Department of Primary Industries

Rice growing guide 2018

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Contents

List of tables

Resources

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

DPI Primefact: *Factors to consider when draining rice*, 2014

DPI Primefact: *Rice water depth management at microspore*, 2018

DPI Primefact: *Rice variety guide 2018–19*

DPI *Rice crop protection guide 2018-19*

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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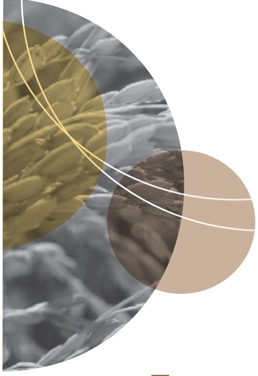


Rice growing guide 2018

Target yield

It is important to understand the yield potential of each variety when planning the next rice crop.

Yield potential varies between rice-growing valleys. Higher minimum temperatures in the Murrumbidgee Valley than the Murray Valley enable higher average yields. Table 1 shows the five-year rolling average yields for each variety in each region and the five-year average yield of the top 20% of farms.

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

Table 1. Five-year average yields for each variety in each region and for the top 20% of farms.

Variety	Region					Top 20%
	MIA	CIA	EMV	WMV	All regions	All regions
Doongara**	11.37	9.39			10.74	
Illabong			11.08		11.08	
Koshihikari			7.77	6.95	7.49	9.08
Langi	9.59	9.06	9.16		9.44	11.47
Opus			10.04	9.84	9.92	11.73
Reiziq	11.87	10.2	10.19	9.95	10.98	13.49
Sherpa			10.76	10.28	10.63	12.60
Topaz*	9.14	8.17			8.88	11.04
YRK5#			7.51	7.04	7.26	9.71
Viand#	9.98	9.26	9.19	8.39	9.48	11.89
All varieties	11.09	9.73	10.23	9.81	10.3	

* 4 years of commercial data
\# 2 years of commercial data
** Not a big enough sample to get top 20%

Target water productivity

Maximising grain yield and quality per megalitre of water is important for efficient water use. Since yield potential and water use vary between the Murrumbidgee Valley and the Murray Valley and between varieties, water productivity targets are specific to valleys and varieties. Water productivity can be improved by increasing yield, reducing water use, or by both, targeting over 1 t/ML.

Water budgeting

Calculate your rice crop water use requirements before sowing. Historical water use for the specific paddock is the best way to estimate rice crop water requirements. Alternatively, calculating the estimate of the amount of water that will be used by the rice crop using historical and/or actual evapotranspiration figures allows you to budget for water use over the whole crop after fill up (water required for fill up or first flush will be significantly less following a wet winter).

Use soil of low permeability for rice growing to slow water seeping through to the water table and prevent excess water use. Total water use will change depending on the season, but should normally be below 14–16 ML/ha. Crop profitability might 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. EM31 and soil sodicity are the main tests for assessing rice land suitability.

Planning

Consistent production of high yielding, high quality and profitable rice depends on forward planning and a high level of management in all aspects of operating the rice farm system. The performance of other crops and pastures in rice rotations will have affect the rice crop's management and yield.

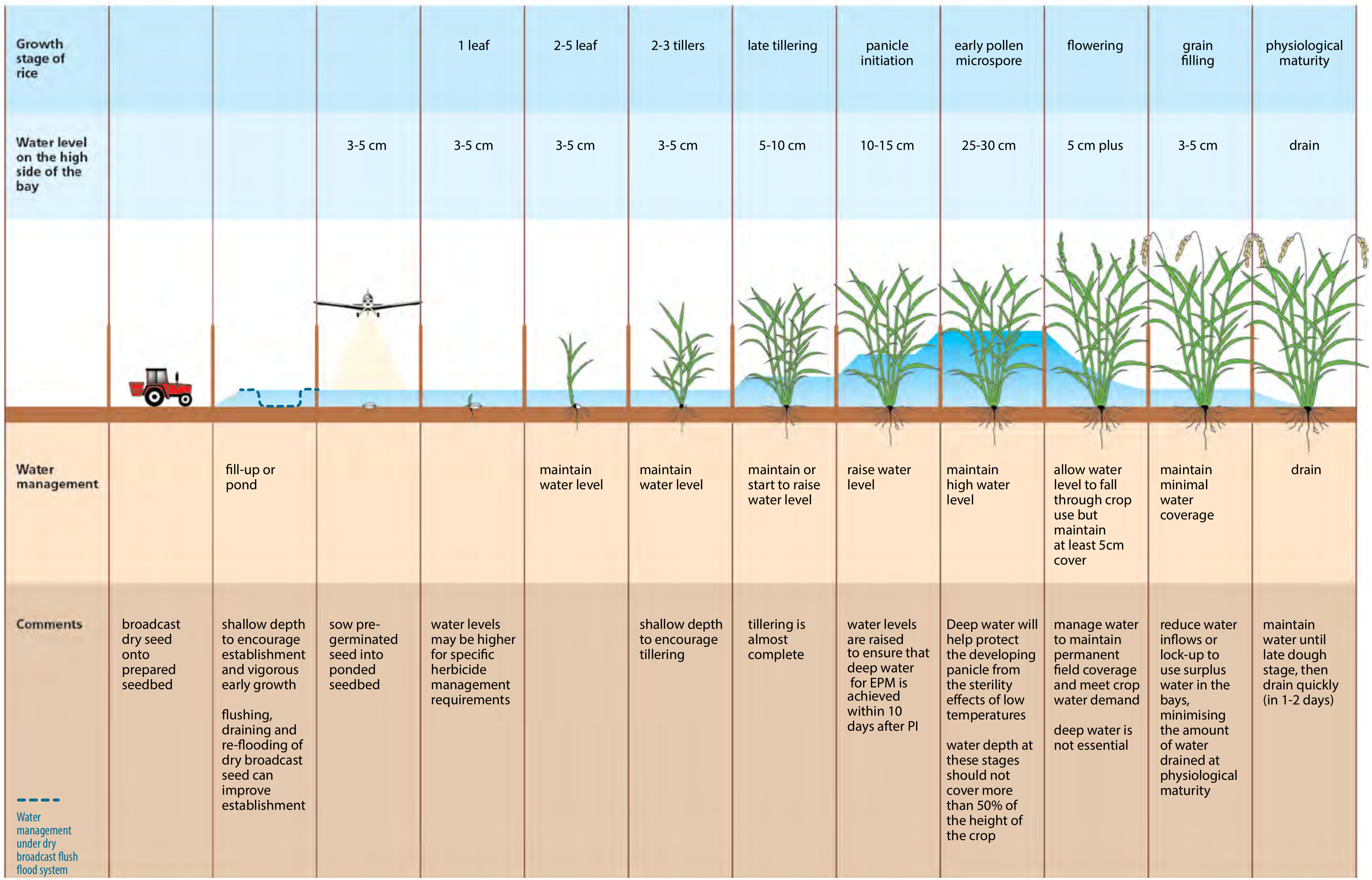
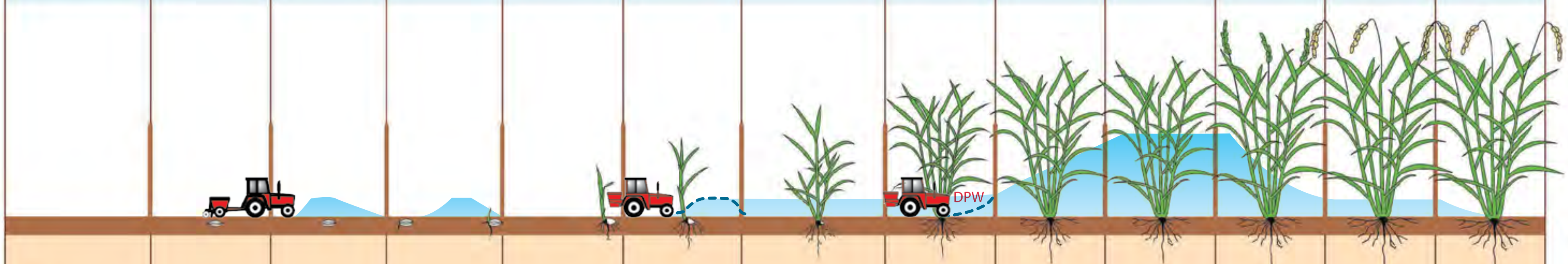


