Department of Primary Industries

Rice growing guide

2nd edition

NSW DPI MANAGEMENT GUIDE

Compiler: Rachelle Ward

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Department of Primary Industries

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2nd edition

Rachelle Ward, Compiling Editor
Cereal Chemist, NSW DPI, Yanco

Contributors

Harriet Brickhill
Extension Officer (Murrumbidgee),
Ricegrowers' Association

Neil Bull
Environmental Projects Manager
Ricegrowers' Association

Brian Dunn
Research Agronomist,
NSW DPI, Yanco

Tina Dunn
Technical Officer
NSW DPI, Yanco

John Fowler
Senior Land Services Officer
Murray Local Land Services

Josh Hart
Research Officer
NSW DPI

Troy Mauger
Rice Extension Officer
Murray Ricegrowers' Association

Sam North
Research Hydrologist,
NSW DPI, Deniliquin

Prakash Oli
Cereal Chemist
NSW DPI, Yanco

Thane Pringle
Independent Precision Ag

Chris Proud
Post Doctoral Research Fellow
University of Queensland

Adrian Smith
Senior Land Services Officer
Murray Local Land Services

Peter Snell
Rice Breeder
NSW DPI, Yanco

Mark Stevens
Principal Research Scientist
DPI, Yanco

Malcolm Taylor
Weed Specialist
Agropraisals Pty Ltd, Vic

David Troldahl
Research and Development Agronomist,
NSW DPI, Yanco

Andrew Watson
Plant Pathologist

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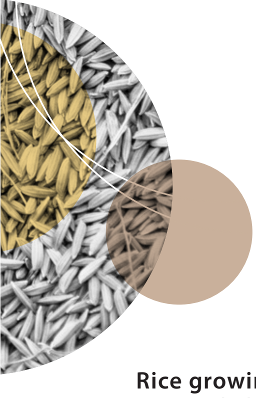
Cover
Main image: Flush irrigation (Tina Dunn); Inset L–R: Applying nitrogen (Brian Dunn); Rice in head (Tina Dunn); Bowl of cooked rice (free image).



Contents

Tables

Figures

Figures ... continued

Resources

DPI Rice growing resources (https://www.dpi.nsw.gov.au/agriculture/ broadacre-crops/summer-crops)

DPI Primefact *Factors to consider when draining rice* (https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/summer-crops/rice/factors-to-consider-when-draining-rice)

DPI Primefact *Rice water depth management at microspore* (https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/summer-crops/rice/water-depth)

DPI Primefact *Rice variety guide 2021–22* (https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/summer-crops/rice-development-guides/rice-variety-guide-202122)

DPI *Rice crop protection guide 2021–22* (https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/summer-crops/rice-development-guides/rice-crop-protection-guide)

DPI *Rice field guide to pests, diseases and weeds in southern NSW* (https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/summer-crops/rice-development-guides/field-guide)

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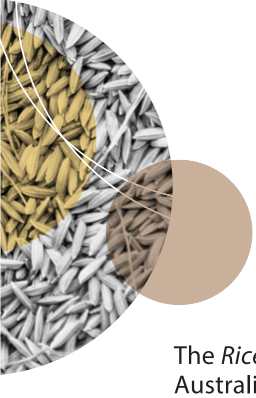


Rice growing guide

The *Rice growing guide* is produced to support growers to successfully produce high quality Australian rice. More detailed information can be found in DPI Primefacts and guides, talking to researchers at pre-season meetings and field days, as well as your local agronomist.

Good planning

To consistently produce high yielding, high quality and profitable rice, growers depend on forward planning and a high level of management in all aspects of operating the rice farm system. How other crops and pastures in rice rotations perform will affect decisions around how the rice crop is managed and the eventual yield.

Good crop establishment

Successful and timely crop establishment are essential for achieving high rice grain yields and quality. Sowing at the recommended time using practices that optimise plant populations and crop uniformity, minimise potential for cold stress at microspore, and deliver high grain quality at harvest.

Minimise pest and disease

Knowing how to prevent, recognise and treat pests and diseases is essential to minimise on-farm risk from crop damage.

Water management

Calculate your rice crop water use requirements before sowing. Historic water use for the specific paddock is the best way to estimate rice crop water requirements. Alternatively, estimating the amount of water that your rice crop might use can be done using historic average evapotranspiration data to provide a water budget for the whole crop after fill up. Water required for fill up or first flush varies significantly, with less needed following a wet winter.

Use soil of low permeability for rice growing to minimise deep drainage and prevent excess water use. Total water use will vary with the season depending on temperature and wind, but should normally be below 14–16 ML/ha. Crop profitability will be affected if water use is high. Some irrigation authorities determine suitable levels of rice water use each year. Irrigation authorities may also determine whether land is suitable for rice growing. Soil texture inferred from EM31 measurements and soil sodicity are the main tests for assessing rice land suitability.

Superior quality grains

By adopting the recommended management practices, the quality can be maintained to premium levels to fetch a good price and hence contribute to the overall equation of profitability. Producing grain with excellent whole grain yield, superior grain colour, less chalk, and excellent cooking quality will make Australian rice a competitive and niche commodity in the markets.

Maximise yield

Table 1 shows the five-year rolling average yields for current commercial varieties. There were higher yields in the Murrumbidgee Valley than in the Murray Valley due to higher minimum temperatures.

The five-year average yield of the top 20% of farms demonstrates the yields growers can achieve using current technology and adopting the best management practices outlined in this guide.

Table 1. Summary of rice yields (t/ha) 2020–21 season compared with five–year averages by region.

	REGION									
	MIA		CIA		EMV		WMV		All regions	
VARIETY	2017–21 avg	2021	2017–21 avg	2021	2017–21 avg	2021	2017–21 avg	2021	2017–21 avg	2021
Reiziq	11.4	11.4	9.1	8.0	9.2	8.4	9.6	8.8	10.4	9.9
Sherpa	–	–	–	–	10.4	10.3	10.1	10.8	10.2	10.5
V071	13.9*	13.9	–	–	11.1*	11.1	13.0*	13.0	12.6*	12.6
Viand	9.5	9.1	8.8	7.7	7.4	5.4	5.8	7.9	8.6	7.6
Opus	–	–	–	–	10.1	9.8	10.1	–	10.1	9.8
Langi	9.1	9.2	8.8	10.0	–	–	–	–	9.0	9.2
Topaz	9.1	8.3	7.9	6.9	–	–	–	–	8.8	8.2
Doongara	11.5	11.0	9.1	6.6	–	–	–	–	11.1	10.3
Koshihikari	–	–	–	–	7.5	7.8	7.1	8.8	7.4	8.1
All varieties	**10.8**	**10.9**	**9.0**	**7.9**	**9.5**	**8.3**	**9.6**	**8.9**	**10.0**	**9.7**

* <4 years of commercial data

MIA Murrumbidgee Irrigation Area
CIA Coleambally Irrigation Area
EMV Eastern Murray Valley
WMV Western Murray Valley

Whole farm plan

Use a whole farm plan to design a farm layout so it meets the goals of the farm. Spending time on planning will ensure the irrigation layout incorporates the farm's major resources (soils, water supply level and flow rates, infrastructure, access) and helps deliver a farm that meets future plans. **To maximise cropping flexibility and minimise production losses (for drill sown rice and crops grown in rotation with rice), it is important that bays can be watered and drained within 10 hours.** Drainage is as important as supply in ensuring irrigation water can be on and off bays within this time. Drainage, recycling and storage are essential for maximising water efficiency.

Field layout

Common layouts for irrigated rice bays include a) basic rice layout, b) a full contour layout and c) bankless channel layout (Figure 1.) Basic layouts are low cost but drainage is slow. Full contour layouts have improved supply and drainage compared with basic layouts, but are more expensive to develop. The bankless channel layout has a lower number of structures and can have good supply and drainage for rice, but does not allow water to be supplied individually to each bay and this can create drainage problems on grades flatter than 1:1500. Structures that allow water circulation through bays have yield benefits in large bays or where lower quality water is used.

Supply channels and flow rates

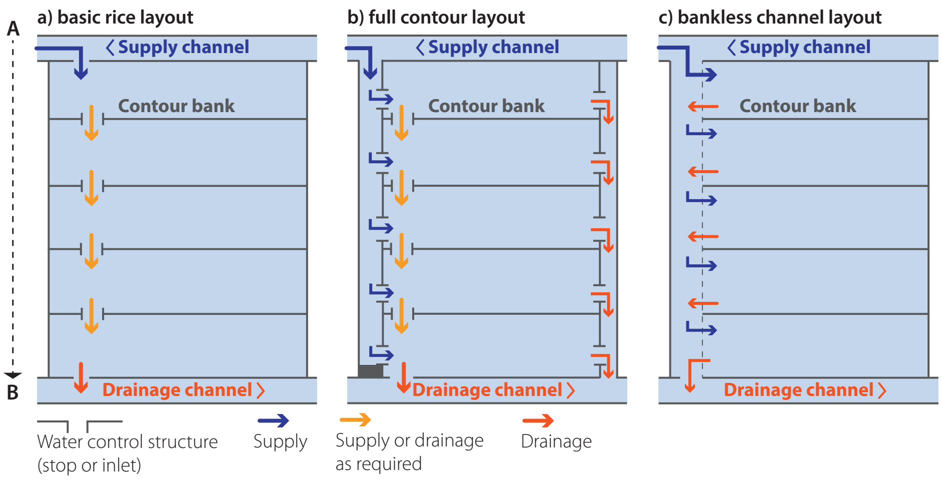


Figure 1. Common rice layouts: a) basic rice layout, b) full contour layout, c) bankless channel layout. The direction of slope for all diagrams is from point A to point B.

A minimum water depth of 25–30 cm is required at microspore to minimise the risk of cold-induced sterility. The operating level in the channel supplying the field should be at least 30–35 cm above the highest point in the layout to achieve this depth of water.

For quick fill up of mid season drained crops, or for flushing drill sown crops, it is recommended that bays be either individually supplied from a channel, or supplied by a side-ditch with a minimum terrace of 10 cm between bays.

To deliver this flow rate to the crop, it is important that channels and structures are correctly sized, installed and well-maintained.

Field drainage

Quick field drainage is critical for drill sown crops and for crops grown in rotation with rice. Drainage rates are determined by the size of structures (i.e. stops or pipes), the slope or field grade (or terrace step), distance to a discharge point, the 'roughness' of the field surface and the cleanliness of field drains (toe furrows or side-ditch).

KEEP YOURSELF SAFE

Agriculture is one of the most dangerous industries due to the range and combination of work hazards. Ensure everyone working on the farm is properly educated on farm risks and trained in farm operations such as chemical use and machinery operation.

Contact Tocal College (https://www.tocal.nsw.edu.au/courses/short-courses)

To flow at their design capacity:

1. Stops need to be installed so the bottom of the stop is level or slightly below the level of the field drain (i.e. the side-ditch and/or toe furrow).
2. Pipes need to be installed so they flow full.
   Toe furrows need to be weed-free and connected to a discharge point (structure or side-ditch).

For quick flushing of drill sown crops, it is best to also drain bays on the opposite side of the field to the supply channel.

For uniform dry-down and trafficability of fields at harvest, it is important to ensure all water can be drained off the bay surface. This is achieved by having a good field layout with a landformed, even grade and unobstructed drains.

All fields should be connected to a drainage recycling system. This will maximise irrigation efficiency and prevent pesticide or nutrient residues entering regional drains. They should be of sufficient size to capture excess water from rainfall or water drained off bays, e.g. to alleviate establishment problems.

Re-grading

Level fields are important for uniform rice establishment and growth. Invest in regular field levelling as variable water depth can dramatically impact rice production and water use efficiency.

Field grade

Types of field grade are shown in Figure 2. **To ensure good establishment and weed control in aerial sown crops, the height difference between the highest and lowest points of a bay should not be more than 5 cm**. The recommended field grade across bays is 1:1000–1:2000 and there should be no slope down the length of bays. Drainage problems can be expected where slopes within bays are flatter than 1:1500.

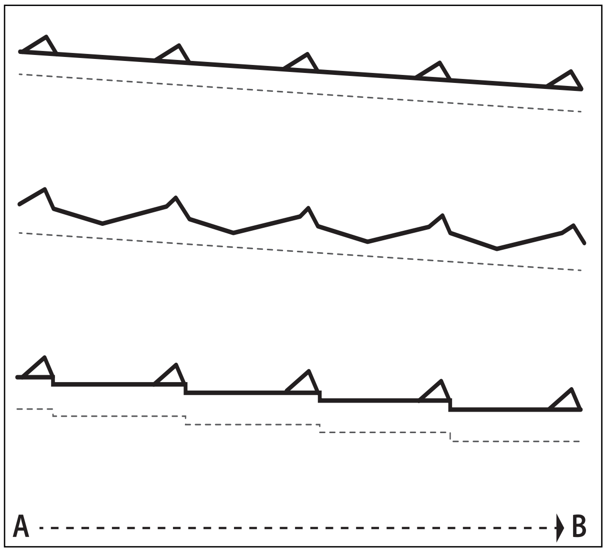


Figure 2. Types of field grade: contour (top), V-bay (middle), terraced (bottom). Point A to point B is the direction of slope and is the cross section of Figure 1.

Flat bays allow very good water depth control for aerial sown rice. However, complete drainage is not possible and this presents challenges for drill sown rice, as water lying in hollows following flush irrigations can kill seedlings and affect weed control.

Drainage and dry-down for trafficability at harvest can also be compromised, particularly following rainfall. Beds are recommended in flat bays for drill sown crops, and other crops in the rotation. Beds allow crop flexibility and reduces waterlogging in winter crops and other summer crops. A terrace of 10 cm is needed between flat bays.

V-bays allow a greater slope (e.g. 1:1500) to be created within bays on naturally flat fields (Figure 3, page 4). Compared with contour bays of the same width, V-bays can also have a smaller height difference between the high and low points of the bay, allowing for a more even water level. V-bay layouts also reduce the total volume of water required to 'fill' the bay.

Landforming to the plane of best fit will minimise the soil volume needed to be moved. To prepare for landforming, perform an electromagnetic (EM) survey to identify leaky areas so they can be excluded from the field. If the survey and design of field heights identifies areas where the depth of cut leaves less than 7.5 cm of topsoil after landforming, these areas should be under-cut and top-soiled to provide a minimum 7.5 cm of top-soil.

Where possible, landforming works should occur at least three months before sowing any crop to allow settling and a further grading, and preferably 12 months before sowing a rice crop. Ideally, a winter cereal should be grown in a newly landformed field before any rice. This allows the surface soil to consolidate, reduces the impact of muddy water, provides better anchorage for establishing seedlings, and allows any needed soil ameliorants to be applied before rice sowing.

Figure 3. V-bays create slope on flat fields and allow for more even water level than contoured fields. Photo: Ricegrowers' Association.

Field banks

Rice field banks should be a minimum of 40 cm high at their lowest point. Higher perimeter banks (up to 60 cm) or removing the toe furrow on the outside of the field might be needed if soils are prone to leaking or cracking through.

New banks need to be constructed at least three months before sowing and, on heavily cracking soils, up to six months. New banks should be wetted up slowly. To prevent leakages and washouts, the optimum bank angle is 30^{0}, especially on sodic soils (Figure 4).

This angle prevents lateral seepage from the outside wall of the bank. In heavily cracking soils, banks might be more stable and less prone to washouts and leaking if they are constructed with only one wide toe furrow on the low side of each bay. Permanent crossovers are recommended to ensure good access to bays. These should not interrupt drainage.

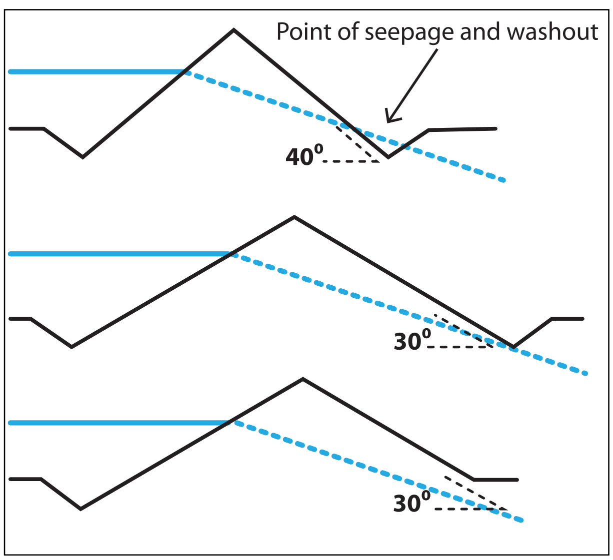


Figure 4. Options for banks: An angle of greater than 30^{0} may washout (top), seepage contained in a bank with a 30^{0} angle, seepage contained in a bank with a 30^{0} and no toe furrow on the outside.

Water control structures

For maximum irrigation application efficiency and cropping flexibility and productivity, the flow rate into a bay (in ML) should be at least four times the bay size (in hectares). For example, the flow rate into a 4 ha bay should be at least 16 ML/day. Water control structures (pipes and stops) must be designed and installed so they can deliver this flow rate.

To flow at their design capacity:

1. Stops need to be installed so the bottom of the stop is level or slightly below the level of the field drain (i.e. the side-ditch and/or toe furrow).
2. Pipes need to be installed so they flow full.

Structures need to be designed and installed so they are capable of holding 30 cm of water above the bay at microspore.

Bay to bay outlets located at both ends of the contour bank maximise the drainage rate and help water circulation, but require extra labour to operate.

Water control structures need to be sediment- and weed-free to maximise flow rates (figures 5 and 6, below).

Figure 5. Water control structures need to be weed free and designed so that they can deliver the flow rate required to fill the bay. Photo: Ricegrowers' Association.

Figure 6. Water control structures need to be weed free and designed so that they can deliver the flow rate required to fill the bay.

Bay size and shape

Bay size is determined by the available flow rate (size in ha = ¼ flow rate in ML). For quick filling and drainage, a bay length of 300 m is recommended. Ideally, bays should not be longer than 450 m and bays longer than 600 m will be very slow to fill and drain.

The optimal bay size is 4–6 ha. Large bays are prone to the effects of wind on crop establishment (mainly through dislodging emerging seedlings), erosion of banks, and poorer water depth control within a bay (prevailing wind can 'push' water up one end of the bay, resulting in deeper water at one end of the bay, and in some cases leaving exposed soil at the other, which can result in poor weed control).

Small and irregular bays can result in significant loss of actual growing area to banks and are inefficient for machinery operation (figures 7 and 8).

Figure 7. Easier water management and more efficient operation is achieved with square bays compared with traditional contour bays. Photos: Ricegrowers' Association.

Figure 8. Easier water management and more efficient operation is achieved with square bays compared with traditional contour bays. Photos: Ricegrowers' Association..

Burning rice stubble

Burning stubble is an important tool to enable the establishment of the next crop in the rice farming system. However, it is important that all farmers implement best practice when burning stubble to avoid third party impacts from stubble smoke.

The two most important considerations when burning rice stubble are:

1. The moisture content of the stubble; rice stubble must be dry when burnt. Mulching and other machinery operations can reduce the dry down time required.
2. The prevailing weather conditions: as most rice stubble is burnt in the period from mid-autumn to early spring there can be many days that are not suitable for burning; the forecast mixing height must be above 1500 metres during the burn and the wind direction should direct smoke away from towns and workplaces.

The Ricegrowers' Association (RGA) has developed the Stubble Burning App that provides the appropriate weather forecast data (available for phones and tablets free from the App stores). The forecasts are also available from the BOM Meteye web site.

The complete details of stubble burning best practice guidelines can be found on the RGA website.

Best practice stubble burning involves:

1. Contacting the RFS to notify them of your intention to burn.
2. Contacting your neighbours.
3. Ensuring adequate fire breaks are in place to avoid fire escapes and protect paddock trees.
4. Having fire-fighting equipment on site.
5. Being prepared to sow or cultivate the paddock as soon as possible after burning. This will minimise the risk of soot and ash being blown into neighbouring houses or places of work.
6. Burning as close as possible to the middle of the day so that burning can be completed before early evening when an inversion layer (low mixing height) is likely. The recommended burning window is between noon and 4 pm.
7. Checking the 'mixing height' information in the MetEye section of the of the Bureau of Meteorology's website . This provides excellent information on current and predicted burning conditions including wind speed and direction.
8. Burning dry stubble; mulching and leaving to dry for at least four days in warm conditions will create a cleaner burn and reduce the volume of smoke. If stubble is not mulched the drying time will be longer and burning should be delayed accordingly.
9. Avoiding burning when winds are variable i.e. when winds are gusting and varying in direction. Wind speeds of 5–25 km/hr are best. Strong winds can lead to fire escaping.

10 Avoiding burning when the wind direction is towards towns or other residential areas. This will reduce the chance of affecting others, including the likelihood of human respiratory problems.

If the wind direction changes sending smoke over roads call 000 immediately. They will refer the call to the local authorities who will advise of what action to take.

Adapted from Ricegrowers' Association.

GO TO PAGES

Details of stubble burning best practice guidelines (https://www.rga.org.au/common/Uploaded%20files/RGA/Publications%20and%20Factsheets/Stubble-Burning-in-Autumn.pdf)

BOM Meteye (http://www.bom.gov.au/australia/meteye/?ref=ftr)

Crop establishment

Successful and timely crop establishment are essential for achieving high rice grain yields and quality.

