new precision agriculture technology and its implications to improve grower productivity.
Outcomes	Australian growers are already maxing rice variety yields in areas of their crops. Further gains to increase yields will have to come from attention to detail, further application of precision agriculture, a change in establishment techniques, and of course progress in plant breeding. Seed dressings and other chemical herbicides could be available to the industry, but need to be approved and registered by the industry for use.
Implications	Australia's water resource will continue to come under further pressure requiring producers of agricultural products to show greater water use efficiency. Therefore production systems that can demonstrate lower water use with no yield penalties will have to be considered, and direct-drilling farming systems can meet those criteria.
Publications	