Figure 1. Stages of crop growth and water management for aerial sown and dry broadcast sown rice. Source: Production of quality rice in south eastern Australia

Growth stage of rice				1 leaf	3–4 leaf	2–3 tillers	late tillering	panicle initiation	early pollen microspore	flowering	grain filling	physiological maturity
Water level on the high side of the bay				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		flush	flush		apply permanent water to conventionally irrigated drill sown crops	maintain shallow water level	maintain or start to raise water level apply permanent water for delayed permanent water crops	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	for combine sown crops, sow into prepared seedbed; or for sod sown crops, sow directly into pasture or stubble	cover field with water then drain quickly	cover field with water then drain quickly	seedlings at the 2 to 4 leaf stage should not be inundated for longer than 3 days as seedling death or retarded growth can result	spread nitrogen fertiliser prior to permanent water	water levels may need to be adjusted for herbicide application	tillering is almost complete spread nitrogen fertiliser prior to permanent water for delayed permanent water crops	water levels are raised to ensure that deep water for EPM 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 delayed permanent water system

Figure 2. Stages of crop growth and water management for drill sown rice.
Source: Production of quality rice in south eastern Australia

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 3.) 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.

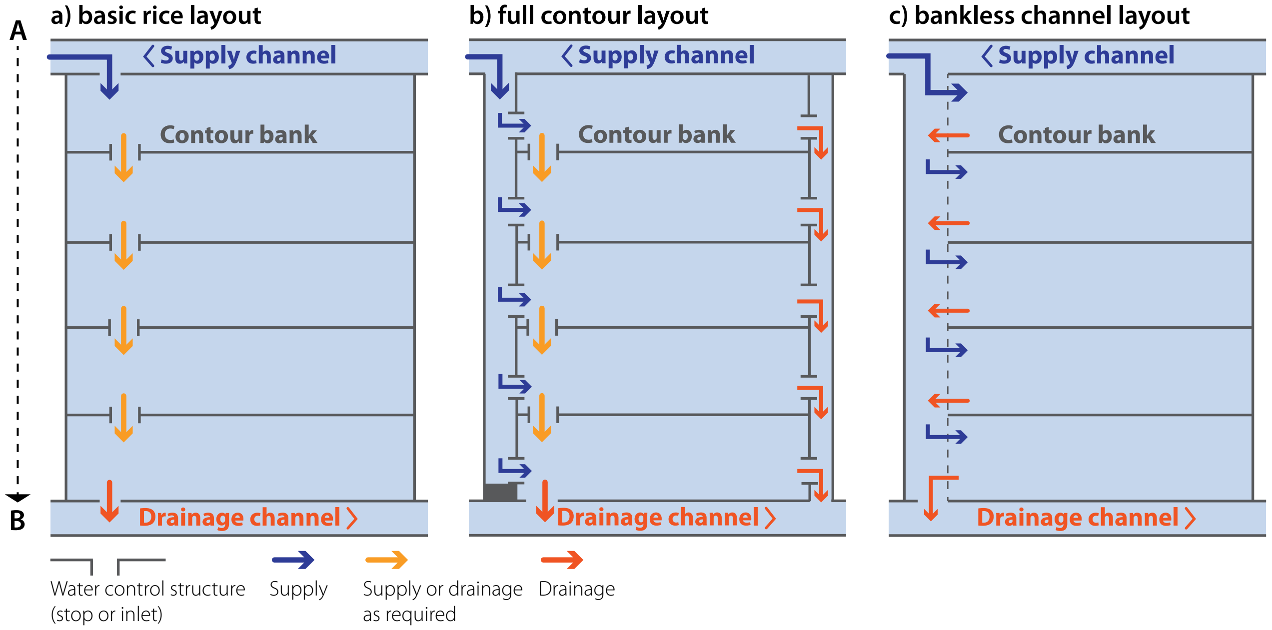


Figure 3. Common rice layouts: a) basic rice layout, b) full contour layout, c) bankless channel layout. The direction of slope for all diagrams is from point A to point B.

Supply channels and flow rates

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).

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 4. 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.

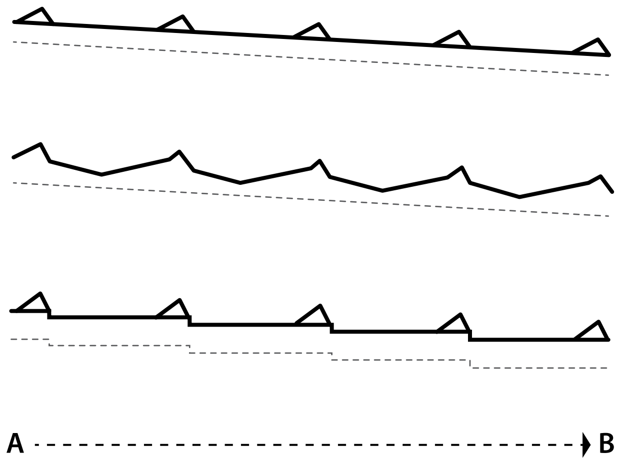


Figure 4. Types of field grade: contour (top), V-bay (middle), terraced (bottom). Point A to point B is the direction of slope and is the cross section of Figure 3.

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 for other crops in the rotation. A terrace of 10 cm is needed between bays.

V-bays allow a greater slope (e.g. 1:1500) to be created within bays on naturally flat fields (Figure 5, overleaf). 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 5. V-bays create slope on flat fields and allow for more even water level than contoured fields. Photo: Neil Bull

Field banks

Rice field banks should be a minimum of 40 cm high at their lowest point. Higher banks (up to 60 cm) might be needed around the outside of the field 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 6).

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.

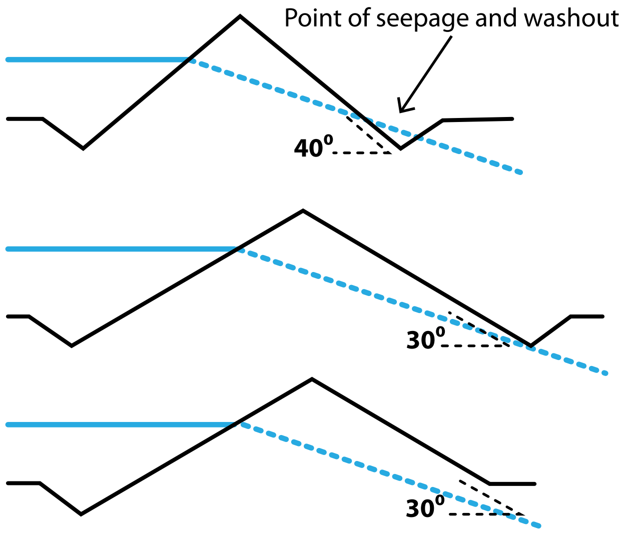


Figure 6. Options for banks: An angle of greater than 30^0 may washout (top), seepage contained in a bank with a 30^0 angle, seepage contained in a bank with a 30^0 and no toe furrow on the outside.