Sowing time

Sowing during the recommended window for each variety allows optimum plant growth and development and increases the probability of consistently achieving a high grain yield. Benefits of sowing on time include:

- Establishment occurs during a period of favourable temperatures for germination and seedling survival.
- The critical reproductive growth stage (microspore) should occur from 15 January to 5 February when temperatures are most favourable and there is less risk of low (<17 °C) night temperatures. Microspore is normally 16–18 days after panicle initiation (PI) but will be quicker in hot weather and slower in cold weather. The crop can still suffer cold damage in about three years out of 10, even if microspore occurs in this favourable period. Therefore, spread the risk by having multiple sowing dates in the recommended window to enable staggered microspore timings.
- Grain ripening, maturity and moisture dry down for harvest occur when 'milder' autumn temperatures are more likely which favour grain quality.

Ideal sowing time

Sowing within the recommended window allows fast, uniform crop establishment, the highest probability of limited cold stress at microspore, and high grain quality at harvest.

The sowing windows are based on each variety's performance over previous seasons and long-term average temperatures (Table 2). Sowing before the recommended window can increase cold risk as much as sowing later than recommended.

The longer a crop grows before permanent water is applied, the slower the crop's development. It is important that crops planned for delayed permanent water management are sown earlier than conventional drill crops to account for this delay in development. Aerial sown and dry broadcast crops that are flooded for most of their growth should be sown last as they develop the fastest.

Table 2. Recommended sowing/first flush dates for rice varieties, regions and sowing methods.

Variety	MIA/CIA – Ideal sow/first flush time			Murray Valley – Ideal sow/first flush time		
	Aerial / dry broadcast	Drill	Delayed permanent water	Aerial/dry broadcast	Drill	Delayed permanent water
Reiziq, Opus, Topaz, V071	25 Oct–5 Nov	15–31 Oct	5–25 Oct	20–31 Oct	10–25 Oct	1–20 Oct
Sherpa, Langi	25 Oct–10 Nov	20 Oct–5 Nov	10–30 Oct	20 Oct–5 Nov	15–30 Oct	5–25 Oct
Koshihikari, Illabong	20 Oct–5 Nov	10–25 Oct	1–15 Oct	15–31 Oct#	5–25 Oct	1–15 Oct
Viand	10–25 Nov	5–20 Nov	25 Oct–10 Nov	5–20 Nov	1–15 Nov	20 Oct– 5 Nov

Do not aerial sow or dry broadcast Koshihikari as this will increase lodging potential.

Figure 9. Aerial sown rice.

Figure 10. Drill sown rice. Photo: Vince Bucello.

Ground preparation and management

Aerial sowing and dry broadcasting

For aerially sown and dry broadcast crops leave the soil cloddy, spray with a knockdown herbicide, sow fertiliser and then ridge roll to knock down clods to obtain even water coverage. If the soil is too fine, it will melt, covering the seed and possibly create muddy water. Ridge rolling creates grooves in which the seedlings can anchor and prevents clods from protruding out of shallow water.

When dry broadcasting, flush the field after spreading the seed and allow it to partially dry before permanent water is applied. If filled immediately with permanent water, the seed might be covered with soil restricting its access to the oxygen needed to germinate. This is especially a problem if the topsoil is sodic. Dry broadcasting without flushing increases the risk of poor plant establishment.

Drill sowing

When drill sowing, a firm seedbed is desirable as it is more likely to crack along the drill rows after sowing, enabling better emergence through crusting soils. Best practice is to cultivate and grader board the field in the autumn before sowing to allow time for the soil to settle, ensuring a firm seedbed. Weeds should be controlled using herbicides over the winter and a knockdown herbicide should be used pre-sowing to improve control of any early germinating barnyard grass plants.

Recommended sowing rate

Rice growers should aim to achieve plant populations between 100 plants/m^2 and 200 plants/m^2 (Table 3). Research shows that plant populations between 40 plants/m^2 and 400 plants/m^2 achieve similar grain yields. To compensate for low plant density, rice plants increase tillering and the number of grains per panicle.

Table 3. Sowing rates (kg/ha) required to meet plant population recommendations based on seed size and establishment vigour.

Variety	Sowing rate (kg/ha)
Reiziq, V071 & Topaz	140
Sherpa, Langi, Viand	125
Opus, Koshihikari & Doongara	110

Rice should not be sown at rates higher than 140 kg/ha for any variety or sowing method. To establish 200 plants/m^2 at a 45% establishment percentage requires a maximum sowing rate of 140 kg/ha for Reiziq⦹, the industry's largest seed variety. If establishment is as low as 25% there should still be at least 100 plants/m^2 established, which is sufficient to achieve maximum grain yield. Lodging is increased by high plant populations in varieties with a high lodging potential. Increasing sowing rates to compensate for poor field layout, unsatisfactory seedbed preparation or unreliable sowing method is rarely successful and not recommended.

Research has shown that lodging is increased by high plant populations in varieties with a high lodging potential.

Sowing rates may be decreased by 15–20% in reliable establishment conditions without compromising yield. Increasing sowing rates to compensate for poor field layout, unsatisfactory seedbed preparation or unreliable sowing method is rarely successful and not recommended.

Yield potential can be reduced if plant numbers are less than 40 plants/m^2 (Table 4, Figure 11). Plant numbers below 40 plants/m^2 can still achieve high grain yields (up to 12 t/ha in recent trials), but it is important that the plants are uniformly spaced. Any large gaps between plants can lead to reduced yield. A minimum plant population of 10 plants/m^2 is required to achieve sufficient grain yield to continue with the crop, provided the plants are uniformly distributed.

Table 4. Plant population and the chance of high grain yield.

Population (plants per m^2)	Chance of high grain yield
100-300	Excellent with good management
40-100	Good with good management
Under 40	High yields can be achieved if uniform. Consider re-sowing if establishment is patchy.
Under 10	Re-sow when establishment is below this level

Figure 11. High yields can be achieved from plant populations below 40 plants/m^2, provided establishment is uniform.

Drill sowing seed placement

Uniform seed depth is important as it is difficult to controls weeds and manage irrigation timings when seeds are sown at variable depths and emerge at different times. For most soil types, seed should be sown at 25–30 mm depth. If sown too shallow, the soil around the seed dries quickly and the field will need additional flush irrigations for successful establishment, making it difficult to apply the crucial three-way mix herbicide treatment (Figure 12).

On crusting soils, the seed might need to be sown 40 mm deep in order to be below the dry crust layer. It is not recommended to sow deeper than 50 mm as it will be difficult for the seedlings to push through the soil and emerge.

Row spacing when drill sowing

Row spacing between 18 and 27 cm is recommended for drill sown rice (Figure 13). Grain yield is reduced when rows are spaced wider than 27 cm as missing rows, or gaps within rows, cannot be compensated for by neighboring plants, reducing yield. Wide row spacings restrict canopy closure, which can allow grass and aquatic weeds to germinate late once chemical control periods have been exceeded.

Figure 12. Drill sown rice receiving a flush irrigation.

Figure 13. Rice drill sown at 30 cm row spacing takes a long time to reach full canopy closure and does not compete well with weeds.

Aerial sowing seed preparation

When aerial sowing, it is recommended to use pre-germinated seed as it greatly increases the reliability of good establishment. The recommended method for pre-germinating rice seed is to soak the seed in water for 24 hours then remove the water and store the grain for 24–48 hours (drain or 'sweating' period). The rice grain normally takes at least 18 hours to fully imbibe water, so don't reduce the soaking period to less than 18 hours if attempting to shorten the pre-germinating period. Temperatures above 35 °C when rice is aerating after soaking in soaker silos or trucks, can severely reduce its germination rate.

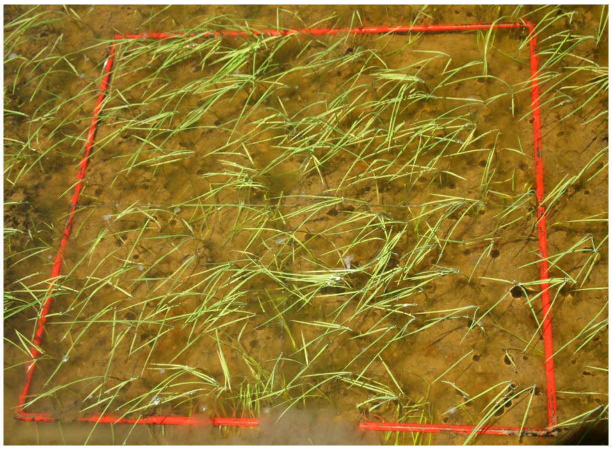


Figure 14. Excellent establishment of aerial sown rice.

Crop establishment

Muddy water when aerial sowing

Good crop establishment is difficult to achieve when aerial sowing on dispersive (sodic) soils because of excessive muddy water (i.e. visibility <3–4 cm). Maintain soil structure by delaying cultivation and plough-in dry plant residue at the end of winter. Although excessive vegetation can decrease establishment, some residue can reduce slaking and dispersion. It is essential to have shallow water during establishment and some crop areas might need to be drained as the muddy water temperature can be 5–8 °C below that of clear water.

Broadcasting gypsum at 1.0–1.5 t/ha immediately before filling up (with water) reduces muddy water. Use the higher rate on extreme muddy water problem sites such as the central Deniboota and Wakool Irrigation Districts. The gypsum purity is important, and coarse particle size is preferred. The aim is to keep the dissolved gypsum in the water column and not wash it into the soil where it can increase deep drainage through the soil profile.

Re-sowing aerially established rice

If you do need to re-sow an area, then it needs to be actively managed as just flying extra seed into the area is not likely to be successful due to low oxygen levels at the soil surface. The area needs to be drained and the soil surface dried out either before or immediately after re-sowing.

Draining before re-sowing: This is probably the most common technique as it is less prone to seed predation by birds. Drain the area until the soil surface is dry, re-flood with fresh water and re-sow immediately. It is preferable that the reintroduced water comes directly from the supply channel rather than from the bay above. Sowing must not be delayed as the area will lose the oxygen far quicker than it did with the original flooding.

Draining after re-sowing: This can be used when birds are not a problem. Sow the seed into the weak area and then drain the water off within 2–3 days. Leave the water off until the soil surface begins to dry. It is preferable that the reintroduced fresh water comes directly from the supply channel rather than from the bay above. This technique, however, leaves the fresh seed exposed to birds and large flocks of galahs or ducks will clean it out very quickly. This is the main reason this technique is not very common.

Reducing cold damage

Cold-induced floret sterility is probably the main risk associated with rice production, especially in the western Murray Valley. In most seasons, low air temperatures can reduce yield. In some seasons, such as in crop year 2021, yield loss can be severe.

Cold temperatures affect rice production in several ways. Below average temperatures in the growing season leads to less N mineralisation and therefore less N uptake and growth. While this can affect yield potential, the main damage from cold temperature is at the reproductive growth stage, which causes cold-induced floret sterility in crops.

The most cold-sensitive growth stage is the young microspore stage (YMS; sometimes referred to as the microspore stage). The second most cold-sensitive stage is flowering. Both lead to floret sterility and yield loss.

- YMS is a specific stage of pollen development when the developing pollen grains are most susceptible to cold temperatures. Night-time temperatures below 18 °C without deep water will start affecting the most sensitive varieties.
- At flowering, cool day-time temperatures pose the greatest risk to floret sterility by reducing pollen shedding from the anthers. Effects from cool temperatures at flowering become evident when daytime temperatures are below 24 °C in sensitive varieties.

The intensity and length of exposure during these critical reproductive periods over a 7–10 day period will determine the amount of cold-induced sterility.

The damage caused by cold temperature cannot be totally avoided, but crops can be managed to reduce the effects. The key steps to managing cold temperatures are:

- water management
- sowing time
- nitrogen management
- variety selection.

Using water to protect crops from cold damage

Water management is the only method of shielding the developing pollen grains from the effects from cold nights at YMS once the crop has been sown. At the YMS growth stage, the panicle is still contained within the rice shoot and is positioned <25 cm above the soil surface in short statured varieties. This can vary depending on several factors such as variety, early crop water management and nitrogen management. Water temperature on a cold night can be significantly higher (often 5–8 °C) than the air temperature (Figure 15). Deep water (25–30 cm) submerges the developing panicle and provides a thermal buffer. It is important to have the water level protecting as much of the panicle as practical with a minimum of 25 cm recommended. Deep water to 30 cm is preferred as it provides additional buffering capacity.

The key to water management is to have water as shallow as practical up until panicle initiation, then increase to a minimum of 25 cm (and preferably 30 cm) by YMS.

If deep water is applied before PI the plants will grow taller (due to nodal elongation) causing the panicle to be higher above ground level, leading to less benefit from deep water (25–30 cm) at YMS.

Water depths of less than 25 cm are unlikely to offer any substantial protection from cold temperatures. A 20 cm water depth, for instance, is unlikely to give better protection than a 10 cm water level as neither are deep enough to submerge (and therefore protect) the developing panicle. Therefore, if low water flow rates mean a crop will not have enough water at YMS for it all to have 25 cm of cover, fill as much of the crop as possible to this level and maintain the rest at a minimal depth (e.g. 5–10 cm). It is better to have 75% of the area with 25 cm and 25% with 8 cm than the whole of the area with only 20 cm water depth.

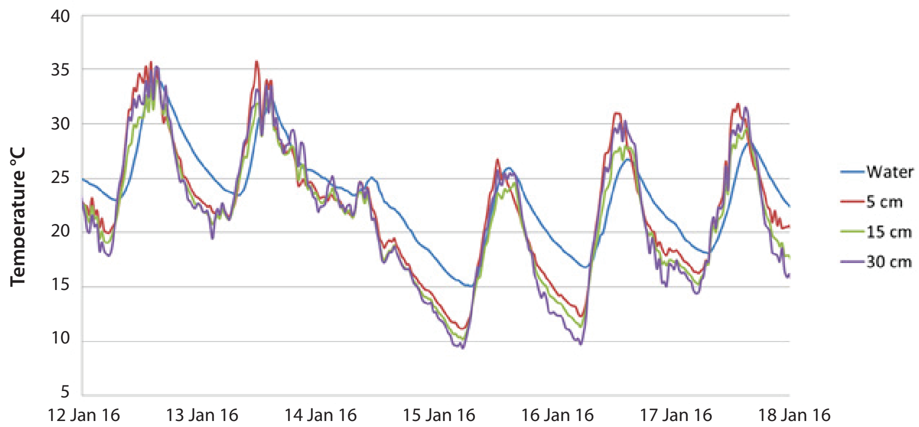


Figure 15. Water and air temperature recorded at different heights in the canopy at Jerilderie in 2016. The water temperature was 8 °C above the air temperature at 30 cm above the canopy during a cold spell on 16 January 2016.

A field guide to YMS is when the collar region of the emerging flag leaf is at the same height as the collar of the leaf below it. It is worth cutting open some rice stems at this stage to see what water depth is required to give adequate protection. **It is too late to adjust water levels at that stage**, but it will help guide future water management decisions (see NSW DPI Primefact *Rice water depth at microspore*.

Good rice banks are necessary to contain deep water at YMS. The section on Whole farm plan provides more detail on timeliness of bank construction and maintenance, bank size, design and soil type considerations.

GO TO PAGES

Rice water depth at microspore
(https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/summer-crops/rice/water-depth).

Rice variety guide
(https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/summer-crops/rice-development-guides/rice-variety-guide)

Sowing time

Take notice of the recommended sowing times which will vary depending on the variety, location and sowing method. Ideally sowing times aim to have YMS occurring in late January to early February as this is the period least likely to incur cold nights (Figure 16). There can still be cold exposure at this time, however, it has the lowest risk year after year. The risk of exposure to average minimum temperatures below 15 °C more than doubles if YMS is near the end of February compared with January to mid February.

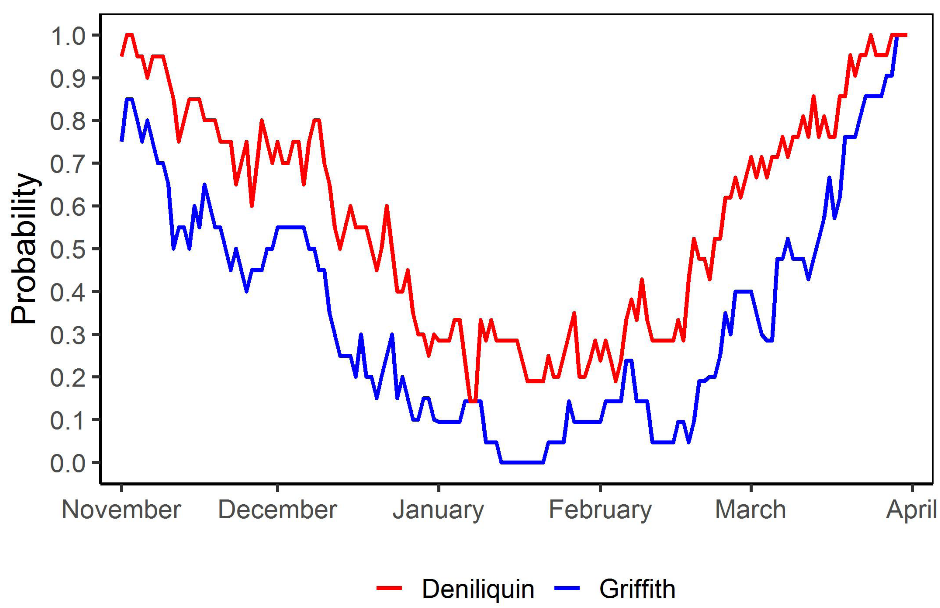


Figure 16. The probability of receiving a nine-day mean minimum temperature below 15 °C at Deniliquin (red; Deniliquin Airport) and Griffith (blue; Griffith Airport) since the beginning of 2001 (Credit: Christopher Proud, data from the Bureau of Meteorology).

Nitrogen management

Crops with high N and excessive vegetative growth are more prone to cold damage than those with more moderate N uptake. However, crops that are substantially under fertilised have a low yield potential that cannot be fully compensated by N top dressing at panicle initiation. This is why there is a recommended optimum N uptake (i.e. sufficient to allow high yield potential, but not to substantially increase risk of cold damage) for each variety in each valley.

The section on Crop nutrition provides more detailed advice on N management as do the individual growing guides for each variety available on the NSW DPI web site.

Variety selection

Rice varieties vary in their tolerance to cold temperatures at the reproductive growth stages. The most sensitive varieties (e.g. Topaz⑪ and Doongara) have a subjective rating of '1' on the cold-stress tolerance scale, so are usually only grown in the Murrumbidgee valley. The more cold-tolerant varieties have ratings of '4' (e.g. Opus ⑪) and '5' (e.g. Sherpa⑪). The ratings are available in the *Rice variety guide* published annually by NSW DPI and in Table 5.

Table 5. Cold tolerance ratings

Variety	Cold tolerance rating
Doongara, Topaz	1
–	2
Langi, Reiziq	3
Koshi, Opus, Viand	4
Sherpa, V071	5

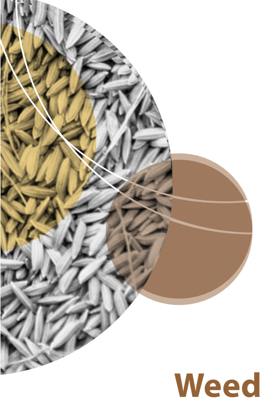
Cold tolerance rating:
1 = most susceptible,
5 = most cold tolerant.

The University of Queensland conducts regular genetic screening to evaluate cold tolerance at YMS of breeding lines (removing management practices such as deep water). The screens are designed to identify extreme levels of cold tolerance, greater than Sherpa⑪, whereby Sherpa⑪ scores approximately 50% floret sterility. Of the varieties, Doongara, Langi, Reiziq⑪ and Topaz⑪ are all considered susceptible to cold temperatures at YMS with high levels of sterility (>80%). However, Reiziq⑪ and Langi generally perform slightly better Doongara and Topaz⑪. Viand⑪ has improved cold tolerance compared with Reiziq⑪ and is comparable with Opus⑪ and Koshihikari (80–60%). The breeding line V071 appears to have improved cold tolerance compared with Reiziq⑪ and Viand⑪ based on results of one screen, however, additional evaluations are ongoing to provide an accurate estimate on its level of YMS cold tolerance.

The western Murray valley is probably the most affected by cold temperatures. Growers in this region need to consider the cold rating of the varieties they plan to grow. Selecting a more cold-tolerant variety, however, does not negate the need for good water and N management, and timely sowing.

Avoiding cold damage

It is worth emphasising that good management will minimise the damage caused by cold temperatures, but cannot eliminate it. In seasons with numerous cold events, damage will still occur. However, it is likely that the damage in well-managed crops will be less than in those with poor water management, and/or excessive nitrogen.



Crop protection

Weed control

Given the high value of rice crops, relatively low densities of grass and aquatic weeds can induce economic losses. Weeds emerging before or during early crop establishment are highly competitive with rice crops, so ensuring seedbeds are free of weeds and preventing subsequent weed establishment for approximately 50 days after sowing is important in attaining the best yield potential of any rice crop. Managing weed densities using a combination of cultural and chemical controls will act to both minimise yield losses and prevent weed seedbanks from rising. Keeping weed numbers low helps to lower selection intensity for herbicide resistance.

Successful weed control requires you to:

1. **Know your rice field**. A good knowledge of the weed situation in each field is important. Observations of previous rice or other rotation crops will provide useful information on weed activity. This is particularly important with perennial or biennial weeds such as water couch, silvertop grass, cumbungi, alisma and umbrella sedge.