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 (Figure 7, below).

Figure 7. Water control structures need to be weed free and designed so that they can deliver the flow rate required to fill the bay. Photos: Troy Mauger and David Troldahl

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 (Figure 8).

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

Road access

Access around fields is very important for field operations: sowing, crop monitoring, water management and harvest. Elevated roads formed on the banks of supply and drainage channels provide ready drainage, are always trafficable and can reduce water seepage. A trafficable area adjacent to the field should be set aside to allow for sowing, spraying and/or harvest operations.

Crop establishment

A uniform crop establishment is important for high yields. Vigorous crops are more competitive against weeds.

Sowing time

Sowing during the 'ideal' sowing window for each variety allows optimum plant growth and development.

1. Establishment occurs during a period of favourable temperatures for germination and seedling survival.
2. The critical reproductive growth stage (microspore) should occur from 1 January to 5 February when temperatures are most favourable and the risk of low (<17°C) night temperatures is least. Microspore is normally 12–16 days after pannicle initiation (PI), but will be quicker in hot weather and slower in cold weather. Cold damage still occurs 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.
3. Grain ripening, maturity and moisture dry-down for harvest occur when 'milder' autumn temperatures are more likely which favour grain quality.

Figure 9. Aerial sown rice. Photo: John Fowler

Figure 10. Drill sown rice. Photo: Vince Bucello

Ideal sowing time

Planting within the recommended sowing 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 the performance of each variety in previous seasons and long-term average temperatures. Sowing before the recommended window can increase cold risk even more than sowing later.

The longer a crop grows before permanent water is applied the slower the crop development. It is important that crops planned for delayed permanent water are sown earlier than conventional drill crops to account for the delay. Aerial sown and dry broadcast crops should be sown later as they develop the fastest (Table 3).

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, Doongara	25 Oct–5 Nov	20–31 Oct	10–25 Oct	20 Oct–5 Nov	15–25 Oct	5–20 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	–	–	–	20–30 Oct#	10 to 25 Oct	1–20 Oct
Viand	10–30 Nov	5–25 Nov	1–20 Nov	5–30 Nov	1–20 Nov	25 Oct–10 Nov
YRK5	–	–	–	–	1–20 Nov	25 Oct–10 Nov

Do not aerial sow or dry broadcast Koshihikari or YRK5 as this will increase lodging potential.

Ground preparation and management

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 seed, possibly creating muddy water. Ridge rolling creates grooves in which the seedlings can anchor and prevents clods from protruding out of shallow water.

Cultivation and grading ground for drill sown crops should be done in the autumn before sowing to allow time for the soil to settle, ensuring a firm seedbed. Cultivation will be necessary if the soil is too compacted for the seeder. Grading will be required if the soil surface is uneven. A firm seedbed is desirable as it is more likely to crack along the drill rows after sowing, enabling better emergence through crusting soils. Weeds should be controlled over the winter and a knockdown herbicide should be used pre-sowing to improve control of any early germinating barnyard grass.

When dry broadcasting, flush the field and allow 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 it needs to germinate. This is especially a problem if the topsoil is sodic. Dry broadcasting without flushing increases the risk of poor plant establishment.

Sowing rate

Rice should not be sown at rates higher than 150 kg/ha for any variety or sowing method.
To establish 200 plants/m^2 at an establishment percentage of 40% requires a maximum sowing rate of 150 kg/ha. If establishment is as low as 20% there will still be 100 plants/m^2 established, which is sufficient to achieve maximum grain yield.

Yield potential can be reduced if plant numbers are less than 40 plants/m^2 (see Table 4 below). 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.

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 10–15% in reliable establishment conditions without compromising yield.

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, Illabong & Topaz	150
Sherpa, Langi, Viand & YRK5	130
Opus, Koshihikari & Doongara	120

Measuring plant number when establishment is poor

When deciding whether to resow or abandon a crop with low plant populations, plant distribution is often more important than the number of plants. Therefore, a method to determine plant population and distribution when establishment problems occur has been devised.

In each zone in the field with different plant population levels, 10 plant counts using the rice ring (0.2 m²) should be obtained.

An average of two plants per ring from the 10 rings counted is needed to meet the 10 plants/m² requirement.

If more than three of the rings have only one plant, or one ring has zero plants, then re-sowing the poor establishment areas in the field is recommended.

Aerial re-sowing once water has been on the bays for more than three weeks is usually unsuccessful unless the country is dewatered.

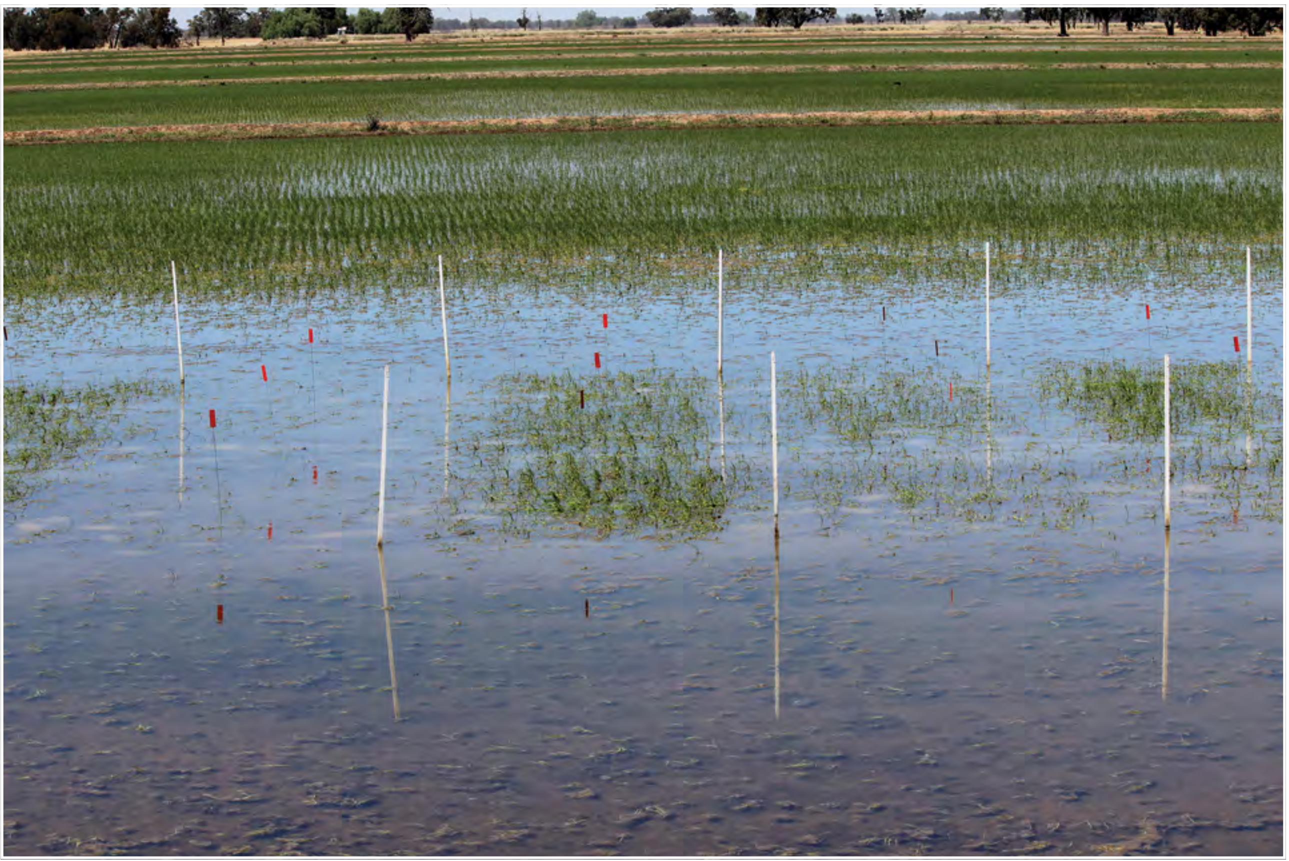


Figure 11. Reiziq⁽ᴰ⁾ rice, 23 days after sowing, 150 kg/ha seed, centre plot is pre-germinated, plot to its right is dry seeded into water, plot to its left is dry broadcast immediately before permanent water (no flushing). Photo: John Fowler

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

Population	Yield
Plants per m²	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

Seed preparation

The recommended method for aerial sown pre-germinated rice 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 this if attempting to shorten the pre-germinating period. Temperatures above 35 °C when rice is aerating after soaking in soaker silos and trucks can severely reduce the germination or kill rice. Thus in hot weather, monitor the temperature of aerating rice and if necessary take action to cool the rice.

Seed placement

In drill sown crops, sowing depth should be no deeper than 2.5–3.0 cm so that the rice coleoptile can emerge. Sowing shallower than this can lead to seed drying out between flushes before emergence. In soils that crust, the seed should be placed below the crust so that the seed doesn't dry out in between flushes.

Muddy water sites

Good crop establishment is more difficult to achieve on dispersive (sodic) soils because of excessive muddy water (i.e. visibility less than 3–4 cm), for example in the western Murray Valley. Plant numbers can be reduced and maturity delayed. Cultivate as little as possible to maintain soil structure and delay ploughing-in dry plant residue until the end of winter. Although excessive vegetation can decrease establishment, some residue can reduce slaking and dispersion.

Shallow water during establishment is essential on muddy soils. These crops might have areas that need to be drained during establishment as the temperature of the muddy water can be 5–8 °C below that of clear water, which greatly inhibits seedling growth. Refill with clear water. Bird control is essential during this process to prevent seed predation.

Broadcasting gypsum at 1.0–1.5 t/ha immediately before filling up reduces muddy water. Use the higher rate on extreme muddy water problem sites such as the central Deniboota and Wakool Irrigation Districts. The purity of the gypsum is important, but the particle size is not – coarse particle size is suitable, even preferred, as 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.

Slime

Slime can reduce seedling establishment. Green slime is an algae which can be treated with algicide or by lowering water levels. Green slime potential is reduced 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 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.

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 water that is reintroduced 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 fresh water that is reintroduced 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.

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 post 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.
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 application are an important aspect of successful weed control. Some herbicides require no water movement for five days after application.
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 extremely 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: https://riceextension.org.au.

   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.

   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, sowing and harvesting equipment, and for footwear and vehicles.
9. **Prevent off-target crop damage.** Consider herbicide program and sowing methods to avoid off-target crop damage and communicate with neighbours to understand where sensitive crops are located.

Pest control

Armyworms 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 rarely a problem. Experience suggests increased monitoring should be undertaken after midseason drainage.

Table 5. Damage thresholds for treating army-worm 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

Aquatic earthworms can cause serious damage to aerial-sown rice crops (Figure 12). They attract ibis, which trample seedlings and muddy the water. However, damage can occur even without ibis. Control options are limited to draining water, drying out bays and scaring away ibis.

Figure 12. Castings are a sign that aquatic earth-worms are present in the crop.Photo: John Fowler

Bloodworms attack most aerially sown and dry broadcast rice crops. All aerially sown crops should be treated for bloodworms at or within 24 hours of sowing or applying water to a dry sown crop, with further treatment(s) up to three weeks after sowing. 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 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 who anticipate problems with ducks can tick the opt-in box on their rice seed order form to obtain a Native Game Bird Management Licence and a quota allocation.

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

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 water surface, inspect the rice leaves for leafminers. Control using insecticide.

Locusts can attack seedling rice between flushes of water for drill sown crops. Aerial sown damage is less than drill as the locusts will only eat to the waterline and 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 problem in aerially sown crops from sowing until mid tillering. Numbers can increase following wet winters and are higher 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*.

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. Drainage water arising from heavy rainfall can be partly minimised by large rice banks, which help to retain water. 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, updated to the *Industry Biosecurity Plan for the Rice Industry* in 2014 aims to prevent and minimise the incursion and spread of any new pests or disease in rice crops.

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

If suspicious symptoms are evident, farmers should contact the NSW DPI, Yanco for the appropriate sampling protocol so that samples can be assessed. Alternatively ring the Emergency Plant Pest Hotline on 1800 084 881.

Aggregate sheath spot and sheath spot. A disease survey in NSW in 2001 confirmed the presence of both diseases in NSW rice fields. Field trials have shown that aggregate sheath spot and sheath spot have the potential to cause yield losses as high as 20% and 10% respectively. Symptoms appear near the water line as spots on the leaf sheaths. The disease cycle of these two diseases is very similar to stem rot, so burning stubble is also recommended to keep these diseases under control.

Stem rot is a fungal disease of rice which was observed in NSW in the 1990s and in the Murray Valley in 2014–16. Although it did not cause major losses, it has been known to cause significant losses in favourable seasons in the US. The most common form of spread is on infected rice stems. When rice is grown on a field infected from the previous year's rice crop, the disease can build up in subsequent crops, particularly if the infected straw is not destroyed immediately after harvest. Straw burning practices appear to be keeping this disease in check.

Rice growers should check their crops 2–3 times between pannicle initiation and draining, and again after harvest. Symptoms of stem rot are small, dark lesions on rice leaf sheaths at the water level (Figure 13). Suspicious samples should be sent to NSW DPI, Yanco for assessment to check the causes of these lesions. Further crop protection details are outlined in the *The rice crop protection guide* and the *Rice field guide to pests, diseases and weeds in southern NSW*.

Exotic threat: Rice blast

Rice blast is considered the most important rice disease in the world. **It is not yet present in southeast Australia** but there are favourable climatic conditions for rice blast here. Rice blast is present in northern Australia.

If travelling or hosting visitors from northern Australia, please adhere to quarantine protocols.

The symptoms of rice blast are lesions which can be found in most parts of the shoot, including leaves, leaf collar, stem, nodes and panicles. Rice growers should be vigilant and report any unusual plant symptoms.

Figure 13. Symptoms of stem rot are small, dark lesions on rice leaf sheaths which get larger as the plant matures. Photo: Andrew Watson

Crop nutrition

Nutrient balance

In the long term, fertiliser strategies should ensure that the nutrients removed from the soil by crops are replaced. Maintaining a balance prevents the development of deficiencies which may alter the sustainability of yield and grain quality of rice and other crops or pastures in the rotation.

Rice nutrition

pH effect on rice nutrition

Many rice soils in the Riverina are acidic with some soils reaching very low levels. At these low pH levels, the availability of many nutrients is reduced even under flooded conditions (Figure 14). A soil pH of <5 requires lime application.