New rice land that has never been irrigated or flooded before might not have a significant weed problem, with the possible exception of cumbungi. Cumbungi often occurs on new paddocks that have been aerially sown and can become a problem if rice is re-sown in the following season.

Expect to have barnyard grass in all situations, except for the first crop in virgin soil.

2. **Inspect the crop**. Look for weeds at sowing and inspect your crop every 4–5 days during the first 3–4 weeks. Pay particular attention to the shallow portions of bays, as intermittent exposure tends to favour grass weed establishment.
3. **Apply herbicides at the appropriate time**. Herbicides should be applied at the correct stage of weed and rice growth, before the weeds become too large. Weed control is more effective and efficient on small weeds.
4. **Apply the correct rate of herbicide**. Apply the registered label rate to ensure adequate control and reduce the risk of herbicide resistance.
5. **Control water depth and herbicide**. Water depth and flow management after herbicide application are an important aspect of successful weed control. Some herbicides require no water movement for five days after application. Rapid initial filling of rice bays is preferred to ensure more synchronous rice and weed development across the fields. Aim to fill up before water seeding in not more than five days, otherwise consider splitting the field for successive sowing dates. Cleaning supply channels, toe furrows and rolling clods all help to speed initial bay filling.
6. **Read the label**. Abiding by label recommendations maximises herbicide effectiveness and safety.
7. **Prevent herbicide resistance**. Resistance to Londax® has been found in populations of dirty dora, starfruit and arrowhead after widespread use. Alternative herbicide options are limited so it is important to closely monitor and record weed burdens, herbicide usage patterns and spray results, to minimise the risk of herbicide resistance. Check crops for any weed escapes. Send seed samples from suspect sites to the Charles Sturt University seed testing service at: Herbicide Resistance Screening, Charles Sturt University, Locked Bag 588, Wagga Wagga, NSW, 2678, and Contact David Troldahl at NSW DPI or Rice extension.

The main herbicide resistance strategies are:

a) Cultural management:
- Rotate paddocks to avoid resistant weed build-up.
- Change sowing methods between aerial and drill sown to rotate herbicides used and modes of action.
- Maintain level seedbeds for improved control of water depth and draining.

GO TO PAGES

Rice extension
(https://riceextension.org.au)

b) Herbicide management:
- Use each herbicide as directed on the label to achieve effective weed control.
- Use knockdown herbicides before sowing for grass control before rice emergence.
- Use two different modes of action for each weed.
- Use a herbicide with a different mode of action in subsequent rice crops.

8. **Ensure biosecurity**. Prevent weeds from spreading to other farms by maintaining good hygiene in cultivation, planting and harvesting equipment, and for footwear and vehicles.
9. **Prevent off-target crop damage**. Consider herbicide program, delivery technique and planting methods to avoid off-target crop damage, and communicate with neighbours to understand where sensitive crops are located.

GO TO PAGES

Rice crop protection guide
https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/summer-crops/rice/water-depth)

APVMA (https://apvma.)gov.au/)

Native Game Bird Management Program
(https://www.dpi.nsw.gov.au/hunting/game-and-pests/native-game-birds)

Pest control

Common and sugarcane armyworms are native species that can affect the crop from tillering until harvest. Spray as soon as the threshold is reached (Table 6) as smaller caterpillars are more readily controlled and re-infestation is seldom a problem. Experience suggests undertaking increased monitoring in delayed permanent water crops and after any midseason drainage.

Table 6. Damage thresholds for treating common and sugarcane armyworm infestations.

Crop stage	Treat if pest density exceeds:
Panicles not exposed	8 armyworm/m^2
Panicles exposed – more than 2 weeks to harvest	10 armyworm/m^2
Panicles exposed – less than 2 weeks to harvest	12 armyworm/m^2

Fall armyworm (Figure 17) has recently become established in Australia and was detected on maize in southern NSW during the 2020–21 rice season. It has not yet been found on rice in NSW, but is a significant rice pest overseas. It is resistant to many of the insecticides used against native armyworm species and growers should consult the *Rice crop protection guide* and the APVMA website for information on control options if they find fall armyworm in rice crops.

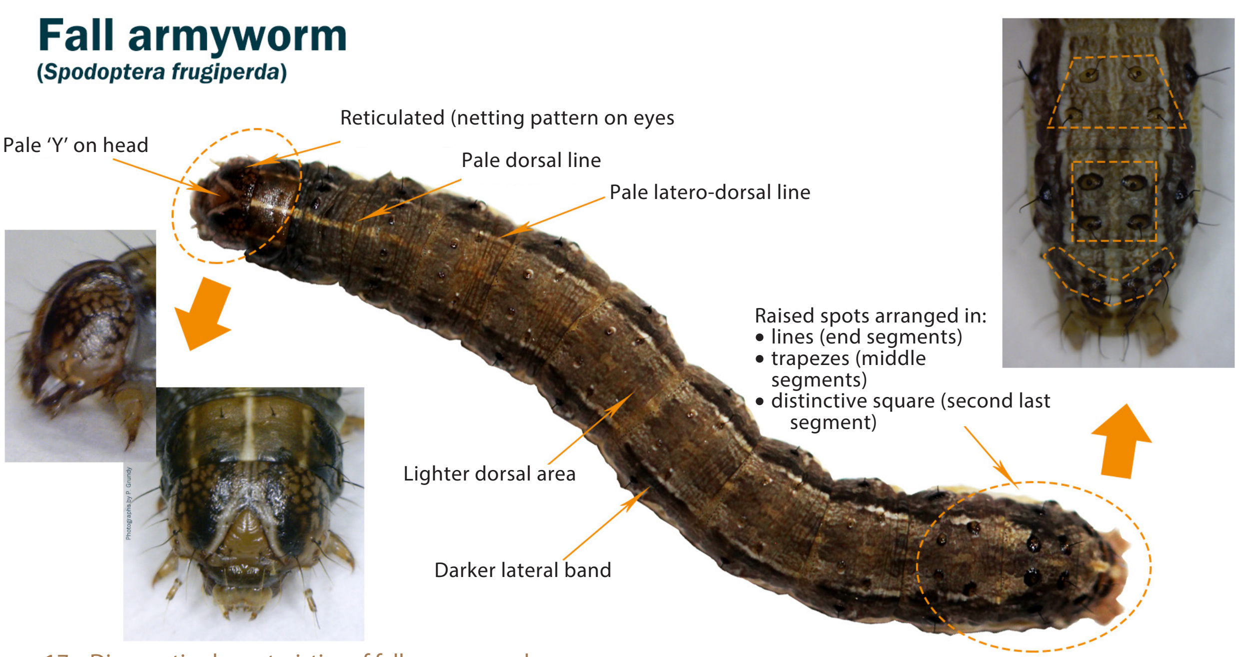


Figure 17. Diagnostic characteristics of fall armyworm larvae.
Source: Paul Grundy, CottonInfo.

Russian wheat aphid has also become established in Australia in recent years. While not known as a serious rice pest, it has been found on rice seedlings in significant numbers. Although chemical control options are available, they should be avoided if possible due to their effect on beneficial insects. Russian wheat aphid has not been found on aerial-sown rice crops or on drill-sown crops after permanent water.

Aquatic earthworms can cause serious damage to aerial-sown rice crops (Figure 18). They attract ibis, which trample seedlings and muddy the water. Earthworm activity can cause poor crop establishment even without ibis. Control options are limited to draining water, drying out bays and scaring away ibis. Dispersive clay soils are particularly vulnerable and aerial sowing rice crops immediately after an irrigated pasture phase should be avoided on these soils.

Figure 18. Castings are a sign that aquatic earthworms are present in the crop.

Bloodworms attack most aerial-sown and dry broadcast rice crops. All aerial-sown crops should be treated for bloodworms at or within 24 hours of sowing. Alternatively apply water to dry-sown crops and treat by air as soon as possible afterwards. A second treatment might 2–3 weeks later. Drill-sown crops are less likely to be affected, although a single treatment could be required after permanent water, depending on pest pressure and plant growth stage. It is important to be able to differentiate between bloodworms and aquatic earthworms, as aquatic earthworms will not be controlled by the chemical treatments currently registered for bloodworms. *The rice crop protection guide* contains diagnostic images and other information to help you correctly identify both pests.

Ducks and ibis often affect late sown crops with weak establishment areas. Use strategic duck shooting, scare guns, lights and plastic bags on stakes to scare birds from rice crops. Aim to prevent any birds from settling, as they are likely to attract additional numbers. Refer to the NSW DPI website for more information regarding the Native Game Bird Management Program. Growers need to apply for a NSW Game Hunting Licence and complete a Waterfowl Identification Test. Rice growers who anticipate problems with ducks can then tick the opt-in box on their rice seed order form to obtain a Native Game Bird Management Licence (Owner/Occupier) and an annual quota allocation.

Galahs, cockatoos and ants carrying away seed can be a problem in dry-broadcast crops before flooding.

Mice can be a serious problem, they will swim from nests on the banks out into the crop where they chew into the side of rice stems before head emergence. The main damage occurs as the crop matures when they feed on the grains as the panicles develop and fill. Baiting along the banks can provide good levels of control, but this should preferably be done before the crop heads are out and must be done before it is drained.

HEALTH WARNING

Several Murray Valley growers have been hospitalised with leptospirosis in previous mouse plagues. It is advisable to wear gum boots and trousers when walking along mice infested banks to prevent the disease from entering through the skin when it brushes on foliage with mouse excrement contamination.

Leafminer larvae burrowing in rice leaves can delay emergence of rice through permanent water and reduce establishment. If rice emergence is slower than expected, or rice plants are laying down on the water's surface, inspect the leaves for leafminers. Control using an insecticide.

Locusts can attack seedling rice between flushes of water in drill-sown crops. Aerial-sown damage is less than in drill-sown crops as the locusts will only eat to the waterline – immature locusts (hoppers), which cannot fly, will not enter a flooded crop in significant numbers. If the growing point has been eaten the plant will not recover. Manipulating permanent water timing and depth is the main control.

Snails can be a serious problem in aerial-sown crops from sowing until mid–late tillering. They can also occasionally affect drill-sown crops. Numbers can increase following wet winters and especially in paddocks that grew rice in the previous season. A year's break from rice significantly reduces snail numbers.

Details of registered pesticides are summarised in the *The rice crop protection guide*.

Algae

Slime can reduce seedling establishment. Green slime is an algae that can be treated with algicide or by lowering water levels. Reduce the potential for green slime by minimising organic matter and phosphorus fertiliser on the soil surface. Avoid slime by effectively burning stubble, hard grazing the pasture or crop residue, and by drilling phosphorus fertiliser beneath the soil surface.

Brown slime is more difficult to control. It is caused by iron-oxidising bacteria found in most rice growing soils. Brown slime tends to increase as the urea rates increase. Control brown slime by lowering water levels and exposing the rice and slime to sunlight. This dehydrates the slime and assists rice growth.

Pesticides in rice drainage water

All rice growers must ensure that pesticides applied to rice fields do not have unintended effects on humans, livestock, or other living organisms.

Regulatory guidelines have been set for all agricultural chemicals used on farms to limit the amount of these chemicals entering drainage water delivered into public drains, swamps and watercourses. Irrigation authorities monitor concentrations in drainage to prevent damage to the environment.

Large rice banks and drainage retention dams can help retain drainage water arising from heavy rainfall. Do not drain rice water into regional drains within 28 days of pesticide application, or as determined by the local irrigation authority.

Suspicious pests and diseases

South-eastern Australian rice areas are currently free of major overseas rice pests such as golden apple snail and diseases such as rice blast.

The *National Rice Industry Biosecurity Plan* launched in March 2005 and was updated in 2014 to the Industry Biosecurity Plan for the Rice Industry. The plan aims to prevent and minimise the incursion and spread of any new pests or disease in rice crops.

Rice farmers and agronomists need to constantly check crops for early detection of any pests and diseases that are accidentally introduced. Be on the lookout for unusual plant symptoms.

If suspicious symptoms are seen, contact NSW DPI, Yanco for the appropriate sampling protocol for assessment. Alternatively ring the Emergency Plant Pest Hotline on 1800 084 881.

EMERGENCY PLANT PEST HOTLINE
1800 084 881

Plant diseases

There have been several diseases seen in rice crops in the southern rice growing regions. These have been documented in the *Rice crop protection guide* and the *Rice field guide to pests, diseases and weeds in southern NSW*. None of these diseases require any special management as they are not sufficiently serious.

A few diseases have been shown to slightly reduce yield such as stem rot, aggregate sheath spot and sheath spot. These diseases, however, are sporadic and the degree of severity can depend on successful stubble burning. See Burning rice stubble on page 6. The disease reproductive structures survive on plant material, so burning and rotation are successful options to reduce the carryover risk of disease infected material. These diseases can become more frequent in areas where stubble burning has not been successful and could become more prevalent if burning becomes an environmental concern.

Unfortunately, many diseases can look similar, so it is important to correctly diagnose the causal agent.

Any disease concerns should be discussed with your agronomist and if further action is required for diagnosis then that should be undertaken.

Biosecurity

There are a number of diseases that are not in Australia or not in the southern growing regions, but it is important for growers to remain aware of these and to quickly report any suspicious symptoms.

GO TO PAGES

Industry Biosecurity Plan for the Rice Industry (https://www.planthealthaustralia.com.au/industries/rice/)

Rice crop protection guide (https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/summer-crops/rice-development-guides/rice-crop-protection-guide)

Rice field guide to pests, diseases and weeds in southern NSW (https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/summer-crops/rice-development-guides/field-guide)

Crop nutrition

Nutrient balance

In the long term, fertiliser strategies should ensure that the nutrients the crops remove from the soil are replaced. Maintaining this balance prevents deficiencies that could alter the yield sustainability and grain quality of rice and other crops or pastures in the rotation (Figure 19; Table 7).

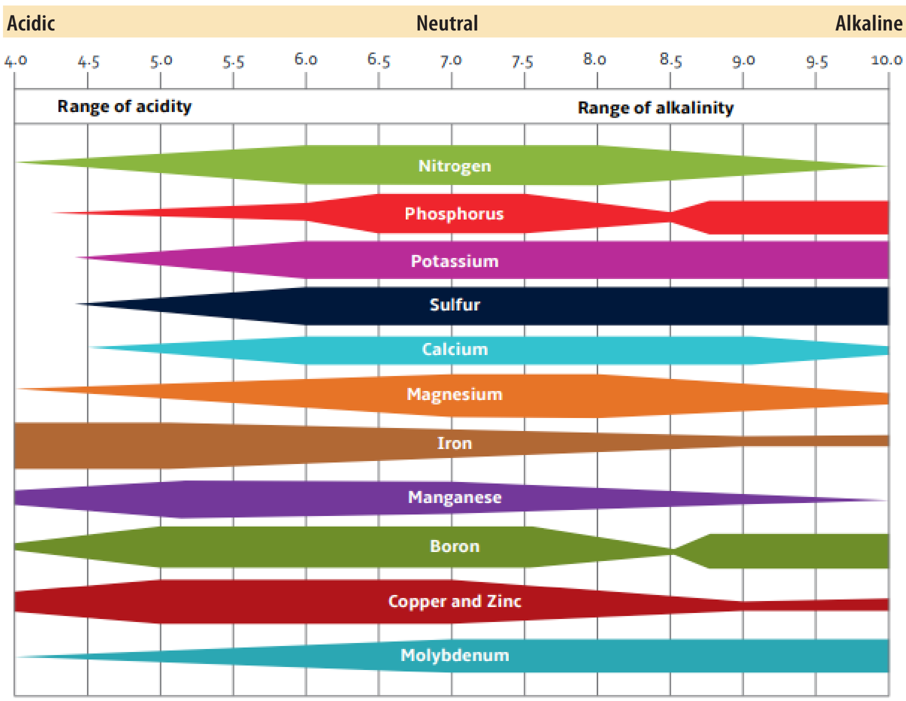


Figure 19. Nutrient availability is determined by soil pH in relatively fertile soils. The wider the band the more readily available is the nutrient (Production of quality rice on page <?>). Note that zinc becomes less available as the soil becomes more alkaline, and more available as the soil becomes more acidic.

Table 7. Summary of adequate and deficient levels of nutrients in rice tissue samples.

Nutrient (symbol)	Deficient level	Normal levels
Nitrogen total (N)	<2.5%	3.0–4.5%
Phosphorus (P)	<0.1%	0.2–0.5%
Potassium (K)	<1.2%	1.5–3%
Sulfur (S)	<0.16%	0.15–0.3%
Zinc (Zn)	<15 mg/kg	20–60 mg/kg
Magnesium (Mg)		40–500 mg/kg, 0.14–2.5%
Calcium (Ca)	<0.1%	0.1–0.3%
Copper (Cu)	<5 mg/kg	7–15 mg/kg
Manganese (Mn)		40–500 mg/kg
Boron (B)		5–15 mg/kg

The levels are from samples of the youngest fully expanded leaf, taken at mid-tillering.

Summary of nutrients important to rice nutrition

Soil tests are recommended to ensure nutrient levels are appropriate. Undertake soil tests three months before sowing to ensure results are available before sowing. Deficient levels for each nutrient are listed in the table below.

Table 8. Rice nutrition – nutrients.

Nitrogen (N)	Rice plants require N throughout the crop cycle. Nitrogen promotes biomass, tillering and yield. Nitrogen will promote grain filling, increase protein levels and delay senescence. Deficiency: stunted plants with older leaves yellowing and dying at tips. Paddock history and grower experience are the only reliable tool for assessing N requirements before season.
Phosphorus (P)	Promotes root development and tillering, panicle number and grain number. Deficiency shows up as stunted plants with a reduced number of leaves. Low P can limit uptake of N and K by the rice crop. Colwell test 0–20 mg/kg apply 25–30 kg P/ha. Colwell test 20–40 mg/kg apply 20–25 kg P/ha. Colwell test over 40 mg/kg apply zero P.
Potassium (K)	Increases stem strength, the number of florets, % of filled grains and grain weight so deficient symptoms occur around flowering. Deficient plants have early leaf senescence, sterile grains, tend to lodge and have poor, blackened root systems. Apply K if soil has <80–150 mg/kg or if K is <1.5% of total exchangeable cations in the soil.
Sulfur (S)	Deficiency causes reduced tillers, fewer and shorter panicles and reduced florets /panicle. New leaves are pale yellow. Heavy cut areas may be deficient in S. Apply S if <5 mg/kg (soil KCL test)
Zinc (Zn)	Promotes fertility and seed production, important in cut soils. Deficiency will result from prolonged Zn removal from high yielding crops. Deficiency shows as patchy colour on seedling leaves, leaves float on water surface. Flooding the soil reduces Zn availability to the crop and is more severe in cold weather and with deep water. In soil with pH >6.5 (pHCa) apply Zn if test shows <0.8 mg/kg DPTA extraction method. In soil with pH <6.5 (pHCa) apply Zn if test shows <0.5 mg/kg DPTA extraction method. Apply Zn close to the seed in pre-plant fertiliser mix or as a seed dressing. Toxicity can occur to crops at soil levels 12–26 mg/kg, so monitor levels regularly.
Silicon (Si)	Promotes strong leaves, stems and roots. Reduces susceptibility to lodging and pests and disease.
Copper (Cu)	Important in pollen formation, respiration and photosynthesis. Deficiency causes chlorotic streaks on young leaves, new leaves do not unroll. In soil apply Cu if DPTA extraction test shows <0.3 mg/kg. In leaf analysis apply Cu if <5 mg/kg.
Calcium (Ca)	Promotes nitrate uptake. Important for cell structure. Calcium deficiency is rare in irrigated rice systems but will appear on youngest leaves as interveinal chlorosis and leaves may bend downwards. Apply Ca if leaf analysis levels are less than 0.1%.
Boron (B)	Promotes pollen viability, flowering and seed production. Boron deficiency appears as white and rolled tips of youngest leaves. Apply B if leaf analysis levels are <5 mg/kg.
Iron (Fe)	Iron is required for chlorophyll in photosynthesis. Yellowing or chlorosis of the interveinal areas of the emerging leaf. Rice growing soils contain high amounts of iron.
Manganese (Mn)	Toxic levels can occur when pH <4.5, liming will increase the soil pH. Rice growing soils contain high amounts of Mn.
Aluminium (Al)	Toxicity can occur where pH <4, liming will increase the soil pH.

Nitrogen (N)

There is no reliable method for determining how much soil N will be available to the rice crop before sowing. The soil N test used for winter cereals and non-rice summer crops is of no value as it measures nitrate, which is lost when the field is flooded for rice.

Very high levels of N supplied from either legumes or N fertiliser can lead to excessive rice growth, making the rice plant more prone to cold-induced sterility and yield loss.

There is also no way to predict whether the season will be cold, average or hot, during the vegetative or cold sensitive reproductive stages.

Because of these limitations, it is recommended that sufficient N fertiliser be applied before permanent water to achieve the target nitrogen uptake at panicle initiation (PI) of between 60–140 kg N/ha depending on variety and location (tables 9 and 10). At PI, test the crop using the NIR (near infrared) tissue test service to determine if more N should be applied to achieve maximum yield with reduced risk. This strategy maximises yield potential and N efficiency and lowers greenhouse gas emissions and the risk of over-fertilisation and cold-induced sterility.