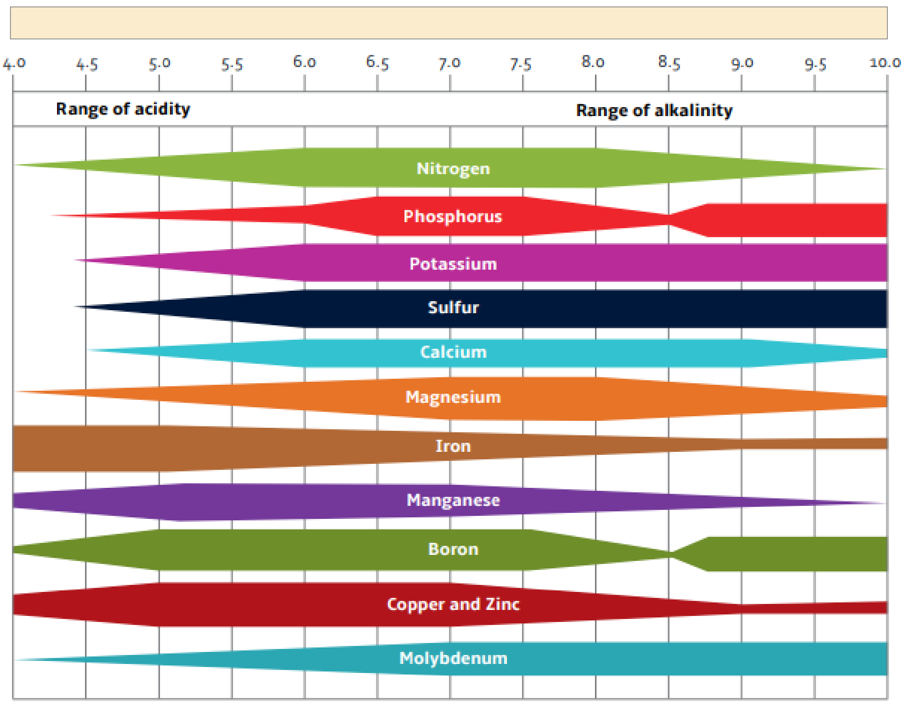


Figure 14. Nutrient availability is determined by soil pH in relatively fertile soils. The wider the band the more readily available is the nutrient (Production of quality rice on page 35). Note zinc becomes less available as the soil becomes more alkaline, and more available as the soil becomes more acidic.

Table 6. 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 7. 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 & 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 potassium 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 removal of Zn 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 ($CaCl_2$) apply Zn if test shows < 0.8 mg/kg DPTA extraction method. In soil with pH <6.5 ($CaCl_2$) apply Zn if test shows < 0.5mg/kg DPTA extraction method. Apply Zn close to the seed in pre-plant fertiliser mix or as a seed dressing. Toxicity can occur to crop 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. Ca 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. B deficiency appears as white and rolled tips of youngest leaves. Apply B if leaf analysis levels are <5 mg/kg.
Iron (Fe)	Fe 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 wheat soil N test 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 of rice growth.

Because of these limitations, it is recommended 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 give more variability in yield 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. A guide to the range of pre-permanent water N application rates that may be required for fields with different cropping histories to achieve the target PI nitrogen uptake is outlined in Table 9.

Pre-permanent water nitrogen

Applying nitrogen fertiliser prior to the application of 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 nitrogen is washed into the soil and attaches to the clay particles where the majority remains until used by the crop.

Sufficient nitrogen fertiliser must be applied pre-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.

For drill sowing, broadcast nitrogen (urea) onto the dry soil then follow with the application of permanent water within 24 hours (Figure 15). 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 evenly.

Figure 15. Broadcast urea onto dry soil before applying permanent water in drill sown crops.
Photo: Vince Bucello

Target nitrogen uptake

The target range of PI nitrogen uptakes for different varieties when applying pre-permanent water nitrogen is shown in Table 9. Farmers in the MIA and CIA aiming for high yields from medium grain varieties (e.g. 12 t/ha for Reiziq⁽ᴾ⁾) can target the high end of the PI nitrogen uptake range. Farmers in the Murray Valley should target 100–130 kg N/ha nitrogen 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 nitrogen uptake ranges because of increased sensitivity to cold temperatures.

High nitrogen 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 8. 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, Sherpa, Opus, Illabong, Langi,	120–140	100–130
Doongara, Topaz, Viand	100–130	80–110
Koshihikari	80–110	60–90

Table 9. 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⁽ᴾ⁾, Topaz⁽ᴾ⁾ 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 have the potential for significant N losses. The wetting and drying of 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 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 is dependent 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 15). However, at PI, the rice crop has lots of surface roots, which quickly take up N from the water, and a full crop canopy, which reduces volatilisation losses of N 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.

Figure 16. Topdress nitrogen at panicle initiation if the required nitrogen uptake has not been reached. Photo: Vince Bucello

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 17). 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 with the added N.

Figure 17. Panicle initiation occurs when three out of 10 main tillers have a visible panicle. Photo: Tina Dunn

The NIR tissue test

Rice N uptake at PI is determined by the Rice NIR tissue test. The test provides growers with N topdressing recommendations. The recommendations are based on the actual PI nitrogen uptake value calculated for the crop and the expected response for added PI nitrogen 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 sent in by the grower 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 are:

1. Sown at the recommended time so PI occurs between the 1st and 14th January
2. Have a minimum microspore water depth of 25–30 cm
3. Located in the MIA/CIA and northern 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 nitrogen that may continue releasing nitrogen after PI may need a lower rate. Conversely, heavily cropped paddocks with very low levels of organic nitrogen may require a higher rate than recommended.

Targeted sampling using aerial imagery

Sampling rice for the NIR tissue test can be made easier and more accurate using aerial imagery (Figure 18). Images taken before PI identify 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 allow farmers to variable rate top dress N on their crops. It is essential farmers 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 32.

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 nitrogen uptake.

Once the rice crop gets past mid-tillering and particularly once it has reached PI, NDRE images are better able to show differences in nitrogen uptake of the crop (Figure 18). The red edge waveband is very sensitive to changes in foliar chlorophyll content, which is strongly related to plant nitrogen concentration.

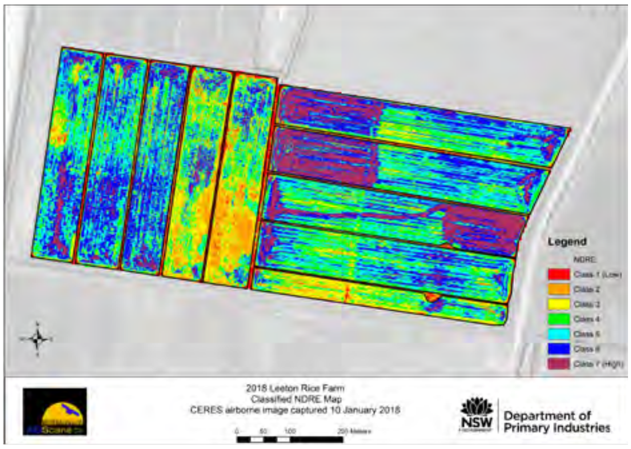


Figure 18. NDRE imagery is used to identify zones of crop vigour in the field to target sampling locations for NIR tissue tests.

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 nutrientsdistribution – often referred to as striping or race tracking – with more vegetative growth in the over 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
- ground contour
- crop and stubble height
- overlapping or misses due to inaccurate runs due to not 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 an Accu Spread calibration?