Paddock history

Paddock history plays a significant role in the N status of a rice crop at PI (Table 9). Both low and high N fertility paddocks have the potential for high yields. However, high fertility paddocks with high PI nitrogen uptakes have more variable yields as they are more sensitive to cold stress at microspore. In colder years, lower yields are likely, especially if water depths at microspore are below the 25–30 cm target. Table 9 has a guide to the range of pre-permanent water N application rates that might be required for fields with different cropping histories to achieve the target PI nitrogen uptake.

Pre-permanent water nitrogen

Applying nitrogen fertiliser before applying permanent water is the most efficient use of nitrogen regardless of whether the crop is aerial or drill sown, or managed with delayed permanent water. Provided the soil is dry, the N is washed into the soil and attaches to the clay particles where the majority remains until used by the crop.

Sufficient N fertiliser must be applied before permanent water to achieve sufficient vegetative growth by PI to obtain a high yield potential for the crop. The amount of N required depends on the cropping history of the field and soil organic N levels. Temperatures before PI affect the release of organic nitrogen and uptake into rice plants.

For aerial sowing, drill N into the soil (7–10 cm deep) before ridge rolling and permanent water is applied. This can be done up to 10 days before fill-up. Spreading N fertiliser onto the dry soil surface after ridge rolling is not recommended as it is less efficient. There is also an increased risk of N loss if permanent water is not applied within a few days, particularly if there are heavy dews or showers of rain.

In deep grooved ridge-rolled paddocks, where seed moves to the bottom of the grooves, ensure the N fertiliser placement is a minimum of 3 cm below the seed to avoid seed fertiliser contact and potential reductions in seed germination and plant establishment.

Figure 20. Broadcast urea onto dry soil before applying permanent water in drill sown crops. Photo: Vince Bucello

For drill sowing, broadcast N (urea) onto the dry soil then follow with permanent water within 24 hours (Figure 20). It is important that the urea is applied to dry soil so the N is washed into the soil when permanent water is applied and will not be lost from the water (and crop) through volatilisation.

It is very important that N is applied evenly across the field. Unevenly applied N increases crop variability making the crop difficult to manage thus reducing grain yield and grain quality. If using spreaders to apply N, ensure they are calibrated and spread the fertiliser evenly.

Slow release and enhanced efficiency nitrogen fertilisers

Slow release and enhanced efficiency N fertilisers work by slowing down the N cycle in the soil. This reduces the available N in the soil and so reduces the speed of N loss.

In a typical drill-sown rice crop, the highest period for N loss is during the flushing phase before permanent water. Once permanent water is applied, N, which is in the form of ammonium, is relatively stable.

The lack of N applications before permanent water has not been found to reduce yield, therefore any N fertiliser applied before permanent water does not increase yield potential in drill and delayed permanent water (DPW) rice crops.

Urea is a low-cost N fertiliser. Its most efficient application window is just before permanent water and provides the best return for dollars spent on N fertiliser.

This has been supported by research involving four experiments conducted over two seasons that showed no advantage in using slow release and enhanced efficiency fertilisers rather than urea and recommended practice (Figure 21).

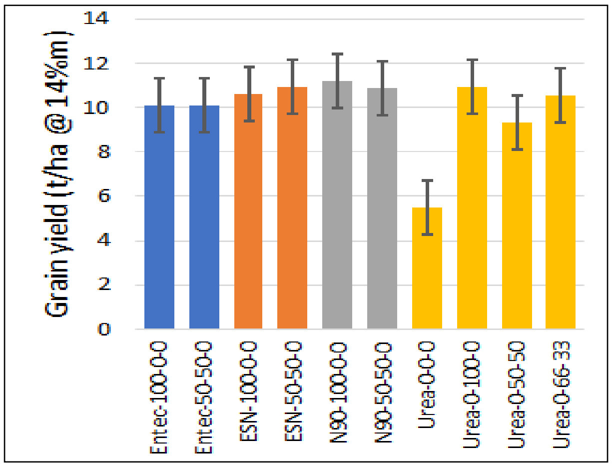


Figure 21. Average results of four experiments over two years. Treatment naming structure includes the fertiliser used at sowing, the rate of N/ha applied at sowing, the rate of N/ha applied at permanent water as urea and the rate of N/ha applied at PI as urea.

Target nitrogen uptake

Table 9 shows the target range of PI N uptakes for different varieties when applying pre-permanent water nitrogen. Farmers in the Murrumbidgee Irrigation Area (MIA) and Coleambally Irrigation Area (CIA) aiming for high yields from medium grain varieties (e.g. 12 t/ha for Reiziq(ɸ)) can target the high end of the PI N uptake range. Farmers in the Murray Valley should target 100–130 kg N/ha N uptake because of the higher cold risk and lower yield potential.

Achieving deep water at microspore is very important, particularly at the high end of PI N uptake ranges because of increased sensitivity to cold temperatures.

High N uptakes above the target range increase the risk of cold damage, while N uptakes below the target range indicate that insufficient pre-permanent water N was applied, and yield potential might be reduced.

Table 9. Target nitrogen uptakes by the crop at panicle initiation (PI) for all varieties.

Variety	Target PI nitrogen uptake (kg N/ha)	
	MIA & CIA	Murray Valley
Reiziq, V071, Sherpa, Opus, Langi	120–140	100–130
Doongara, Topaz, Viand	100–130	80–110
Koshihikari	80–110	60–90

Table 10. Suggested pre-permanent water nitrogen fertiliser rate ranges for medium grain rice varieties based on paddock history.

Paddock fertility	Paddock history[1]	Total nitrogen fertiliser (kg N/ha)
Low	3 or more years of continuous rice	180–240 (e.g. 390–520 kg/ha urea)
Fair	Rice after rice, cereals or poor grassy pasture	120–180 (e.g. 260–390 kg/ha urea)
Moderate	1–2 years of fair subclover/ grass pasture	60–120 (e.g. 130–260 kg/ha urea)
High	2–4 years of good subclover	0–60 (e.g. 0–130 kg/ha urea)

[1] Suggested rates for Opus(ɸ), Topaz(ɸ) and Langi are the same as for medium grain varieties
For Doongara apply 30 kg N/ha less.
For Koshihikari apply 60 kg N/ha less.

Applying N after drill sowing but before the flush irrigations has the potential for significant N losses. Wetting and drying the soil during flush irrigations changes the N form in the soil. Each time the soil dries and is saturated again, N is lost.

Starter fertilisers containing N, P and Zn are useful in assisting seedling growth, particularly when drill sowing. Phosphorus and Zn need to be located close to the germinating seed to be of benefit, and drill sowing provides the ideal situation for this to occur.

Although urea applied with the seed when drill sowing might increase seedling growth, in all experiments where it has been tested, grain yield has not been increased.

Post-flood to pre-panicle initiation nitrogen (mid season topdressing)

Extensive research has shown that N fertiliser for rice is best applied at the pre-permanent water stage and at PI. This maximises the N availability to, and uptake by, the rice plant and minimises losses.

However, when vegetative growth before PI is obviously restricted by N deficiency (stunting, poor tillering and severe yellowing) and the predicted N uptake at PI is less than 80 kg N/ha, then immediate topdressing with 125 kg/ha of urea is advisable to stimulate normal crop growth until PI.

If possible, wait until mid tillering before applying mid season N. It is important not to apply N into the water when the rice plants are young. The plants have a small root system and are unable to take up the N quickly, while the open water surface leads to quick N loss through volatilisation.

In severe cases of under fertilisation before permanent water, it might be beneficial to remove the water from the crop, dry out the soil and apply the N to the dry soil surface before re-flooding. This depends on being able to reuse the water drained from the field.

Panicle initiation nitrogen

Applying N fertiliser at PI is not as efficient as application before permanent water (Figure 22). However, at PI, the rice crop now has lots of surface roots, which can quickly take up N from the water, and a full crop canopy, which reduces N volatilisation losses from the water before the rice plants can take it up. Yield potential is better known at PI than pre-permanent water, so applying the extra N at PI lowers the risk of over-fertilising and consequential cold-induced sterility and lodging, and maximises grain yield.

When to topdress

The topdressing window ranges from when PI is identified to 10–12 days after PI. Panicle initiation occurs when three out of 10 main tillers have a visible panicle (normally about 1–2 mm long; Figure 23). It is too late to topdress crops once the majority of panicles are more than 50 mm long. Crops should be topdressed as soon as possible after NIR tissue test results are obtained. This is most important for the crops that are most deficient in N as it allows more time for the crop to grow using the added N.

Figure 22. Topdress nitrogen at panicle initiation if the required nitrogen uptake has not been reached.
Photo: Vince Bucello

Figure 23. Panicle initiation occurs when three out of 10 main tillers have a visible panicle.

The NIR tissue test

Rice N uptake at PI is determined by the rice NIR tissue test. The test provides growers with pannicle initiation N topdressing recommendations. The recommendations are based on the actual PI N uptake value calculated for the crop, and the expected response for added PI N, developed from several years of N topdressing experiments. Sampling procedures are outlined in the SunRice protocol

The NIR tissue test measures N uptake from the fresh weight measurements that the grower supplies, and the tissue N content of the submitted sample. The fresh weight determines the growth that has already occurred; the N content gives an indication of potential growth. The crop density does not affect N uptake at PI or N topdressing requirements. A dense crop will have a high dry matter and low N percentage, while a thin crop will have a low dry matter and high N percentage.

Two N topdressing recommendations are given, with the higher rate applying to crops that:

1. are sown at the recommended time so PI occurs between the 1 and 14 January
2. have a minimum microspore water depth of 25–30 cm
3. are located in the MIA/CIA and northern Murray Valley (MV) areas so have a slightly lower cold risk.

As well as the NIR tissue test, consider paddock history when deciding the topdressing rate. Fields with recent legumes containing high organic N that might continue releasing N after PI could need a lower rate. Conversely, heavily cropped paddocks with very low levels of organic N might require a higher rate than recommended.

GO TO PAGE

SunRice protocol
(https://riceextension.org.au/documents/2020/12/15/crop-sampling-instructions-nir-rice-pi-tissue-tests)

Targeted sampling using aerial imagery.

Sampling rice for the NIR tissue test can be made easier and more accurate using aerial imagery (Figure 24). Images taken before PI identifies zones of crop vigour in the field to target sampling locations for the NIR tissue test. Using tools such as NDRE (normalised difference red image) imagery and the NIR test allows farmers to apply variable rate of topdress N to their crops. It is essential for farmers to walk in to check or ground truth their images with the crops, because the differences between the biomass zones might not be from N but from other causes such as weeds or poor establishment. Thus, each zone needs checking before making decisions on N application. Also read Precision agriculture on page 38.

Remote sensing in rice historically involved using normalised difference vegetation index (NDVI) maps of rice fields generated from satellite, aircraft or drone sources. Although these maps can appear to show significant differences within fields, once the rice crop develops a full canopy, which often occurs before PI, NDVI becomes saturated and cannot detect difference in crop biomass or N uptake. Once the rice crop gets past mid-tillering and particularly once it has reached PI, normalised difference red edge (NDRE) images are better able to show differences in the crop's N uptake (Figure 24). The red edge waveband is very sensitive to changes in foliar chlorophyll content, which is strongly related to plant N concentration.

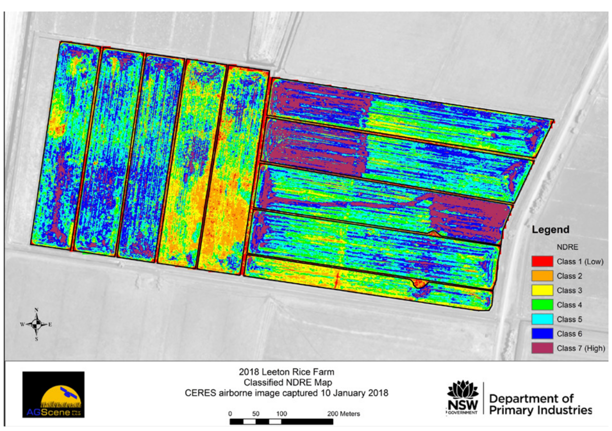


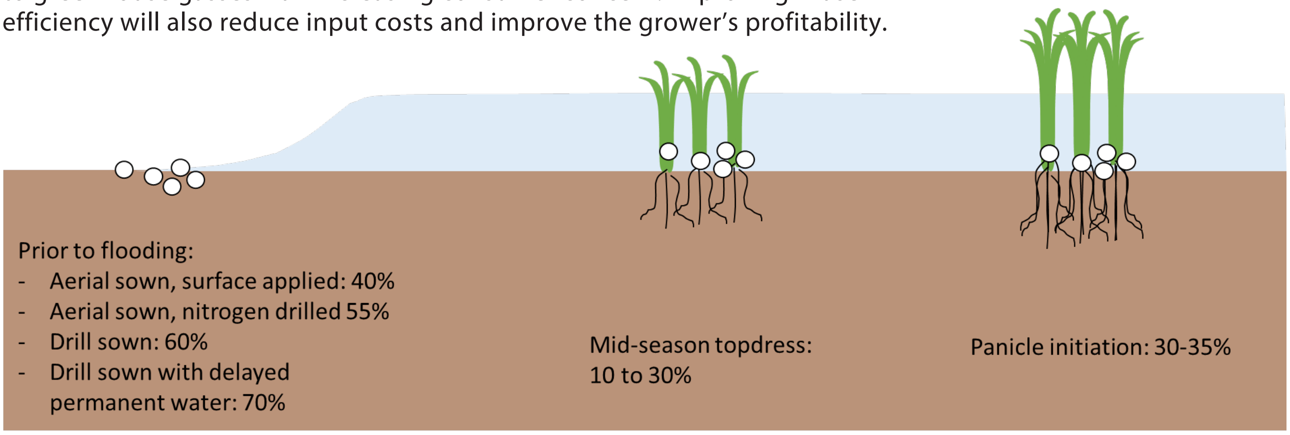
Figure 24. NDRE imagery is used to identify zones of crop vigour in the field to target sampling locations for NIR tissue tests.

Crop nutrition

Nitrogen use efficiency

Nitrogen use efficiency (NUE) is the percentage of applied N that the plant uses. Figure 25 changes depending on the type of fertiliser used, soil and weather conditions, but most importantly how and when N fertilisers are applied throughout the rice crop cycle.

Nitrogen that the plant has not used is lost through volatilisation, leaching or denitrification. Denitrification is of particular importance due to its contribution to greenhouse gasses – an increasing consumer concern. Improving N use efficiency will also reduce input costs and improve the grower's profitability.



Note these are estimates and can change significantly, there have been no experiments directly comparing all treatments.

Figure 25. Nitrogen use efficiency figures for different nitrogen fertiliser application methods.

Mid-season topdressing has lower efficiency than other application methods, but varies depending on crop growth stage.

If you change sowing method, you might need to adjust fertiliser rates to account for the change in efficiency. For example, if you surface applied 100 kg/ha N to an aerially sown crop then the rice plant will be able to use 40 kg/ha. However, if 100 kg/ha was applied on a DPW crop before permanent water you would have 70 kg/ha that the rice plant could use (Table 11).

Table 11. Scenarios on the remaining N that the plant can use, depending on the NUE for different methods of fertiliser application.

Scenario	Nitrogen amount (kg/ha)	Remaining nitrogen that the plant can use (kg/ha)
Aerial sown, surface applied urea	100	40
Drill sown	100	60
Drill sown, DPW prior to permanent flood	100	70

Nitrogen use efficiency in aerial and dry broadcast sown rice

It is most efficient to drill urea or ammonium fertilisers into the soil. It is also efficient to spread urea onto dry soil immediately before rain or irrigation so it can be washed into the soil.

Both methods prevent volatilisation. Volatilisation is where the N is converted to a gas and is lost to the atmosphere. Urea will be volatised if it is applied to moist soil (Figure 26) or directly into ponded water (Figure 27). The rate of volatilisation will depend on the plant's growth stage.

Both methods will minimise N loss by trapping it underneath the soil.

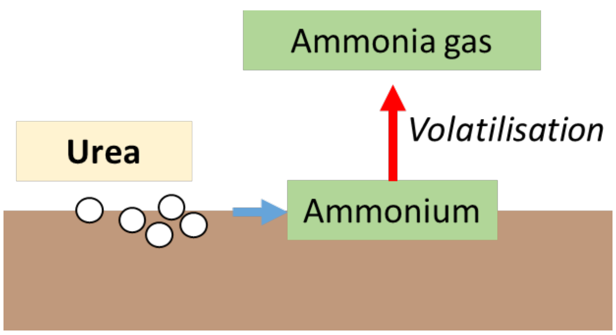


Figure 26. Urea/ammonium fertilisers (eg MAP) applied to the soil surface can be lost to the atmosphere through volatilisation, particularly in alkaline soils and in hot and windy conditions.

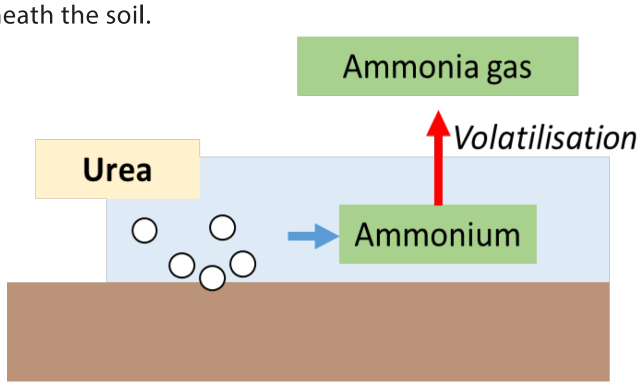


Figure 27. Urea/ammonium fertilisers applied into ponded water in flooded paddocks are also lost as ammonium gas.

If the crop is drained and re ponded at any stage, other significant losses can occur .

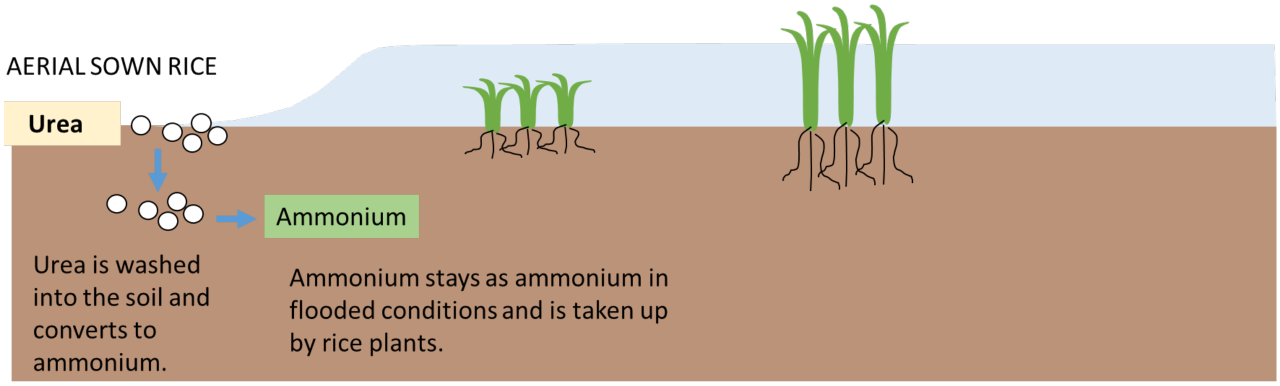


Figure 28. For aerial sown rice, it is most efficient to apply urea before permanent water.

Drill and delayed permanent water sown rice

It is most efficient to apply N onto dry soil immediately before permanent water minimising leaching and denitrification losses (figures 29 and 30).

Flushing creates a moist and aerobic environment so that N can be converted to nitrate. Leaching is when nitrate is moved out of the root zone preventing the plant from using the applied N. Denitrification is when nitrate is lost as nitrous oxide gases, which occurs when a paddock is ponded and becomes anaerobic.

There will be losses between each flush, but once the crop goes to permanent water, any remaining nitrate will be lost. This scenario is unique to rice, which is why it is recommended to delay any N application until just before permanent water.

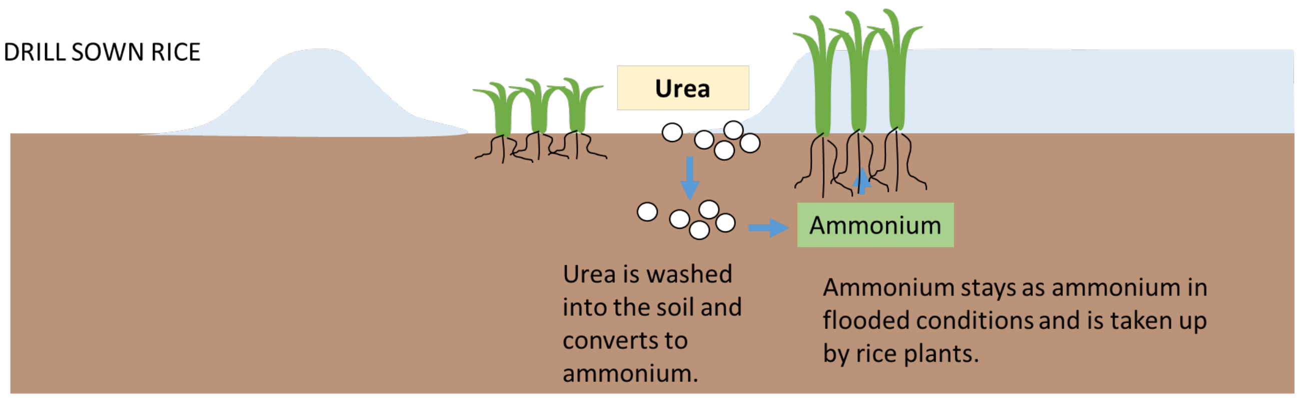


Figure 29. For drill sown rice, it is most efficient to apply N just before permanent water.

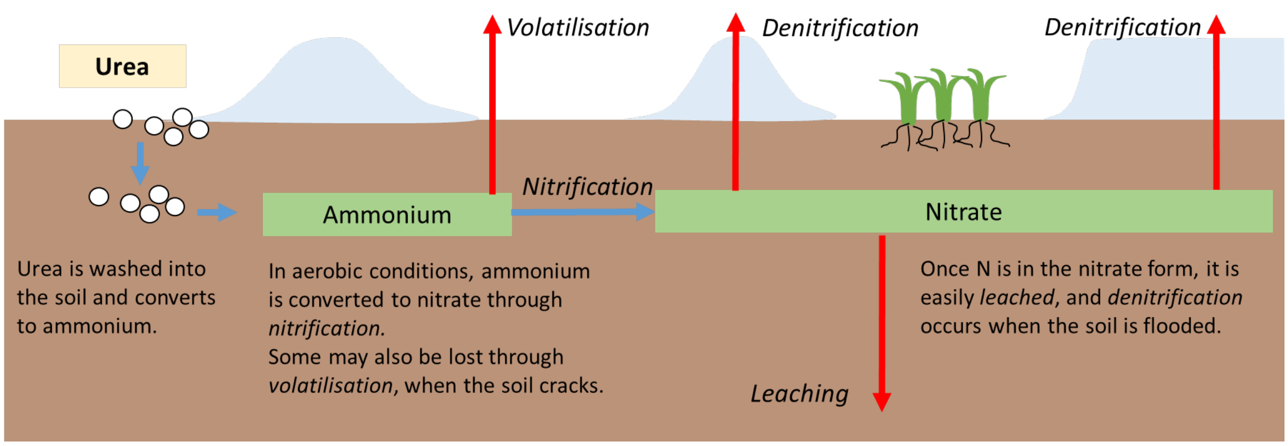


Figure 30. There are many ways N can be lost if N fertiliser is applied before flushing.

The nitrogen cycle

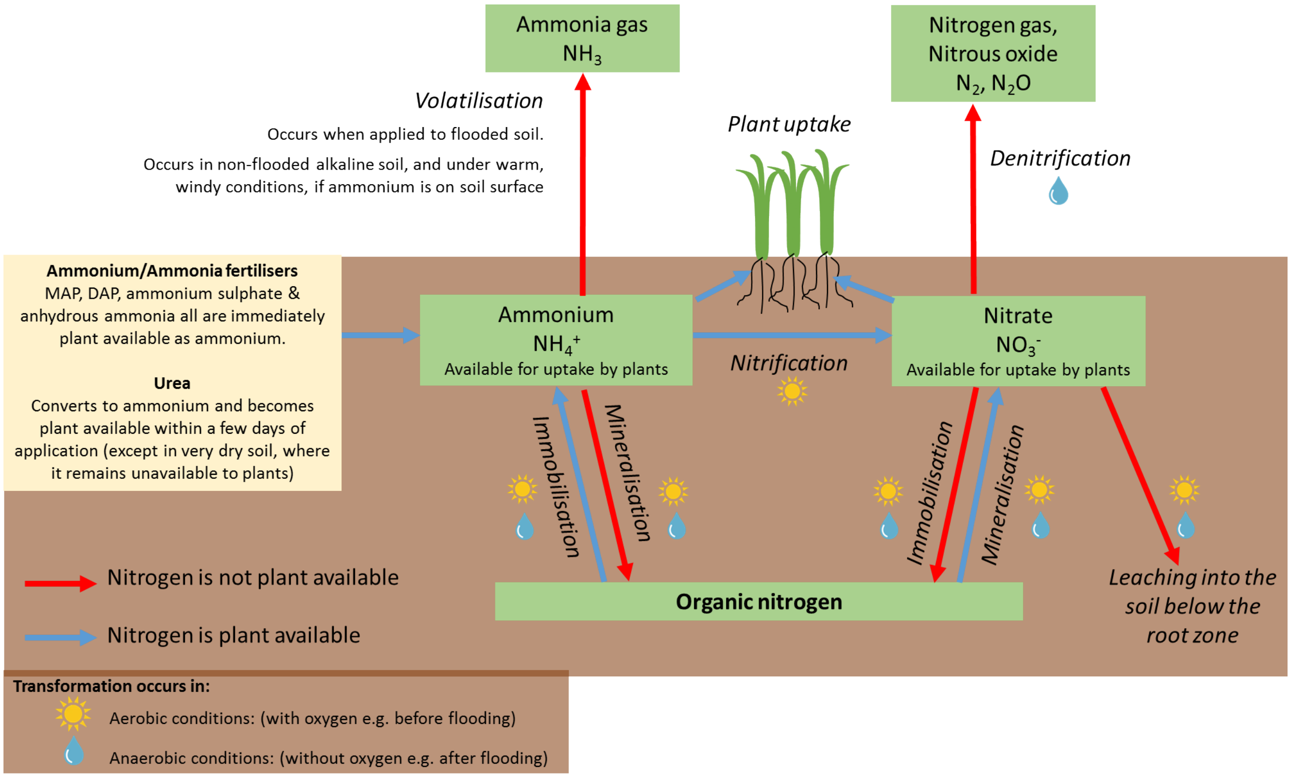


Figure 31. Nitrogen use efficiency through the season

The importance of spreader calibration

Using ground rig spreaders with horizontal spinning discs to apply nutrients to rice fields has increased significantly in the last eight years. These spreaders are prone to poor fertiliser distribution, which leads to non-uniform nutrient distribution – often referred to as striping or race tracking – with more vegetative growth and lodging in the over fertilised strips, and lower yields in the under fertilised strips.

While the economic impact of this has not been scientifically researched in rice, independent agricultural economist and modeller, Chris Lightfoot said:

My analysis indicates uneven urea spreading on wheat can easily result in $25–40/ha reduction in wheat gross margin.

This assessment is based on accepted N response functions, income and expenditure data. Clearly each situation is different, however, this work shows the importance of even fertiliser broadcasting.

To overcome poor distribution, the setup and calibration of the fertiliser spreader is a vital task for growing a uniform, high yielding rice crop. Spreaders need to be calibrated and swath width adjustments are necessary to take into account the fertiliser particle size and density, as well as the spreader speed and height above crop.

Main factors that affect spreader performance include:

- machine setup and maintenance (factory settings are a guide only)
- fertiliser product characteristics (granular size and density)
- environmental factors (e.g. wind speed and direction)
- operator competence
- crop and stubble height
- overlapping or misses due to inaccurate runs due to not using GPS auto steer system.

The best way to test the accuracy of your spreader is by contracting an Accu-Spread certified technician to test it. Accu-Spread is a program that involves independent testing and accreditation for fertiliser equipment for accuracy and evenness of spreading.

The test uses 0.5 m^2 trays aligned across the spreader width that collect the fertiliser as the spreader passes. The fertiliser in each tray is weighed (to 0.001 g accuracy) and weights are entered into the Accu-Spread computer program. The program calculates a distribution curve and co-efficient of variation (CV) chart that determines the optimum swath width specific to that spreader and that fertiliser. The industry standard for spread pattern variation is <15% for fertilisers and <25% for lime and gypsum.

What are the benefits of calibrating your spreader?

- fertiliser placement is more accuratenutrient uptake by plants is uniform
- reduced fertiliser runoff
- reduced excessive vegetative growth
- a wider swath is possible for reduced application time and cost.

Figure 32. Poor fertiliser distribution leads to non-uniform distribution of nutrients showing up as striping on rice crops. Photo: Peter Draper.

Phosphorus (P)

High-yielding crops remove substantial quantities of P from the soil. On some soil types when permanent water is applied to a rice field, chemical processes in the soil allow higher levels of P to become available for the crop.

Responses to P applications can occur in the following situations:

- cut areas in landformed fields
- continuous rice crops, particularly after the second or third crop, where no P has been applied to the previous crops
- when insufficient P has been applied to previous crops or pastures.

Phosphorus can improve plant vigour and yield. The P recommendation table (Table 12) indicates application rates. Phosphorus fertiliser can be applied from July onwards to reduce labour demands near rice sowing.

When aerial sowing, P fertiliser is best drilled into the soil, since surface application just before permanent water encourages green algae growth.

When drill sowing, P is best and most economically applied as a compound or starter fertiliser sown with the seed.

Table 12. Phosphorus recommendations.

Soil phosphorus (mg/kg, Colwell test)	Recommended rate (kg P/ha)
0–20	25–30
20–40	20–25
Over 40	nil

Rates

Soil tests give a guide to the likely rice yield response from P. Undertake soil tests 2–3 months before sowing to ensure that the results are back before fertilising.

In rice rotations it is common practice to fertilise winter crops with 125–150 kg/ha DAP or MAP targeting 30–40 mg/kg soil P as a sustainable level of soil fertility in rice-based farming systems.

Responses to P application for Colwell tests of 15–20 mg/kg might be variable. A response might be noticed in crop vigour and growth without any significant increase in grain yield. Test strips are the best way to confirm P responses.

Rice yields in many paddocks are not limited by P when Colwell phosphorus levels are around 20 mg P/kg.

Farmers growing continuous rice should routinely apply 20–25 kg P/ha.

Mid season phosphorus application

Phosphorus fertiliser should preferably be applied before permanent water. If, however, a trial strip shows low P or the crop is showing P deficiency symptoms (e.g. dark green colour, stunting, poor tillering or unexpectedly high NIR nitrogen), then an aerial application of 20–25 kg P/ha (e.g. as DAP) into the water often gives a positive response. Use single superphosphate if S is required in addition to P.

Phosphorus status following rice

When a soil is flooded for rice production, soil P becomes much more available to the rice plants. However, when the soil is drained, it can become severely P deficient. The soil can tie up much of the applied P in this state, causing plant growth problems. For soils with a soil P level (Colwell) greater than 15 mg/kg, apply 20 kg P/ha to winter crops after rice and for soils with a soil P level below 10 mg/kg, apply 40 kg P/ha.

Zinc (Zn)

Deficiency

Seedlings establishing on Zn deficient soils can lose turgidity and lay on the water becoming starved of oxygen. This can happen in aerial sown crops or when permanent water is applied early in a drill sown crop. In drill sown rice, Zn deficiency symptoms often appear within three days of permanent water being applied. Typically, the portion of the leaf nearest the stem becomes light green while the leaf tip remains darker green, but could have bronzing/brown spotting.

Zinc deficiency is most likely to occur in cut and deep fill areas that have not been topsoiled, with high P fertiliser applications, especially where bicarbonates are present, such as calcareous, alkaline soils. Temperatures below 16 ^{0}C at rice establishment can inhibit the translocation of Zn to rice leaves, which will cause Zn deficiency symptoms.

Where Zn deficiency is observed, the field must be quickly drained or the rice plants will die. However, this action puts the crop at risk, as existing N applications are vulnerable to loss through denitrification, and existing weed control strategies are nullified.

Zinc deficiency is best addressed at or before sowing. Soil testing should be considered, especially where symptoms of possible Zn deficiency have previously been observed.

Where soil pH is greater than 6.5 (pHCa), deficiency is possible if the soil Zn level is 0.8 mg/kg or lower. In soils of pH less than 6.5, deficiency is possible with soil Zn levels 0.5 mg/kg or lower.

Where Zn is deficient, apply in a readily plant-available form, close to the rice seed to achieve maximum effectiveness. The seed can be coated with Zn before sowing. Zinc can also be blended with a P- and/or N-based compound fertiliser. Alternatively, zinc sulfate or oxide can be applied at 5–10 kg Zn/ha to the soil. When applied in a fertiliser it is best in a compound fertiliser. Zinc sulfate or oxide is very fine so it does not stay evenly distributed in the blend.

Toxicity

Heavy Zn applications can result in very high soil Zn levels. Toxicity can occur to crop plants at soil levels of 12–26 mg/kg. Therefore, Zn should be applied carefully and soil levels monitored every few years.

Sulfur (S)

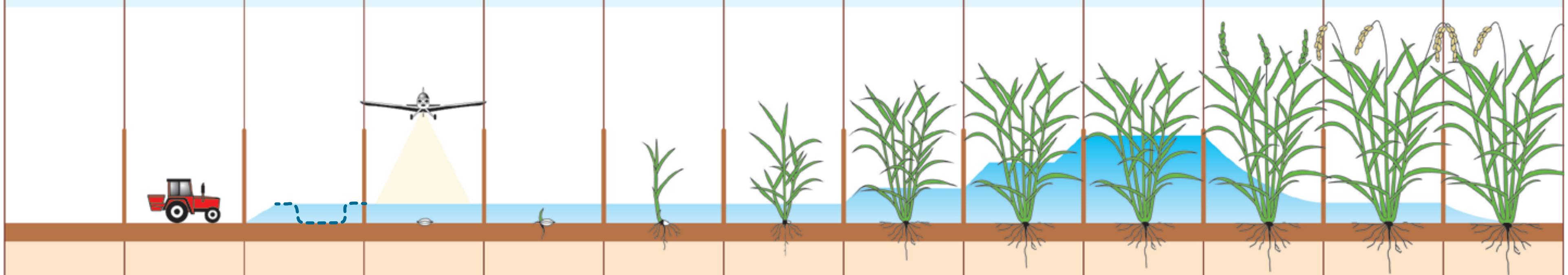
Irrigation water often contains adequate S for most crops. However, deficiencies have been recorded in crops on lighter soils where S-containing fertilisers have not been used in recent years, and where soil S levels are below 5 mg/kg (KCl test).

Sulfur deficiencies have similar plant symptoms to N deficiencies in terms of pale green plant colour. However, S deficiencies show up in the young leaves and N deficiencies show up in the old leaves. Sulfur deficiencies respond quickly to top dressed S in available forms (e.g. single superphosphate or a low rate of gypsum).

Lime

Continuous use of high rates of N fertiliser, along with removing large amounts of grain at harvest, have an acidifying effect on soils. Soil testing will indicate the presence of an acid soil problem and whether lime is required to ameliorate it. Rice yields are rarely influenced by acid soils as the pH temporarily rises during the period of permanent water. However, soil can be permanently damaged if the problem is not addressed and other crops or pastures in the rice rotation will also be adversely affected. A soil pH (pHCa) <5 requires lime application.

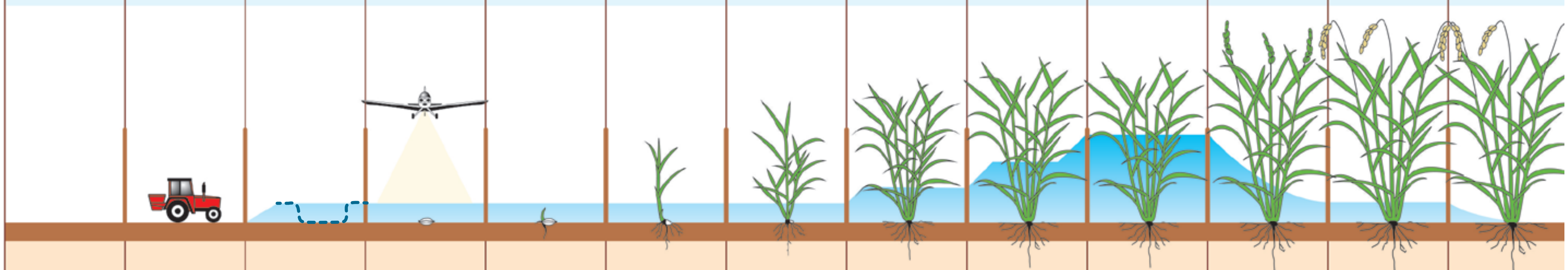
Growth stage of rice				1 leaf	2-5 leaf	2-3 tillers	late tillering	panicle initiation	microspore	flowering	grain filling	physiological maturity
Water level on the high side of the bay			3-5 cm	3-5 cm	3-5 cm	3-5 cm	5-10 cm	10-15 cm	25-30 cm	5 cm plus	3-5 cm	drain
Water management		fill-up or pond			maintain water level	maintain water level	maintain or start to raise water level	raise water level	maintain high water level	allow water level to fall through crop use but maintain at least 5cm cover	maintain minimal water coverage	drain
Comments	broadcast dry seed onto prepared seedbed	shallow depth to encourage establishment and vigorous early growth flushing, draining and re-flooding of dry broadcast seed can improve establishment	sow pre-germinated seed into ponded seedbed	water levels may be higher for specific herbicide management requirements		shallow depth to encourage tillering	tillering is almost complete	water levels are raised to ensure that deep water for microspore is achieved within 10 days after PI	Deep water will help protect the developing panicle from the sterility effects of low temperatures water depth at these stages should not cover more than 50% of the height of the crop	manage water to maintain permanent field coverage and meet crop water demand deep water is not essential	reduce water inflows or lock-up to use surplus water in the bays, minimising the amount of water drained at physiological maturity	maintain water until late dough stage, then drain quickly (in 1-2 days)



- - - - Water management under dry broadcast flush flood system

Figure 35. Stages of crop growth and water management for aerial sown and dry broadcast sown rice. Source: Production of quality rice in south eastern Australia.

Growth stage of rice				1 leaf	2-5 leaf	2-3 tillers	late tillering	panicle initiation	microspore	flowering	grain filling	physiological maturity
Water level on the high side of the bay			3-5 cm	3-5 cm	3-5 cm	3-5 cm	5-10 cm	10-15 cm	25-30 cm	5 cm plus	3-5 cm	drain



Water management		fill-up or pond			maintain water level	maintain water level	maintain or start to raise water level	raise water level	maintain high water level	allow water level to fall through crop use but maintain at least 5cm cover	maintain minimal water coverage	drain
Comments - - - - Water management under dry broadcast flush flood system	broadcast dry seed onto prepared seedbed	shallow depth to encourage establishment and vigorous early growth flushing, draining and re-flooding of dry broadcast seed can improve establishment	sow pre-germinated seed into ponded seedbed	water levels may be higher for specific herbicide management requirements		shallow depth to encourage tillering	tillering is almost complete	water levels are raised to ensure that deep water for microspore is achieved within 10 days after PI	Deep water will help protect the developing panicle from the sterility effects of low temperatures water depth at these stages should not cover more than 50% of the height of the crop	manage water to maintain permanent field coverage and meet crop water demand deep water is not essential	reduce water inflows or lock-up to use surplus water in the bays, minimising the amount of water drained at physiological maturity	maintain water until late dough stage, then drain quickly (in 1-2 days)

Figure 36. Stages of crop growth and water management for drill sown rice. Source: Production of quality rice in south eastern Australia.

Water management

Water management is a critical component of rice growing at all growth stages. Figures 35 and 36 illustrate the growth stages for aerial, broadcast and drill-sown crops.

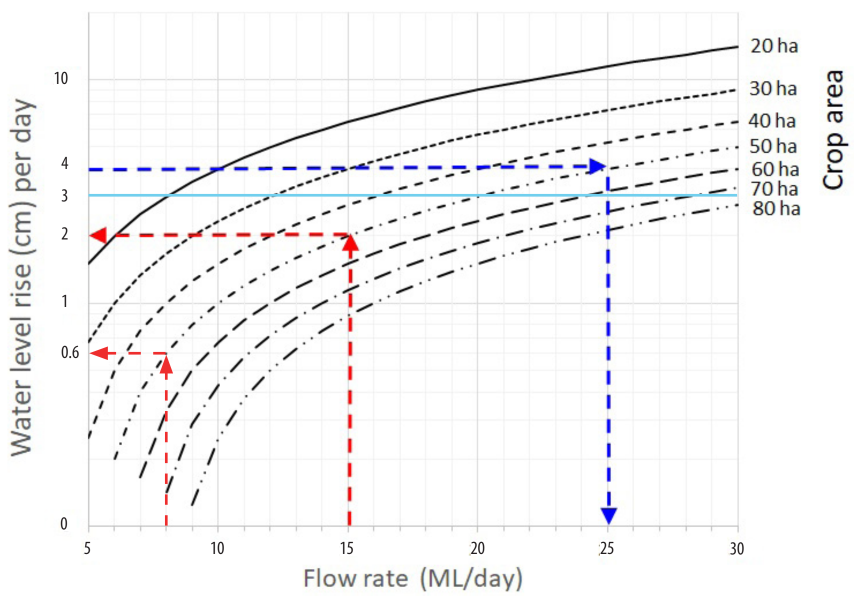
The key water management decision is to decide how much area you are going to plant. This should be based on your available supply flow rate, as this determines how quickly you can raise water levels from panicle initiation (PI) to achieve a water depth of 25–30 cm at microspore. You need to be able to raise your water levels by 20 cm over seven days (i.e. 3 cm/day) during this crop stage with your supply flow rate. Planting a larger area without increasing your flow rates means it will take longer to raise water levels to achieve the desired 25–30 cm at microspore and increases the risk of yield loss from cold temperature.

Figure 33 can be used to determine the maximum planted area for a given supply flow rate assuming 10 mm of crop evapotranspiration and deep drainage.

Water management at establishment and tillering

Rice is a semi-aquatic (i.e. not a true aquatic) plant that grows best in shallow water (Figure 34). During establishment and tillering, the water needs to be deep enough to fully cover the soil surface (to help control weeds), but kept as shallow as practical. Deep water during tillering stresses the rice plants. It can lead to plants having fewer tillers that are taller but with less biomass (growth). This results in taller, spindlier plants with lower yield potential.