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

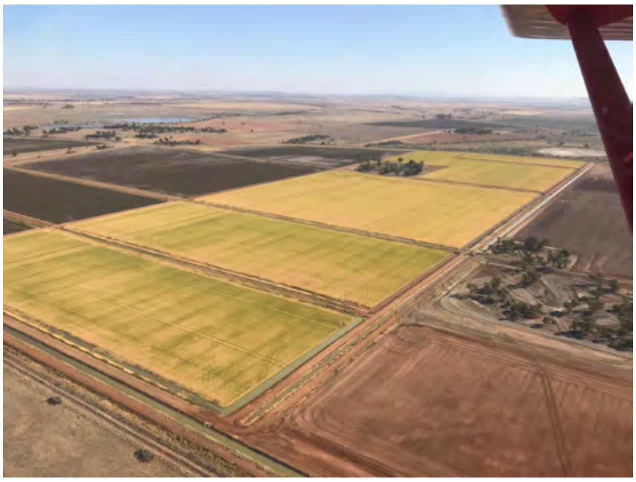


Figure 19. Poor fertiliser distribution leads to non-uniform distribution of nutrients showing up as striping on rice crops. Photo: P Draper.

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 11 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 10. 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 positive responses. 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 may 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 whilst 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, where high P fertiliser applications have occurred, 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 drained quickly 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 been observed previously.

Where soil pH is greater than 6.5 (pH_{Ca}), 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 sulphate 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 sulphate or oxide is very fine so it does not stay evenly distributed in the blend.

Toxicity

Heavy applications of Zn 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).

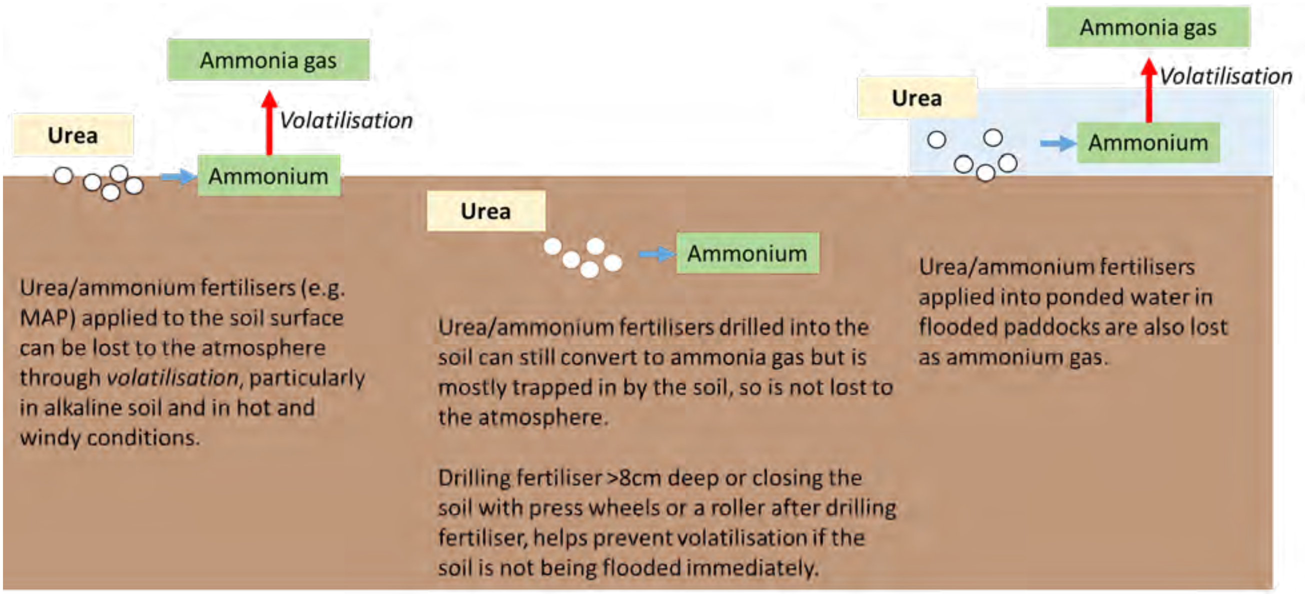
Sulfur deficiencies have similar plant symptoms to N deficiencies in terms of pale green plant colour. However S deficiencies shows up in the young leaves and N deficiencies shows up in the old leaves. Sulfur deficiencies respond quickly to top dressed S in available forms (e.g. single superphosphate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

Lime

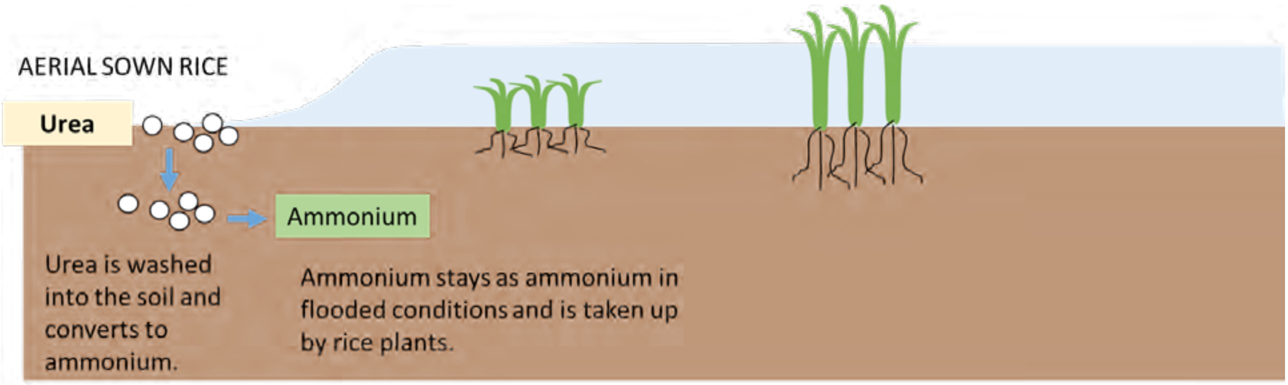
Continuous use of high rates of N fertiliser along with removing large amounts of grain at harvest, have an acidifying effect on soils. Soil testing will indicate the presence of an acid soil problem and whether lime is required to ameliorate it. Rice yields are rarely influenced by acid soils as the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

Nitrogen use efficiency

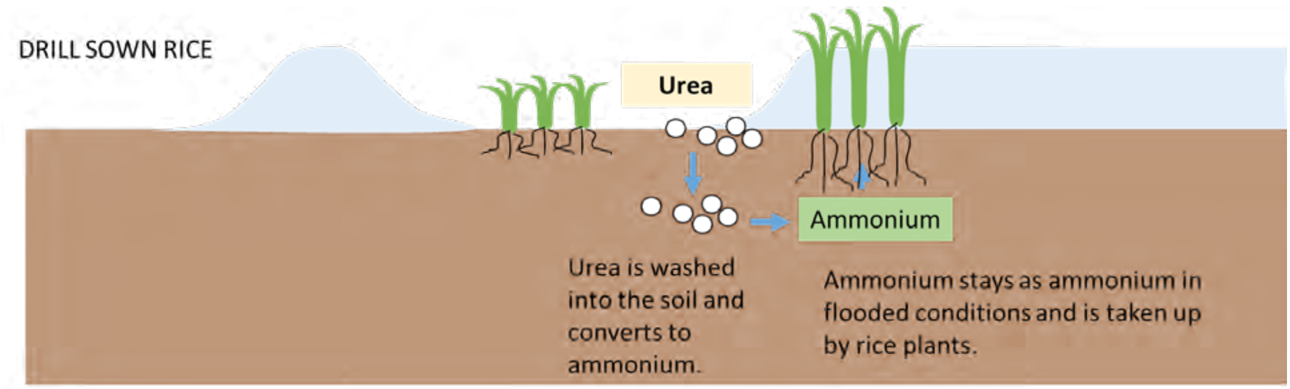
It is more efficient to drill N fertiliser underneath the soil surface in aerial sown rice.