Shallow water should be maintained up to PI. Water depth can be increased in late tillering (i.e. just before PI) but only if required this early to ensure deep water at microspore. It is desirable to delay increasing water depth until PI, but only if supply flow rates are high enough to achieve deep water before microspore (see Figure 33 for flow rate guide).



The pale blue horizontal line indicates a water level rise of 3 cm/day. The intersection of this pale blue line with the flow rate shows the maximum area you should plant with that flow rate.
NOTE: these calculations assume that average crop evapotranspiration and deep drainage during the fill-up period is 10 mm/day.

Figure 33. Calculator for estimating the time it will take to fill a given crop area (right axis) by a desired depth of water (left axis) with a given supply flow rate (bottom axis), OR for estimating the flow rate required to fill a given crop area to a desired depth.

Water management at microspore

At microspore, air temperatures below 15–17 °C can damage the developing pollen, leading to floret sterility. Managing water depth to ensure the panicle is covered by water at microspore is critical for protecting the developing panicle from cold-induced floret sterility and potentially large yield losses.

Deep water (>25 cm) is a very effective management tool to minimise damage caused by low temperatures, because water temperatures in bays can be up to 8 °C higher than the air temperature above the water (Figure 15).

The ideal time to achieve the 25 cm target water depth at microspore is approximately seven days after PI, as there are approximately 12–16 days between PI and microspore.

The amount of time required to fill up for microspore will vary for each paddock. Figure 33 can be used to estimate how long it will take to fill your paddocks with a given supply flow rate. For example, if you have a 15 ML/day flow rate (bottom axis) and are filling a 50 ha paddock (right axis), then by following the red arrow you will see that you will raise the water level by 2 cm/day (left axis). If your current water level is 5 cm and you wish to raise it to 25 cm (difference = 20 cm), then it will take you 10 days (20 cm ÷ 2 cm/day). However, if flow restrictions are imposed due to high demand or limited supply channel capacity, and only 8 ML/day is available, then you would only be able to lift water levels by 0.6 cm/day in a 50 ha paddock and it would take you 33 days to achieve a 20 cm lift or 17 days for a 10 cm lift.

You can also use Figure 33 to estimate the supply flow rate needed to lift water levels by a desired amount over a given time. For instance, if you have five days to lift your water 20 cm, then you will need to lift your water levels by 4 cm/ day (20 cm ÷ 5 days). Following the blue line in Figure 33, you will see that you will need a flow rate of 25 ML/day to achieve this in a 50 ha paddock.

Good planning is required, particularly where supply flow rates are likely to affect your ability to lift water levels in time to achieve a depth of 25–30 cm at microspore. If supply flow rates are an issue, you might need to start filling the field earlier than PI. However, raising water levels earlier than PI is not recommended because it increases the plant height and elongates the airspace below the developing panicle. This pushes the panicle higher and if water depths of 25–30 cm are reached too early, then the panicle will be above the water surface at microspore and not protected from cold.

Deep water levels (25 cm) should be maintained during the microspore stage until mid flowering when water levels can be allowed to recede to 5 cm deep until draining. Maintaining water levels of at least 5 cm depth throughout the flowering stage helps reduce the risk of moisture stress.

The question then is how early do I need to start filling up?

Use the PI Predictor to determine the PI dates for each of your paddocks sown and record.

Determine the microspore date for each paddock. This is the start of the cold sensitive reproductive period, which is 16–18 days after PI and record in a table.

Use figures 35 and 36 on the following pages to determine the number of days it will take you to fill your rice paddocks up. This will be dependent on your available flow rates and the increase in water depth required as well as the crop area.

Subtract the time to fill (in days) from your microspore date to determine when you should start filling to ensure water depths of 25–30 cm are achieved before microspore.

An example and template to record your own crops has been provided in Table 13.

GO TO PAGE

PI Predictor (http://pipredictor.sunrice.com.au/)

Figure 34. Flushing, draining and immediately re-flooding dry broadcast seed can improve establishment.

Table 13. Paddock and crop details for microspore water management

Crop details				
Paddock name	P1*	P3		
Variety	Reiziq	Viand		
Date sown	15/10/18	10/11/18		
Area(Ha)	20	40		
Sowing method	Aerial sown	Drill sown, permanent water at 4 leaf stage		
PI date from PI predictor	4/1/19	12/1/19		
Microspore date (12–16 days after PI)	18/1/19	26/1/19		
Water depth at PI (cm)	5	5		
On farm flow rate (ML/day)	12	12		
Days to fill up to 25 cm by microspore (from Figure 33)	4 days	10 days		
Estimated date for a 25cm water depth(assuming water depth lift commenced at PI)	8/1/19	22/1/19		

*Note that P1 and P3 are examples. You can add your own details in the third and fourth columns.

Options when flows are restricted

Options to manage water depth when irrigation supply flows are restricted include:

1. Do not sow more area than you can safely deliver water to between PI and microspore to achieve 25–30 cm water depth. Use the pale blue line in Figure 33 with your flow rate to work this out.
2. Sow different varieties or stagger your sowing dates and methods to spread out microspore.
3. Fill farm water storages leading up to PI to be used to assist paddock fill up after PI.
4. If it will not be possible to achieve 25–30 cm water depth by microspore across the whole crop area, then use Figure 33 to determine the area you will be able to get 25–30 cm deep water on and fill that area to ensure the major portion of your crop is protected from cold. Do not aim for a lower level of water over your whole crop as that will risk 100% of your crop (see Table 5 page 13).

Figure 37. This channel will restrict flow.

Other factors that need to be considered are:

1. Flow restrictions on farm:
   - If head loss from the irrigation outlet to your rice paddock is restricting flow rates, then fill the bottom bay first and work your way back up to the top bay to maximise the percentage of crop that is insulated from cold temperatures.
   - Silted and incorrectly sized pipes, and bay outlets cause flow restrictions on farm. Consider replacing them, removing them or using syphons to increase flow rates.
   - Channels with a high weed burden will restrict flows. Depending on the density consider spraying them before peak flows are required or use an excavator to desilt the channels.
2. Keep an eye on the weather forecasts: colder minimum temperatures are often forecast 7–10 days out.
   If the forecast is predicting minimum temperatures lower than 17 °C then get that water on as quickly as possible.

GO TO PAGES

weather forecasts
(http://www.bom.gov.au/nsw/forecasts/map7day.shtml):

3. Fixed price contracts and varietal premium: Protect higher value crops by prioritising fill-up to achieve 25–30 cm at microspore. Paddocks with higher yield potential will also be higher value crops.
4. Variety: Crops with lower tolerance to cold stress are the highest priority to be protected by 25–30 cm deep water at microspore.
5. Sowing method: drill sown plants are shorter and have panicle development lower to the ground, making it easier to protect the panicle with deep water during microspore.
6. Topdressing rates: When you get your results from your NIR tissue testing, there are two recommendations for topdressing rates. One rate is for deep water at microspore and the other is for shallow water at microspore. If you are unsure of achieving the 25–30 cm water depth consider adopting the lower nitrogen (N) rate and accepting a lower yield.

Depth indicators

Water depth indicators marked from 0–30 cm located on the deep side of every bay near the bay stops will make it easy to assess your water depths and make necessary adjustments to water flows and levels (Figure 38). Problems of shallow or too deep water can be easily detected and rectified using the depth indicators.

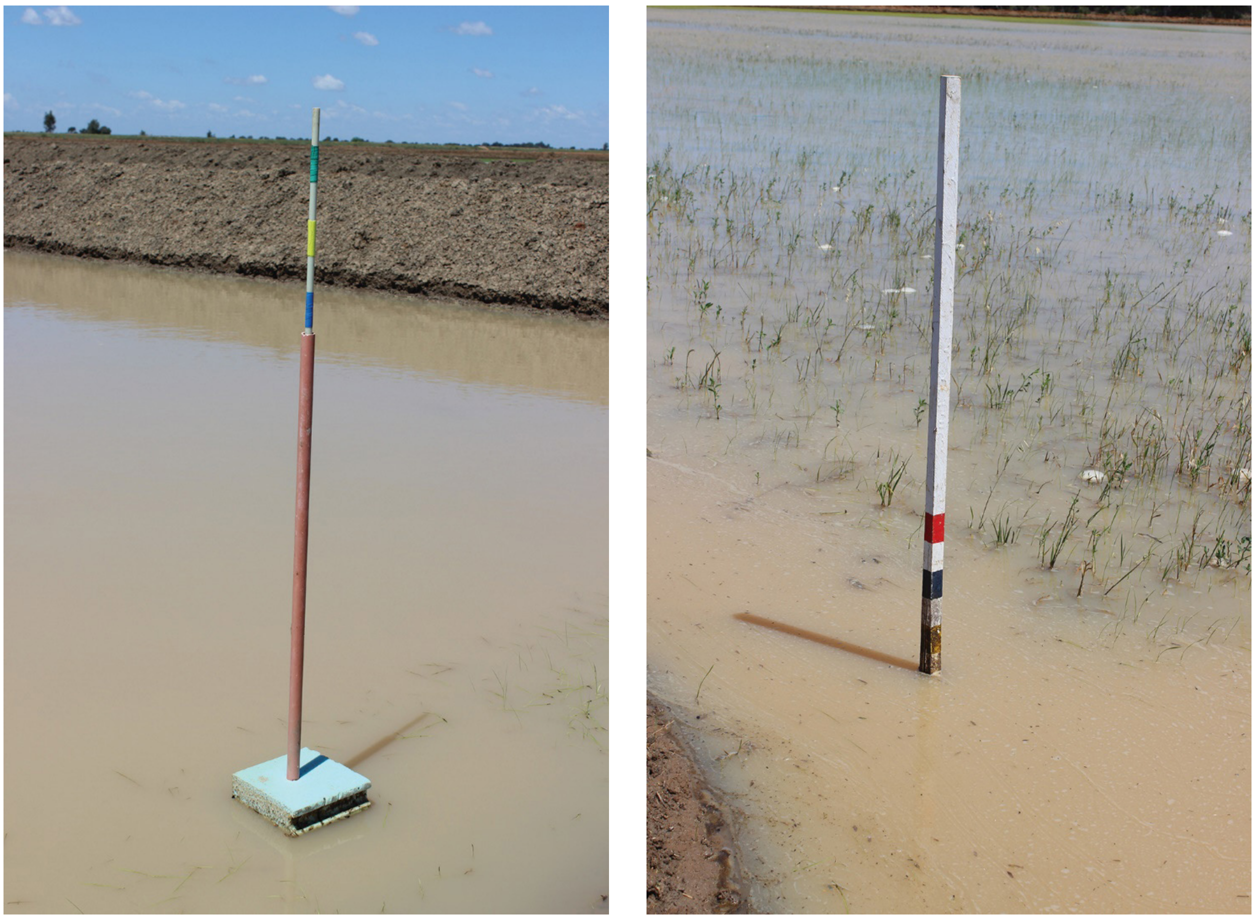


Figure 38. Examples of water floating and static depth indicators.

Water quality

Groundwater irrigators need to be aware that groundwater salts have the potential to reduce crop yields. Salinity tolerance in rice varies considerably with its growth stage. The most sensitive stages are the early seedling stage and the reproductive development stage between PI and flowering. Long grain varieties are more sensitive to salinity than medium grains.

The salinity of the water supply to the rice field should, ideally, not exceed 1 dS/m (640 ppm), particularly during those sensitive seedling and reproductive stages.

Growers should monitor the water salinity at the inlet and in the bottom bay of every layout each week: use a calibrated portable electrical conductivity (EC) meter and keep a record.

Salinity in bays increases because water is lost through evapotranspiration leaving the salts behind. Consequently, the salinity increases down to the next layout and the last, or bottom, bay is always the saltiest.

If the salinity in the bottom bay is approaching 1.5 dS/m during either the seedling stage or between PI and early grain fill, then fresh water should be applied and/or bays flushed to reduce salinity. During tillering and after early grain fill, a threshold salinity of 2 dS/m is acceptable, but this depends on variety, temperature (>35 ^{o}C), and the level of leaching in the particular field.

Mixing channel water with groundwater will reduce the EC of the groundwater – but increase the salinity of the fresh water - in the same proportion as they are mixed. For example, a 10 ML/day flow of channel water mixed with a 10 ML/day flow of groundwater will reduce the groundwater EC by half (i.e. 10 ÷ (10 + 10) = 10/20 = 1/2).

It is better to use different quality waters strategically, rather than just mix them at the same rate through the season. Channel water supplies should be conserved to ensure lower salinity water through the seedling stage (up to 4 leaves), and from PI through to early grain-fill. If using higher salinity water (>1.2 dS/m), it is advisable to flush saline water out of lower bays (and irrigate a salt tolerant crop or pasture) as the season progresses to lower salinity levels.

Delayed permanent water

The practice of delaying the application of permanent water involves extending the period of flushing for drill sown rice, from the normal conventional 3-leaf stage until about two weeks before PI. Delayed permanent water is a useful technique to save water, improving water productivity (t/ML) and profit (see *Delaying permanant eater on drill sown rice*).

Research conducted over four seasons has demonstrated **water savings of 17%** resulting in a **15% increase in water productivity**.

The biggest issues to consider when delaying the application of permanent water to rice are weed control, N fertiliser management and delaying crop development. Weed control is more challenging when the crop is not ponded, but current strategies are proving effective. The *NSW DPI rice crop protection guide* includes delayed permanent water weed control strategies.

Nitrogen should be applied just before permanent water as large losses can occur when N applications are made early in the crop's growth. The greater the moisture stress applied to the rice crop the greater the delay in crop development, therefore delayed permanent water crops should be sown 7–10 days earlier than the planned sowing date of conventionally irrigated drill sown crops of the same variety.

GO TO PAGES

Delaying permanant eater on drill sown rice (https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/summer-crops/rice/dpw)

NSW DPI rice crop protection guide (https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/summer-crops/rice-development-guides/rice-crop-protection-guide)

Factors to consider when draining rice (https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/summer-crops/rice/factors-to-consider-when-draining-rice)

Bitterns in Rice Project (https://www.bitternsinrice.com.au/).

Figure 39. Midseason dry down can alleviate straighthead (right).

Midseason drainage

Midseason drainage is a practice some growers of aerially sown rice have found to be beneficial. It involves draining and drying down bays at the late tillering stage in early to mid December. The rice should remain without water for 70–80 mm of evaporation (typically 10–14 days). Commercial scale demonstrations over four years indicated that this practice can increase yields, particularly on the poorer structured sodic soils. Midseason drainage has been used with success by Western Murray Valley farmers to alleviate 'straighthead' problems (Figure 39; see *Straighthead in Australian rice crops*). Often, substantial yield increases were obtained even though the typical straighthead symptoms were not obvious in the crop. Dry-down can delay flowering by four days, which might or might not influence yield responses in cold years. It is suggested that farmers wishing to test midseason drainage should test the method in one or two bays rather than in a whole crop.

Midseason drained crops usually require spraying for armyworm after re-flooding. The practice does have the positive side effect of controlling the aquatic weed chara, which can otherwise form a dense mat on the soil surface and significantly delay drainage before harvest.

GO TO PAGE

Straighthead in Australian rice crops (https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/summer-crops/rice/straighthead)

Drainage

Rice must not suffer moisture stress before physiological maturity (26–28% grain moisture) or yield and grain quality will be reduced. However, the field should dry out sufficiently for a timely and efficient harvest at high grain moisture (20–22%) with harvest machinery not damaging the soil surface. The speed of draining is determined by field layout, soil type, sowing method, crop N and weather. See the NSW DPI Primefact, *Factors to consider when draining rice* for more information.

Figure 40. It is important to select representative panicles and squeeze the glumes to determine their stage of development.

Table 14. Time of drainage – use as a guide only.

Time of crop maturity	Quick drying field • Landformed • Drill sown • Loam soil	Slow drying field • Contour layout • Aerial sown • Clay soil
Late February to early March	Late dough stage	No milky grains
Early March to mid-March	No milky grains	5% milky grains
Late March to early April	5% milky grains	10-15% milky grains

AUSTRALASIAN BITTERNS

Australasian bitterns will use the habitat provided by rice crops across the Riverina, however, for successful breeding they require crops that are aerial sown or dry broadcast with early ponding. Ponding periods of 130–150 days are required to provide sufficient time for bittern chicks to hatch, grow and fledge before harvest. In addition, grassy or barnyard covered rice banks provide cover and protection from predators, particularly for young birds. For more information see the Bitterns in Rice Project.

Precision agriculture

Farmer knowledge about their fields is the starting point for any precision agriculture (PA) program.

Before you start any PA program, make sure you are getting the basics right first.

Timeliness is key. Achieving all the other rice check is part of growing a profitable rice crop.

PA is not a panacea for poor management, it compliments and gets the best out of good management.

Set targets and define goals

Objective: Reduce variability across the paddock and increase profitability

There are 3 main ways to improve the economics within a field:

1. Maintain inputs and increase profitability.
2. Reduce inputs and increase profitability.
3. Increase inputs and increase profitability.

Any one of these will improve your efficiencies and reduce environmental impact.

Agronomics, economics and mechanics

Agronomically, is what you are trying achieve, worthwhile? Is applying more fertiliser the solution? Determine how much to change the rate of fertiliser by for each zone. The size of the rate step varies by the type of product and concentration. Smaller rate steps are used for fertilisers, whereas larger rate steps are used for soil conditioners and manures. Is 10 kg/ha enough? Maybe 25–30 kg/ha, 50 kg/ha or 0.5 t/ha is an appropriate rate step.

Economics: What is the economic return from applying variable rate inputs, such as manures, urea, phosphorus etc.

Experience has shown that variable rate application (VRA) of nitrogen results in very similar total amounts of fertiliser when compared to a uniform blanket rate across a paddock.

Typically, VRA urea rates can range by 125 kg/ha or more. A blanket rate of 250 kg/ha urea was normally applied. Using VRA, urea rates ranged from 180 kg/ha to 300 kg/ha. The average rate was 249.5 kg/ha. No more was spent on urea, however the crop was much more uniform. The highs and lows had been evened out. See Figure 42, nil strip photos.

Mechanics: VRA has been practiced in the rice industry as long as laser levelling has been used. Traditionally, growers would drive over the cut areas twice, applying extra phosphorus or nitrogen. Automatic rate changes allow for a single application pass.

Do you have the equipment to apply the product? Do you have a narrow or wide swath width? The wider the swath width, the greater potential benefit from section control.

Check your offset to application point distance is set correctly, particularly for spreaders. Many manuals and in screen instructions refer to the offset application point for spreaders as the distance to the spinners. Spreaders typically apply most of the fertiliser over 66–75% of half of the swath width, behind the spinner. Experience has shown this is an ideal offset distance to use.

Example: spread width is 24 m, half is 12 m. 66–75% of 12 m = 8–9 m behind the spinners. If this offset is not correct, you will see under-fertilised areas as you approach a headland due to the spreader shutting off early. Inversely, you will see over-fertilised areas in the headlands as the spreader is turning on too early.

How evenly are you applying product?: Fertiliser spreaders have become common and provide a simple way of applying variable rate fertiliser. This can create issues if they are not set up correctly. Even a well set up spreader has a coefficient of variation (CV) of 10–15%.

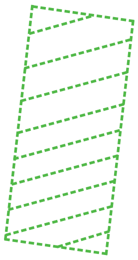
Example: spreading 200 kg/ha, is applying 170–230 kg/ha of urea across the swath width of the spreader. Range 60 kg/ha.

If you are changing urea rates by 25–30 kg/ha, there is double the variation in rate across the spreader than the rate changes being made.

Field layout: section control

Square field. Square bays vs angled bays.

This field has a rectangular shape, however, the internal layout results in 25–30 % overlap (Figure 41). This would benefit greatly from section control.



Precision agriculture is an extension of normal farming practices. Instead of managing a field as a single unit, the field is managed as zones. Each zone is managed according to the best agronomic practices for that area.

Farm records and data are recorded spatially, which is very different to traditional record keeping where there is only one recorded rate for a paddock.

Figure 41. Rectangular field with overlap.

Farming businesses are more sustainable through:

- improved economics. If a business is not profitable it cannot be sustainable.
- improved agronomy, through matching inputs to crop needs, leading to efficiency and productivity improvements.
- reduced environmental impacts from farming, through better resource management.

Rice yields vary greatly within fields. It is common for yield to vary by 3–4 t/ha or more within a field. This equates to $1400 +/ha. Calibrated yield data is important to quantify the economic variability within a field and quantify any response to variable rate treatments. However, yield might not be the best indicator of input efficiency such as nitrogen. Assessing crop maturity and evenness pre-harvest can be a simple way of a reviewing nitrogen application effectiveness.