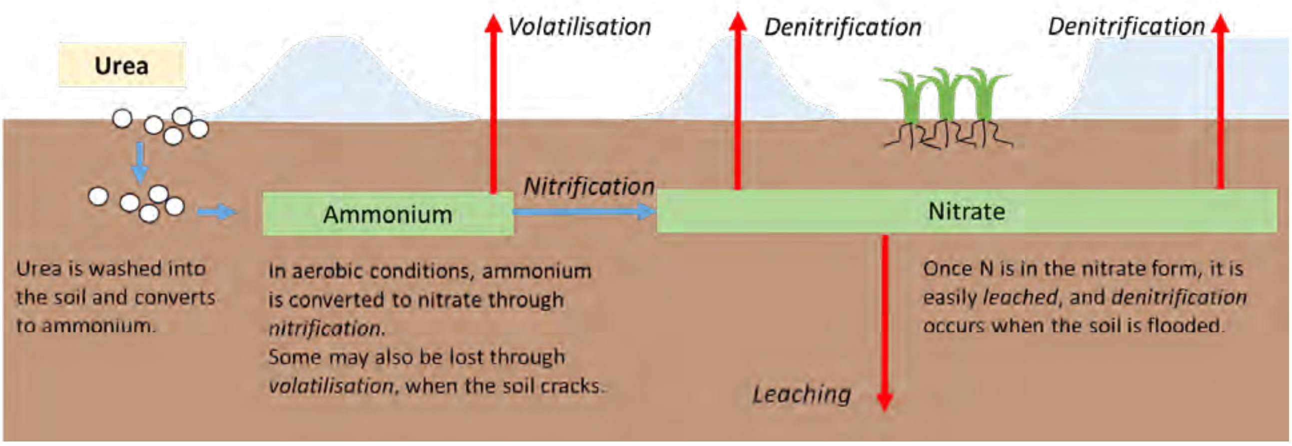
It is most efficient to apply urea before permanent water.



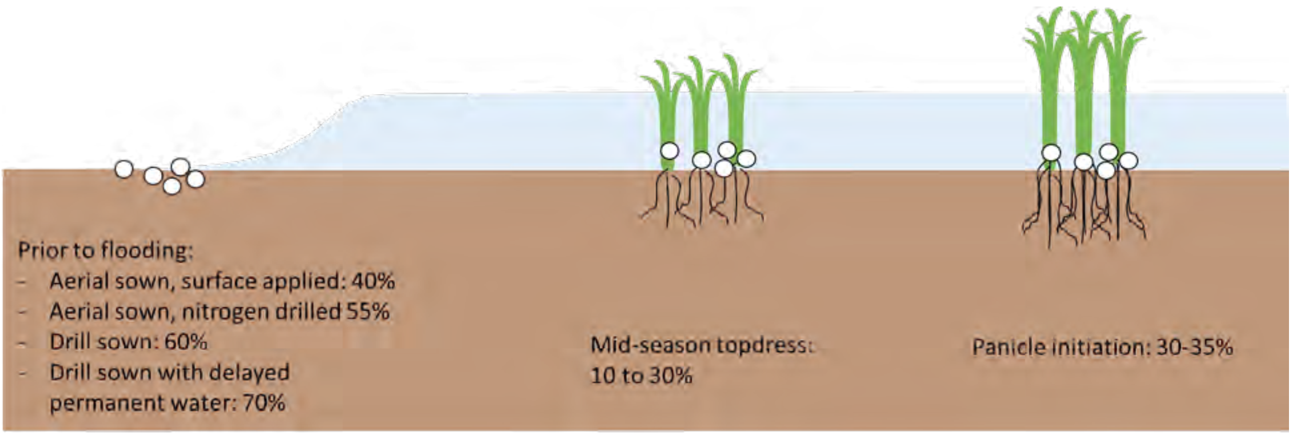
Even in flooded conditions, the very top layer of soil and around the rice roots will be aerobic. So some ammonium will still **nitrify** (to nitrate) and be lost through **denitrification** and **leaching**.



If urea is applied before flushing, there are many ways N can be lost once the soil dries out and is then re-flooded. Especially in the early stages, when there are no plants to take up available N.



Nitrogen use efficiency changes throughout the crop cycle.



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

These N use efficiencies are estimates and can change significantly, there have been no experiments directly comparing all treatments.

Note: At 70% efficiency, 70 kg/ha will go into the plant if you apply 100 kg/ha nitrogen.

Nitrogen cycle

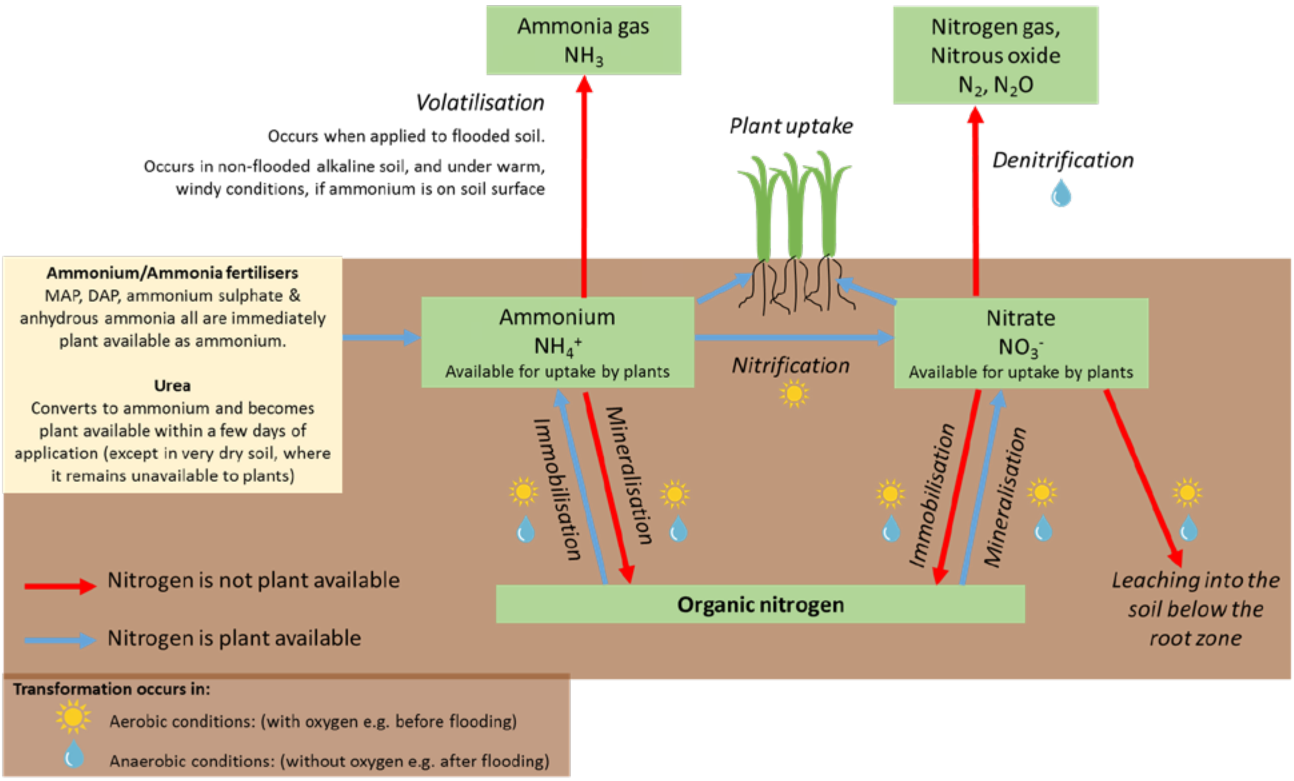


Figure 20. Nitrogen use efficiency through the season.