Imagery

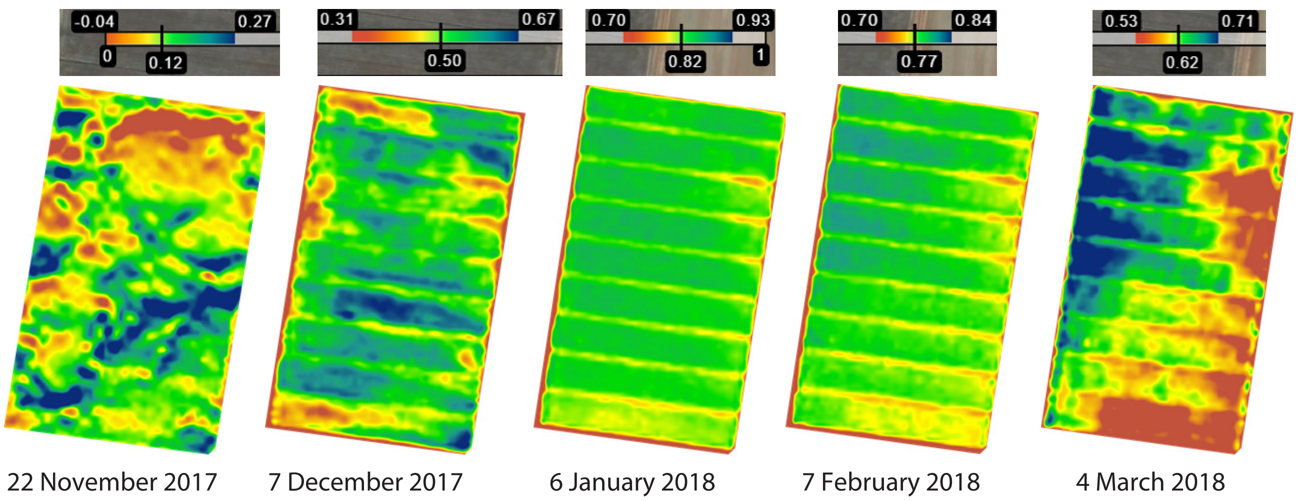


Figure 42. Normalised distance vegetation index changes over time.

These five images sourced through Data Farming, show how normalised distance vegetation index (NDVI) changes over time (Figure 42). NDVI is a mix of crop health, biomass/vigour and greenness. Red is low NDVI and blue is high. The scale is not fixed, so the colours and classification only apply to that image. Therefore, red in one image does not represent red in another image, the same applies for blue.

The November and mid December images are quite different from the images in early January. Mid season NDVI imagery does not express variation in the crop's nitrogen status at PI as the imagery is saturated by the high biomass levels. NDRE imagery is required to show differences in rice at this stage.

Around panicle initiation (PI), the crop appears relatively uniform, however, as the crop matures distinct zones appear. By March the differences in the crop have become very obvious. The March image is probably the most useful as it represents maturity or the uneven maturity across the paddock–. In this case the red area matured early and was ready to harvest 3-4 weeks before the blue. The red areas were under-fertilised and the blue area was rank and over fertilised.

As a result of the uneven maturity, water was held on the paddock longer to allow the blue areas to fill properly and not hay off. At the same time the red area has stopped using water. The grain is much dryer and more prone to cracking and low whole grain mill out (WGM). The red areas are boggy, making harvest more difficult and requiring more ground preparation next year.

The imagery reflects the paddock's cut and fill zones. The grower knew where they were, but the imagery helps define the spatial zones and where in the paddock the rates should be changed. Ground truthing, was used to quantify the difference between the zones.

Imagery needs careful interpretation. Factors that affect the quality can include:

- plant stand
- variations in crop population
- water depth and turbidity
- growth stage
- variety.

Low NDVI values can occur where the crop is thin, with vigorous robust plants. There can also be low NDVI where the crop is thicker, yellow (nitrogen deficient) and lacks vigour and biomass. It is important to understand what is driving the low NDVI. Those areas could have vastly different nitrogen requirements.

The best resolution for imagery varies depending on the purpose. High resolution <1m is useful for targeting NIR tissue sampling sites, whereas low resolution (10–30 m) is better when zoning for applying fertiliser as it better matches the common application widths.

A new index has been evaluated normalised difference red edge (NDRE). This can identify variations in nitrogen better than NDVI.

A yield variation of 4 t/ha does not provide the complete picture. Grain moisture by the truckload can mask the true variability of grain moisture within a paddock. Grain moisture can range from <10% to >24%. Low grain moisture is associated with low (WGM) whole grain millout. Variable rate fertiliser application has the potential to increase both yield and quality.

Topography and elevation/real time kinematic (RTK)

RTK global navigation satellite system (GNSS) collects elevation data as coverage is logged across the paddock. This data has the potential to model elevation and identify high and low areas across bays.

Caution: low areas can be caused by soft soil and tractors sinking in.

CAUTION

Low areas can be caused by soft soil and tractors sinking in.

The best elevation data is collected when driving over firm ground. Elevation data from non RTK GNSS receivers, is not of a high enough quality to be used.

High areas affect your ability to achieve deep water at microspore. As a result, less nitrogen should be applied in line with the guidelines for low–medium water, until the problem is rectified either by land forming or higher water stops.

Low spots in paddocks pose an establishment problem, particularly in drill sown rice, where the seedling rice is prone to drowning. These low spots can be thin or bare, which creates an opportunity for ducks to move in often leading to bigger barer patches.

Yield data

The analysis is only as good as the data. Data from poorly calibrated yield monitors CANNOT be fixed after harvest.

Both the moisture sensor and mass flow sensor need to be checked.

CAUTION : DATA

Garbage in = garbage out

Pre harvest setup

Either using software or on the screen itself, enter all the farms and fields. With software, a range of other features can be loaded, such as field boundaries, AB guidance lines and obstacles/map features.

A yield map only shows variation in yield, it does not have any contextual data to help understand why the yield varies. Setting up mapping features and having a skilled harvester operator is important. Many screens come with default options, such as rocks, gates etc. These can be customised and renamed to more appropriate tags such as:

- thin crop
- BYG, broad leaf weeds
- over fertilised
- blown
- under fertilised
- duck damage
- lodged
- boggy etc.

Different monitors have different configurations, but are all able to log these observations. This information can be critical in understanding why yield was low.

Section control and GNSS accuracy affects yield

Typically, harvesters have the lowest quality GNSS correction. If section control for the front is active, poor quality GNSS can turn sections off when the harvester is cutting a full swath. This results in artificially higher yield and noisy data.

Test strips

Small unfertilised areas are useful for assessing the background fertility in a zone. Although it is not possible to collect yield data, they are extremely useful when combined with NIR tissue tests.

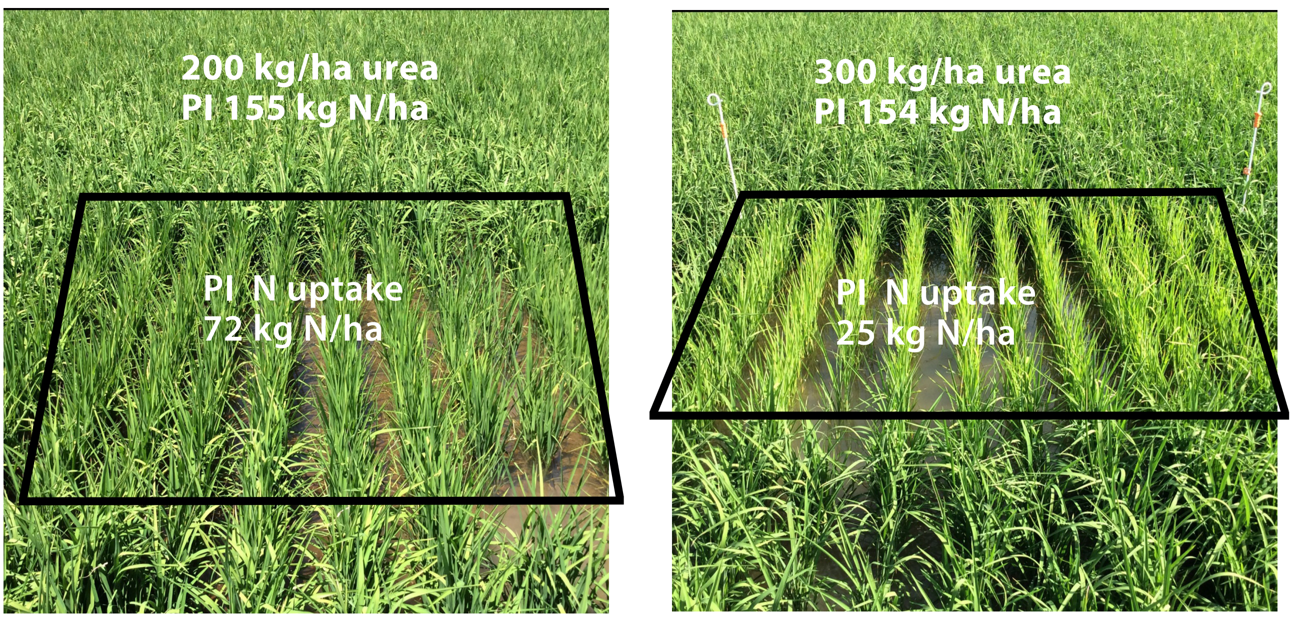


Figure 43. NIR tissue tests at panicle initiation are useful to determine fertilisation needs.

The above nil strips were achieved by placing a tarp on the ground in front of spreading urea before permanent water. Following up with an NIR tissue test helps quantify the background fertility. Although there is 100 kg/ha difference in the crop's applied urea rate, the PI nitrogen uptake is the same for both management zones (Figure 43).

Summary

Don't over think it. Keep it simple.

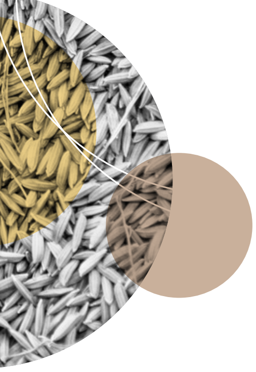
It is more important to make a start. You don't need to get every area 100% right. Compared with blanket rate applications, up to 50% of the paddock could be getting the wrong rate. You are aiming to reduce that to 10–15%.

If you don't get it right this season, you can make improvements for next season. Make notes as to where you would increase/decrease urea and by how much. Refer to these notes for the next crop.

Any VRA should match your understanding of the paddock.

REMEMBER

Hindsight becomes foresight.



Production of quality rice

Grain quality

Australian produced rice is prized for its superior quality with traits purposefully selected to access premium markets. Opportunities to enhance grain quality are sought at every step from varietal development to product supply chain. While the developed varieties are genetically improved for desired quality traits, the grower, management and the environment also play important roles in dictating the final quality. In particular, what variety to grow, sowing rate, crop nutrition, irrigation management and time of harvest, as well as harvest and transport processes, can all influence your rice crop's the quality and profit.

To maintain Australia's reputation for producing premium quality rice, the industry has adopted a price incentive and discount policy for the incoming paddy quality (Table 16).

Table 15. Summarised from the SunRice Circular for 2021/22 'Paddy quality specification and discounts'.

Quality criteria	Description	Incentive/penalty
Paddy moisture	Less than 22%	$1.00/tonne discount for every 0.1% above 22.0% moisture for up to 100 t and discount of $3.00/tonne for every 0.1% above the 22.0% moisture to additional tonnes.
Stackburnt paddy	Should be NIL	If declared at delivery, a discount of $10.00/tonne per 0.05% stackburnt paddy. If not declared at delivery, the discount is double.
Mixed paddy	Mixed variety, other variety	Various discounts based on the varieties
Mild shot and sprung paddy	More than 3 grains in a 25-g sample have a dark coloured embryo with or without desiccated sprout that are no longer than half the length of grain	If declared at delivery, discount of $3.00/tonne If not declared at delivery, discount of $7.00/tonne
Seriously shot and sprung paddy	More than 3 grains in a 25 g sample have a dark coloured embryo with desiccated sprout that are longer than half the length of grain	If declared at delivery, the price will be equivalent to the stockfeed quality. If not declared at delivery, discount of 10% of total payment
Paddy contaminated with glass	The specification is NIL	If declared at delivery, discount of $50.00/tonne/piece. If not declared at delivery, discount up to $100.00/tonne .
Paddy contaminated with foreign matters	Seeds, fertiliser, stones, metal	If declared at delivery, discount of $5.00/tonne for the first two pieces and $1.00/tonne thereafter to a maximum of $30.00/tonne applies. If not declared at delivery, discount of $10.00/tonne for the first two pieces and $3.00/tonne thereafter to a maximum of $100.00/tonne applies.
	Burrs, mud, dirt, stored grain insects	If declared at delivery, discount of $1.00/tonne for the first two pieces and $1.00/tonne thereafter to a maximum of $5.00/tonne applies. If not declared at delivery, discount of $3.00/tonne for the first two pieces and $2.00/tonne thereafter to a maximum of $10.00/tonne applies.
	Excessive trash	For each 0.1% higher trash above 1.5%, a discount of $0.20/tonne.
Whole grain yield	1% higher than variety average	$2.00/tonne premium.
	2.5% lower than variety average	$2.00/tonne discount.
Colour of dehulled and milled rice	Colour of milled rice	For a slightly grey milled rice, a discount of $7.00/tonne For very grey milled rice, a discount of $14.00/tonne
	Discoloured brown rice	Maximum $13.00/tonne for stained kernels

Source: SunRice (https://www.sunrice.com.au/media/documents/2021_22_Quality_Specifications_and_Discounts.pdf)

Quality evaluation program

In the NSW DPI rice quality evaluation program, up to 7000 breeding lines are objectively measured each year for a combination of traits specific for certain rice quality types. Traits include:

- **Whole grain yield (WGY)** – also known as head rice yield, it is the percentage of whole white rice obtained from clean paddy rice. This is an important quality attribute because rice is sold as intact kernels to consumers, whereas broken grains are generally regarded as low value. Therefore, producing whole grain rice is critical to the farmers who are paid according the whole grain yield of the product supplied. There are several factors that affect whole grain yield. Among these, the most important is crack formation in the rice grain before milling. The paddy dries in the field cracks and eventually produces broken grains.

- **Chalkiness:** chalk is an opaque area on the grain surface (Figure 44). It is generally not desirable except in Arborio and Saki style grains. Chalky grains are prone to breakage during milling, which often results in a mushy texture when cooked. In quality evaluation, image analysis is used to measure and calculate the chalk percentage.

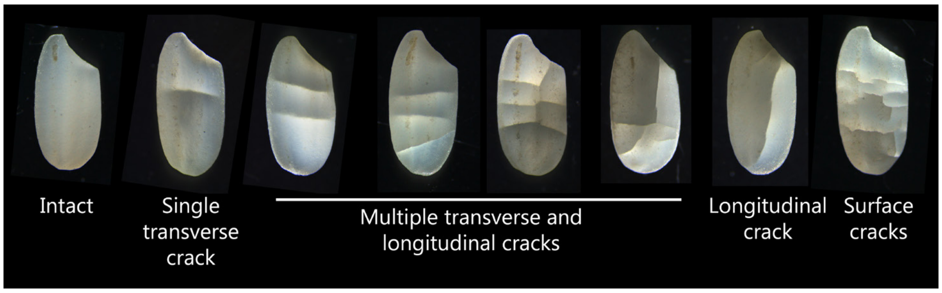


Figure 44. Chalkiness in rice. From left: non chalky or translucent grain, the grain with dorsal chalkiness, white core in the centre, grain with 'white belly', grain having a big chalky area on the surface (milky), and the grain with full chalk area (opaque). All the grains were from the variety Sherpa⏀.

- **Milled grain colour** – milled rice can appear yellow or grey, and can change during storage (Figure 45). Consumer markets require grain that has a high degree of whiteness with high translucency. Grain colour and translucency are affected by nitrogen fertiliser, stack burn, infestation and lodging. A spectrophotometer is used in the quality evaluation program to measure the colour; overall colour is expressed as a whiteness, redness and yellowness value.

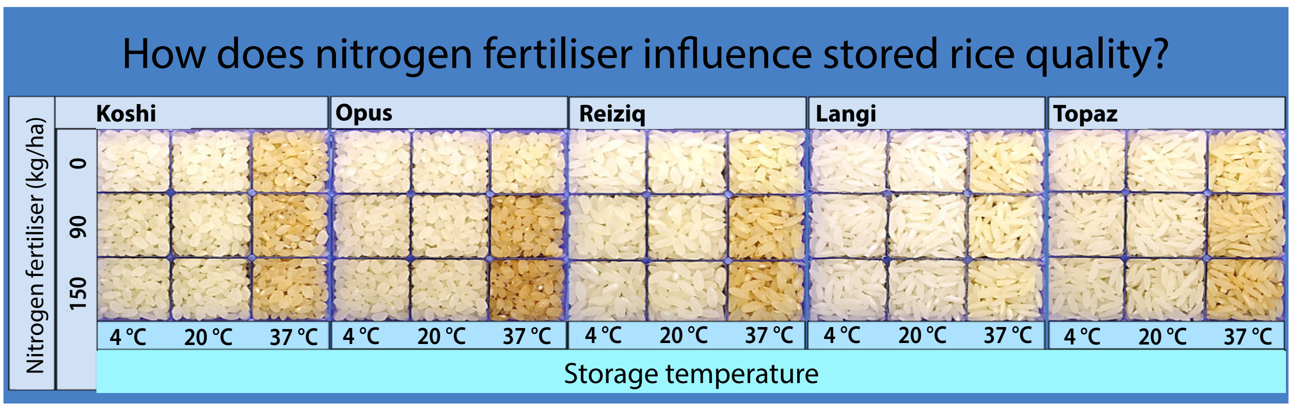


Figure 45. Milled rice colour of five rice varieties after nine months of storage at 4, 20 and 37 °C. The grains that were produced with a high nitrogen level (on bottom row) discoloured faster than the grains produced with optimum or no nitrogen.

- **Grain dimension** – is described by the length, width and thickness of milled grain. Rice is marketed by length – short, medium or long grain and shape – such as slender, bold or round. Shape is defined by the ratio of length and width. The Australian premium variety Reiziq⏀ is classed as a bold medium grain. Dimension uniformity is an important aspect of quality control. For example, consumers will not accept a mixture of long and medium grains in premium quality rice. Mixing different varieties during harvesting and not cleaning the header properly when changing variety can cause a mix of grain sizes and shapes. Inadequate nutrition and pest infestations also cause poorly-shaped grains.
- **Cooking properties** – Cooking properties determine the type of market the grain will target. In the quality evaluation process, a variety's cooking properties are determined by analysing the amylose content, gelatinisation temperature, viscosity during heating, texture, water absorption ratio, elongation ratio, flavour and aroma. In addition, sensory evaluation is also used to determine more realistic cooking and sensorial properties.

Grower management in maintaining the quality

Grain moisture decline

The rate at which grain dries during ripening determines the percentage of the whole grain. Weather conditions, time of sowing date and drainage practices are major influences on grain moisture decline.

Harvesting in mild conditions with low temperatures and low evaporation rates will allow the crop to dry slowly. Where temperatures are high and evaporation is greater than 2 mm (March evaporation averages 6 mm), crops will dry quickly, grain moisture can fall at 0.5% per day for moist soils and at 1% per day for dry soils. Farmers need to closely monitor grain moisture under these conditions.

Wetting and drying grain after rain or heavy dews is known to increase grain cracking and reduce whole grain yield.

Harvest as close as possible to 22% moisture level. Whole grain yield will be maximised by harvesting at 18–22% moisture. Once the grain is delivered and stored under a controlled dry down process the chance of stress cracking is virtually eliminated. Also, at the lower moisture levels (less than around 16%) mechanical damage through the header and handling machinery can significantly affect quality.

Time of sowing

Sowing at the recommended time for each variety will help place the grain ripening stage and harvesting into the milder April period. Be aware that April can still have spikes of hot weather with high daily evaporation, which will cause grain cracking and decline in WGY, especially if harvest moisture is below 18%.

Aim for a uniform crop

Fields with good layout and levelling will allow even establishment and water control resulting in a uniformly maturing crop at harvest time.

Varietal harvesting order

If at similar moisture contents, medium grain varieties, Reiziq⏀, Sherpa⏀, and Viand⏀ should be harvested before long grain varieties, as WGY declines in faster. Harvesting Reiziq⏀ and Langi should not be delayed due to shedding risk. Delaying harvest could lead to lodging and stress cracking problems with Koshihikari.

Nitrogen management

Growing rice at the optimum N levels will maximise WGY because the crop will mature later in cooler conditions than a crop with low N. High N levels can delay crop maturity and cause lodging. However, using excess N in short grain types deteriorates storage and cooking quality of rice (Figure 45).

Draining

Draining at the right time is very important for achieving high grain quality. Draining too early can result in the crop haying off, which will cause WGY, grain quality and total yield to decline. Draining too late might mean the paddock is too wet and harvest will be delayed beyond the optimal moisture content for the highest grain quality (figures 46 and 47)

Quality assurance

Consumers expect rice to be:

- true to type
- clean
- free from:
  - discolouration
  - off-flavours
  - chemical residues
  - foreign matter.

Farmers have a responsibility to harvest and deliver paddy grain that can meet the food safety and quality standards. There are quality assurance programs in place within the NSW rice industry to ensure that those standards are met.

There are several quality specifications that can affect your harvest return including:

- contamination with foreign material (high penalties for glass, metal, fertiliser and insect contamination)
- discolouring
- excessive trash
- high moisture
- stackburnt paddy
- shot and sprung paddy.

During harvest, it is vital to take particular care with harvester cleaning and setup, and monitoring operations to ensure minimum discounts apply to payments. Clean headers, bins and trucks before harvest to prevent weed, insect and varietal contamination.

Variety purity

Grain samples must be free of other varieties. It is important to consider paddy quality when placing your seed order. If you plan to sow on the stubble of last season's crop, please order the same variety or an approved variety to avoid admixture.

Withholding periods

Be aware and comply with harvest withholding periods when applying agricultural chemicals. SunRice regularly tests rice grain for chemical residues to ensure levels are below maximum residue limits.

So what can you do to improve whole grain yield (WGY)?

Variety and seasonal influences are excluded from WGY appraisals discounts and premiums as the annual variety average is used as the base price. But what is in your control?

Drain on time: Haying-off the crop is extremely detrimental to grain yield, quality and WGY. When draining be aware that fields will dry quicker in March than April; heavy clay soil will dry slower; drill sown will be quicker than aerial; and landformed in beds will dry faster than contour layouts. Watch the weather forecast for possible hot dry spells or cooler conditions for drying.

Harvest on time: Between 18% and 22% moisture. Grain will suffer less cracking stress under controlled drying in the shed than after delivery to the storage shed. Mechanical damage during harvesting operations will be more severe if grain is drier.

Sow within the planting window: Aim to harvest in the milder April period.

Aim for a uniform crop: Even establishment and water control will prevent uneven ripening at harvest.

Delivery moisture affects the whole grain yield

The whole grain yield of long grains is more consistent than medium grains as the effect of lower delivery moisture is not as detrimental. The effect of moisture on the short grain varieties is less than on medium grains (Figure 46) and more severe than for long grains (Figure 47).

Grain delivered at between 18% and 22% moisture achieved higher whole grain yield %. When the delivery moisture of medium grain percentage is below 18%, the whole grain yield is less likely to be high. The orange points are Grower example 1. The purple point is Grower example 2.

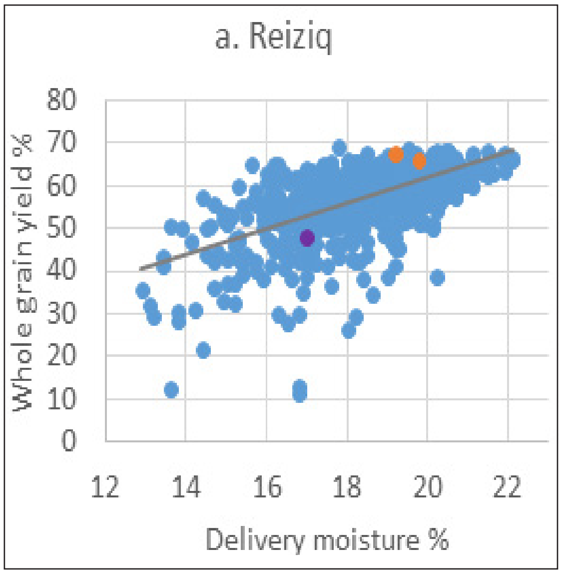


Figure 46. The effect of delivery moisture on whole grain yield of Reiziq(l) in the 2016–17 season. Grain delivered at between 18% and 22% moisture achieved a higher whole grain yield (%).

Grower example 1: Excellent whole grain yield

Variety: Reiziq(l) (whole grain yield average 2016/17: 56.1%)

Grower whole grain yield: 65.7 to 67.4%

Deliver moisture: all above 18%

The crop was harvested quickly, over 2000 tonnes delivered within seven days. Two headers were used during the peak periods to get the crop off before rain.

Grower example 2: Rain on dry crop increases grain moisture however this still resulted in poor whole grain yield

Variety: Reiziq(l) (whole grain yield average 2016/17: 56.1%)

Grower whole grain yield: 47.6%

This crop has a low starting moisture of 14.2% followed by 50 mm rain.

Rain increases the moisture so even though the majority of the grain was delivered between 16 and 18% moisture, this was an after-rain induced moisture. The dry grain absorbed moisture during the rain events and research shows this induces cracking.

Had harvest started at a higher grain moisture earlier in April, then the majority of the harvest could have been delivered at higher moisture and before the April rain event.

The crop was drained too late, which delayed harvest.

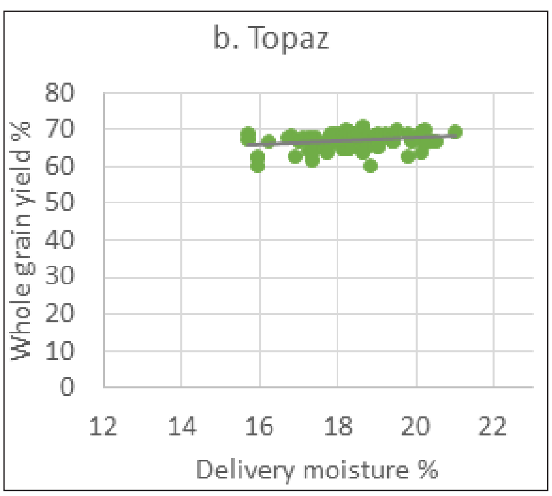


Figure 47. Effect of delivery moisture on whole grain yield of Topaz(l) in the 2016–17 season. The whole grain yield of long grains is more consistent than medium grains as the effect of lower delivery moisture is not as detrimental.

Business of rice growing

Decision making in your farm business

Each season, growers make decisions around what crops to grow, the area of each crop, how much water is required and how much the water costs. Understanding how to calculate the price of water, crop gross margins and sensitivity analysis to determine risk are essential for making the best decision for your business.

Each rice farming business is different. They vary in size, enterprise mix, location, structure, resource availability, equity and capital. Therefore, it is important that you understand your own numbers. Rice Extension's Rice $cenario is a web-based tool you can use to enter your own numbers to help in making water purchase, crop mix and risk management decisions. If your computing skills are not great, work within this book by using the following hard copy templates from Rice$cenario (starting at page 48).

Water budgeting

Calculating the real cost of water in your gross margin is important to help you determine your enterprise mix. Many growers will use the temporary water price only in their gross margin. Others will decide which crops they are assigning their purchased and allocated water to. Some advisors think an average purchased water cost is a better indicator. What is most important is that you use a consistent process from crop to crop or between years. The average purchase water cost assigns the cost of the water purchased and the water allocated consistently across all cropping enterprises grown within the irrigation year.

An example of calculating the average purchase water price is provided in the template on page 48. Enter your own figures in the shaded areas.

Fixed costs are not included in calculating this water price because they are accounted for in the overhead costs of managing the business.

Gross margins

Gross margins are used to compare the relative profitability of different farm management practices and similar enterprises. They consequently provide a starting point to decide or alter the farm's management practices or overall enterprise mix. A gross margin can be defined as the gross income from an enterprise less the variable costs incurred in achieving that income.

A gross margin includes only the variable costs of your farm business. Variable costs are costs directly attributable to an enterprise and which vary in proportion to the size of an enterprise. For example, if double the area of rice is sown, then the variable costs associated with growing the extra area, such as seed, chemicals and fertiliser will also roughly double.

A gross margin is not net profit because it does not include fixed or overhead costs such as depreciation, interest payments, rates, permanent labour or fixed water costs, which have to be met regardless of enterprise size or mix.

Gross margins are generally quoted per unit of the most limiting resource, e.g. land (per ha) or irrigation water (per ML).

Gross margins need to be used carefully. As overhead costs are excluded, it is advisable to only make comparisons of gross margins between enterprises that use similar resources. If major changes are being considered, more comprehensive budgeting techniques such as cash flow budgeting, profit and loss statements, cost of production and balance sheets are required. Details of these budgeting techniques can be found in Chapter 16 of *Production of Quality Rice in South Eastern Australia*. For more detailed budgeting see the Farming the business manual from GRDC.

GO TO PAGES

Rice $cenario
(http://ricescenario.sunrice.com.au./)

Production of Quality Rice in South Eastern Australia
(https://ret.sunrice.com.au/DocumentsAndForms/Production%20of%20Quality%20Rice%20in%20South%20Eastern%20Australia%20-%20Copy.pdf)

Farming the business
(https://grdc.com.au/resources-and-publications/all-publications/publications/2015/01/farming-the-business-manual)

GROSS MARGINS

Gross margins are a valuable aid in farm planning, but they should be by no means the sole determinant of enterprise mix.

Please note that in the following examples the gross margins (tables 18–20 on pages 49–51) are designed to represent 'average case scenarios'. They should be used as a guide only. We recommend that you put in your own costs to match your own situation in the blank lines provided. Add or delete operations and/or inputs if necessary.

These gross margin examples are GST exclusive. Prices are based on contract rates and the latest available input costs as of the time of printing.

Table 16. An example of calculating the average water price. Enter your figures in the shaded areas.

Calculate your water allocation in ML before purchases		
Water entitlement × allocation %	1500 × 65% = 975	(A)
Carryover	365	(B)
Delivery efficiency	60	(C)
Total available water before purchases (A + B + C)	1400	(D)

Calculate your water requirement for your planned cropping program						
Crop	**Area (ha)**		**Estimated use (ML/ha)**		**Total ML**	
Rice	120		13		120 × 13 = 1560	(E)
Wheat	120		2		120 × 2 = 240	(F)
Barley						(G)
Canola						(H)
Other						(I)
Total water required (ML) (E + F + G +H + I)					1800	(J)
Water budget (D–J)					**–400**	**(K)**

If the water budget (L) is negative, you will need to calculate the cost of water purchases						
Water purchase	**ML**		**$/ML**		**Total price (ML x $ / ML)**	
Purchase 1	200		$110		200 × $110 = $22,000	(L)
Purchase 2	200		$130		200 x $130 = $26,000	(M)
Total water purchases					**$48,000**	**(N)**

Variable water charges						
	ML (J)		**$ / ML**		**Total price (ML x $ / ML)**	
Irrigation company and/or government charges	1800		$11		1800 × $11 = $19,800	(O)
Total variable water cost (N +O)					$48,000 + $19,800 = $67,800	(P)
Total variable water cost / ML (P ÷ J) (Total water costs ÷ number of ML used)					$67,800 ÷ 1800 = **$38.00**	

Table 17. Example gross margin for drill sown Reiziq$^{\Phi}$, Langi and Opus$^{\Phi}$.
Add in your own figures in the 'Your estimate' column.

	Rate/ha	Price	Reiziq	Langi	Opus	Your estimate
INCOME						
Price per tonne*			$400	$430	$415	
Yield @ 14% moisture**	t/ha		11	9.5	10.5	
Gross income per hectare			**$4,400**	**$4,085**	**$4,358**	
VARIABLE COSTS						
OPERATIONS * **						
Disc	0.45 hrs	$100/hr	$45	$45	$45	
Grader board	0.25 hrs	$100/hr	$25	$25	$25	
Ground spray	0.1hrs	$100/hr	$10	$10	$10	
Drill fertiliser and seed	0.45 hrs	$100/hr	$45	$45	$45	
Reform banks	0.25 hrs	$100/hr	$25	$25	$25	
Ground spray	0.1 hrs	$100/hr	$10	$10	$10	
Broadcast fertiliser	0.1 hrs	$100/hr	$10	$10	$10	
Aerial topdress			$27	$27	$27	
Harvest @ 20% moisture		$25/t	$296	$255	$282	
Fuel			$34	$34	$34	
Field bin/tractor @ 20% moisture		$4/t	$47	$41	$45	
Cartage @ 20% moisture		$15/t	$177	$153	$169	
SEED	Reiziq 150 kg Langi 130 kg Opus 120 kg	$508/t $563/t $528/t	$76	$73	$63	
FERTILISER						
Urea 1st application	275 kg	$520/t	$143	$143	$143	
Urea 2nd applicaton	75 kg	$520/t	$39	$39	$39	
MAP	120 kg	$700/t	$84	$84	$84	
HERBICIDE						
Glyphosate	1 L	$5/L	$5	$5	$5	
Gramoxone	0.8 L	$7/L	$6	$6	$6	
Magister	0.5 L	$72L	$36	$36	$36	
Stomp	3.4 L	$11/L	$37	$37	$37	
IRRIGATION						
Variable water charges	11.5 ML	$10/ML	$115	$115	$115	
Purchased water cost						
OTHER						
Insurance		$3/t	$33	$29	$32	
Levies		$3/t	$33	$29	$32	
TOTAL VARIABLE COSTS PER HA			**$1,358**	**$1,275**	**$1,319**	
GROSS MARGIN PER HA			**$3,042**	**$2,810**	**$3,039**	
GROSS MARGIN PER ML			**$264**	**$244**	**$264**	

* Price is based on the contract prices for Reiziq$^{\Phi}$ Langi and Opus$^{\Phi}$ at the time of writing.
** Yield is based on the 5-year average for each variety.
*** Contract rates are used.

Table 18. Example gross margin for aerial sown Reiziq(b), Langi and Opus(b).
Add in your own figures in the 'Your estimate' column.

	Rate/ha	Price	Reiziq	Langi	Opus	Your estimate
INCOME						
Price per tonne*			$400	$430	$415	
Yield @ 14% moisture*	t/ha		11.0	9.5	10.5	
Gross income per hectare			$4,400	$4,085	$4,358	
VARIABLE COSTS						
OPERATIONS***						
Disc	0.45 hrs	$100/hr	$45	$45	$45	
Grader board	0.25 hrs	$100/hr	$25	$25	$25	
Ground spray	0.1 hrs	$100/hr	$10	$10	$10	
Drill fertiliser	0.45 hrs	$100/hr	$45	$45	$45	
Reform banks	0.25 hrs	$100/hr	$25	$25	$25	
Ridge roll	0.2 hrs	$100/hr	$20	$20	$20	
Aerial sow	150kg	$0.36/kg	$54	$54	$54	
Aerial spray			$21	$21	$21	
Aerial spray			$21	$21	$21	
Aerial topdress			$27	$27	$27	
Harvest @ 20% moisture		$25/t	$296	$255	$282	
Fuel			$34	$34	$34	
Field bin/tractor @ 20% moisture		$4/t	$47	$41	$45	
Cartage @ 20% moisture		$15/t	$177	$153	$169	
SEED	Reiziq 150 kg Langi 130 kg Opus 120 kg	$508/t $563/t $528/t	$76	$73	$63	
FERTILISER						
Urea 1st application	275kg	$520/t	$143	$143	$143	
Urea 2nd applicaton	75kg	$520/t	$39	$39	$39	
MAP	120KG	$700/t	$84	$84	$84	
HERBICIDE / INSECTICIDE						
Glyphosate	1L	$5/L	$5	$5	$5	
Taipan	2L	$71/L	$142	$142	$142	
Molinate	3.5L	$34/L	$119	$119	$119	
MPCA	2.7L	$7/L	$19	$19	$19	
Lorsban	0.15L	$33/L	$5	$5	$5	
Dominex	0.1L	$8/L	$1	$1	$1	
IRRIGATION						
Variable water charges	13ML	$10/ML	$130	$130	$130	
Purchased water cost						
OTHER						
Insurance		$3/t	$33	$29	$32	
Duck control			$5	$5	$5	
Levies		$3/t	$33	$29	$32	
TOTAL VARIABLE COSTS PER HA			**$1,681**	**$1,598**	**$1,641**	
GROSS MARGIN PER HA			**$2,719**	**$2,487**	**$2,716**	
GROSS MARGIN PER ML			**$209**	**$191**	**$209**	

* Price is based on the contract prices for Reiziq(b) Langi and Opus(b) at the time of writing.
** Yield is based on the 5-year average for each variety.
*** Contract rates are used.

Table 19. Example gross margin for dry broadcast Reiziq(I), Langi and Opus(I).
Add in your own figures in the 'Your estimate' column.

	Rate/ha	Price	Reiziq	Langi	Opus	Your estimate
INCOME						
Price per tonne*			$400	$430	$415	
Yield @ 14% moisture*	t/ha		11.0	9.5	10.5	
Gross income per hectare			**$4,400**	**$4,085**	**$4,358**	
VARIABLE COSTS						
OPERATIONS ***						
Disc	0.45 hrs	$100/hr	$45	$45	$45	
Grader board	0.25 hrs	$100/hr	$25	$25	$25	
Ground spray	0.1 hrs	$100/hr	$10	$10	$10	
Drill fertiliser	0.45 hrs	$100/hr	$45	$45	$45	
Reform banks	0.25 hrs	$100/hr	$25	$25	$25	
Ridge roll	0.2 hrs	$100/hr	$20	$20	$20	
Broadcast seed	0.1 hrs	$100/hr	$10	$10	$10	
Aerial spray			$21	$21	$21	
Aerial spray			$21	$21	$21	
Aerial topdress			$27	$27	$27	
Harvest @ 20% moisture		$25/t	$296	$255	$282	
Fuel			$34	$34	$34	
Field bin/tractor @ 20% moisture		$4/t	$47	$41	$45	
Cartage @ 20% moisture		$15/t	$177	$153	$169	
SEED	Reiziq 150 kg Langi 130 kg Opus 120 kg	$508/t $563/t $528/t	$76	$73	$63	
FERTILISER						
Urea 1st application	275 kg	$520/t	$143	$143	$143	
Urea 2nd applicaton	75 kg	$520/t	$39	$39	$39	
MAP	120 kg	$700/t	$84	$84	$84	
HERBICIDE/INSECTICIDE						
Glyphosate	1 L	$5/L	$5	$5	$5	
Taipan	2 L	$71/L	$142	$142	$142	
Molinate	3.5 L	$34/L	$119	$119	$119	
MPCA	2.7 L	$7/L	$19	$19	$19	
Lorsban	0.15 L	$33/L	$5	$5	$5	
Dominex	0.1 L	$8/L	$1	$1	$1	
IRRIGATION						
Variable water charges	13 ML	$10/ML	$130	$130	$130	
Purchased water cost						
OTHER						
Insurance		$3/t	$33	$29	$32	
Duck control			$5	$5	$5	
Levies		$3/t	$33	$29	$32	
TOTAL VARIABLE COSTS PER HA			$1,637	$1,554	$1,597	
GROSS MARGIN PER HA			$2,763	$2,531	$2,760	
GROSS MARGIN PER ML			$213	$195	$212	

* Price is based on the contract price for Reiziq(I) Langi and Opus(I) at the time of writing.
** Yield is based on the 5-year average for each variety.
*** Contract rates are used.

Budget sensitivity tables

Table 20. A sensitivity budget showing gross margin per hectare for the example crop in Table 20 for dry broadcast Reiziq[(l)] rice production affected by variation in yield and rice price. **In this example no water is purchased from the temporary water market.**

Rice price ($/t)		340	360	380	400	420	440	460
Yield (t/ha)	9.5	$1,673	$1,863	$2,053	$2,243	$2,433	$2,623	$2,813
	10.0	$1,816	$2,016	$2,216	$2,416	$2,616	$2,816	$3,016
	10.5	$1,960	$2,170	$2,380	$2,590	$2,800	$3,010	$3,220
	11.0	$2,103	$2,323	$2,543	**$2,763**	$2,983	$3,203	$3,423
	11.5	$2,246	$2,476	$2,706	$2,936	$3,166	$3,396	$3,626
	12.0	$2,390	$2,630	$2,870	$3,110	$3,350	$3,590	$3,830
	12.5	$2,533	$2,783	$3,033	$3,283	$3,533	$3,783	$4,033

Table 21. A sensitivity budget showing gross margin per hectare for the example crop in Table 20 for dry broadcast Reiziq[(l)] rice production as affected by variation in yield and water price **when 20% of the required water is purchased from the temporary market**.

Water price ($/ML)		0	50	100	150	200	250	300	350
Yield (t/ha)	9.5	$2,243	$2,113	$1,983	$1,853	$1,723	$1,593	$1,463	$1,333
	10.0	$2,416	$2,286	$2,156	$2,026	$1,896	$1,766	$1,636	$1,506
	10.5	$2,590	$2,460	$2,330	$2,200	$2,070	$1,940	$1,810	$1,680
	11.0	**$2,763**	$2,633	$2,503	$2,373	$2,243	$2,113	$1,983	$1,853
	11.5	$2,936	$2,806	$2,676	$2,546	$2,416	$2,286	$2,156	$2,026
	12.0	$3,110	$2,980	$2,850	$2,720	$2,590	$2,460	$2,330	$2,200
	12.5	$3,283	$3,153	$3,023	$2,893	$2,763	$2,633	$2,503	$2,373

Table 22. A sensitivity budget showing gross margin per hectare for the example crop in Table 20 for dry broadcast Reiziq[(l)] rice production as affected by variation in yield and water price **when 40% of the required water is purchased from the temporary market**.

Water price ($/ML)		0	50	100	150	200	250	300	350
Yield (t/ha)	9.5	$2,243	$1,983	$1,723	$1,463	$1,203	$943	$683	$423
	10.0	$2,416	$2,156	$1,896	$1,636	$1,376	$1,116	$856	$596
	10.5	$2,590	$2,330	$2,070	$1,810	$1,550	$1,290	$1,030	$770
	11.0	**$2,763**	$2,503	$2,243	$1,983	$1,723	$1,463	$1,203	$943
	11.5	$2,936	$2,676	$2,416	$2,156	$1,896	$1,636	$1,376	$1,116
	12.0	$3,110	$2,850	$2,590	$2,330	$2,070	$1,810	$1,550	$1,290
	12.5	$3,283	$3,023	$2,763	$2,503	$2,243	$1,983	$1,723	$1,463

Paddock diary

Paddock name	1	2	3
Layout			
Preparation			
Pre plant fertiliser			
Variety			
Sowing date			
Sowing method			
Establishment counts			
Pre flood nitrogen			
Weed control			
Pest control Bloodworms Snails Leafminers Armyworms Other			
Mid-season topdressing rate			
PI date			
PI topdressing rate			
Deep water after PI Y/N			
50% flowering date			
Lockup date			
Drainage date			
Harvest moisture %			
Harvest dates			
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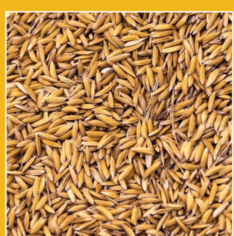

Rice growing guide

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