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Water management

Water management at microspore

The water management practices for the rice crop growth stages are shown in tables 13 and 14.

Water management at microspore

Rice water depth management at the microspore stage is critical in helping to protect the developing panicle from cold-induced floret sterility which can lead to large reduction in rice grain yield at harvest. At microspore, air temperatures below 15–17 °C can damage the developing pollen, leading to floret sterility and yield loss.

Deep water (25 cm) is a very effective management tool to minimise damage caused by low temperatures and can provide up to 8 °C increase over the air temperature (Figure 21).

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

Both on-farm and supply channel flow rate and the area of crop grown on each outlet can have enormous impacts on the ability to achieve deep water in time for microspore.

If water availability is going to be an issue you may need to start filling the field earlier than PI. Applying deep water earlier, during late tillering and at PI, is not recommended as it increases the plant height and also elongates the airspace, which in turn pushes the panicle higher above the soil and water surface. This means that even deeper water is required to protect the panicle from cold at microspore.

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 depth until draining. Maintenance of water levels of at least 5 cm depth throughout the flowering stage helps reduce the risk of moisture stress.

The amount of time required to fill up for microspore will vary for each paddock. For example, using Table 12, to lift the water depth by 20 cm from 10–30 cm (or 5–25 cm) on 60 ha of rice via one irrigation outlet in 12 days requires a minimum flow rate of 16 ML/day.

However, if flow restrictions were imposed, due to high demand or limited supply channel capacity, to a level of 8 ML/day per holding (or flow share) it would take 60 days to achieve a 20 cm lift or 30 days for a 10 cm lift.

This demonstrates that some water management planning is required, especially where water flow rate restrictions can impact.

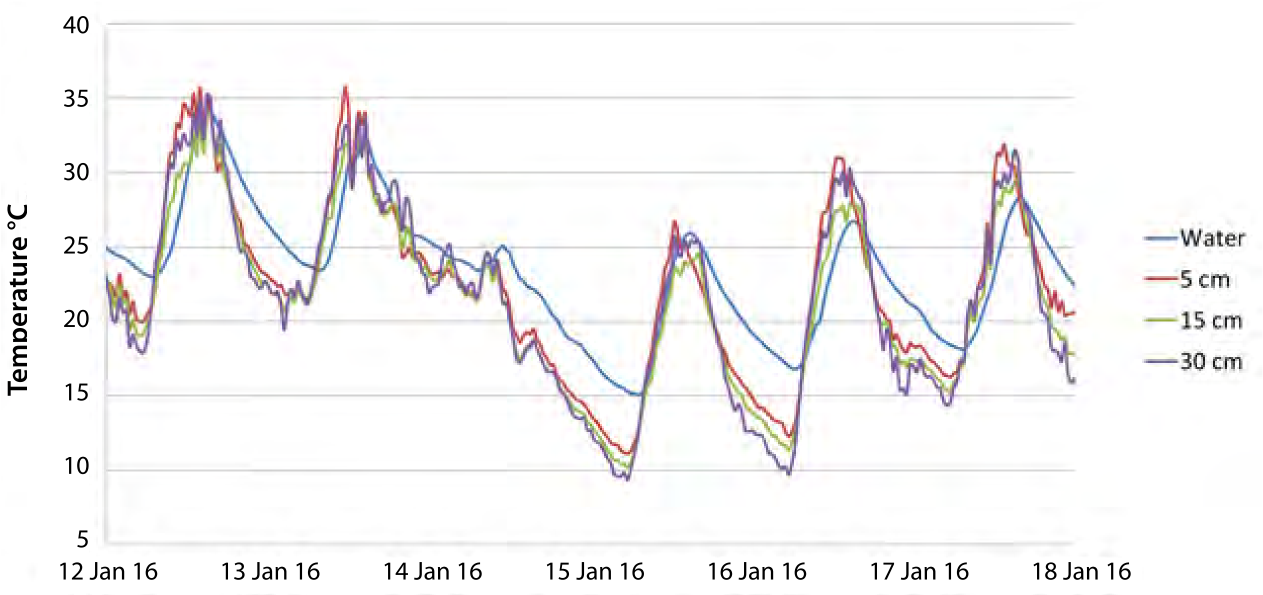


Figure 21. Water and air temperatures recorded at different heights in the canopy at Jerilderie in 2016. The water temperature was 80 °C above the air temperature at 30 cm above the canopy during a cold spell on 16 January 2016.

Table 11. The time (days) to add 10 or 20 cm water depth for various crop areas (ha) at the different flow rates (ML/day) assuming 10 mm/day evapotranspiration*.

Flow rate (ML/day)	Crop area (ha)	20		30		40		50		60		70		80	
	Additional water depth (cm)	10	20	10	20	10	20	10	20	10	20	10	20	10	20
	6	5.0	10.0	10.0	20.0	20.0	40.0	50.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	7	4.0	8.0	7.5	5.0	13.3	26.7	25.0	50.0	60.0	n/a	n/a	n/a	n/a	n/a
	8	3.3	6.7	6.0	12.0	10.0	20.0	16.7	33.3	30.0	60.0	70.0	n/a	n/a	n/a
	9	2.9	5.7	5.0	10.0	8.0	16.0	12.5	25.0	20.0	40.0	35.0	70.0	80.0	n/a
	10	2.5	5.0	4.3	8.6	6.7	13.3	10.0	20.0	15.0	30.0	23.3	46.7	40.0	80.0
	11	2.2	4.4	3.8	7.5	5.7	11.4	8.3	16.7	12.0	24.0	17.5	35.0	26.7	53.3
	12	2.0	4.0	3.3	6.7	5.0	10.0	7.1	14.3	10.0	20.0	14.0	28.0	20.0	40.0
	13	1.8	3.6	3.0	6.0	4.4	8.9	6.3	12.5	8.6	17.1	11.7	23.3	16.0	32.0
	14	1.7	3.3	2.7	5.5	4.0	8.0	5.6	11.1	7.5	15.0	10.0	20.0	13.3	26.7
	15	1.5	3.1	2.5	5.0	3.6	7.3	5.0	10.0	6.7	13.3	8.8	17.5	11.4	22.9
	16	1.4	2.9	2.3	4.6	3.3	6.7	4.5	9.1	6.0	12.0	7.8	15.6	10.0	20.0
	18	1.3	2.5	2.0	4.0	2.9	5.7	3.8	7.7	5.0	10.0	6.4	12.7	8.0	16.0
	20	1.1	2.2	1.8	3.5	2.5	5.0	3.3	6.7	4.3	8.6	5.4	10.8	6.7	13.3
	22	1.0	2.0	1.6	3.2	2.2	4.4	2.9	5.9	3.8	7.5	4.7	9.3	5.7	11.4
	24	0.9	1.8	1.4	2.9	2.0	4.0	2.6	5.3	3.3	6.7	4.1	8.2	5.0	10.0
	26	0.8	1.7	1.3	2.6	1.8	3.6	2.4	4.8	3.0	6.0	3.7	7.4	4.4	8.9
	28	0.8	1.5	1.2	2.4	1.7	3.3	2.2	4.3	2.7	5.5	3.3	6.7	4.0	8.0
	30	0.7	1.4	1.1	2.2	1.5	3.1	2.0	4.0	2.5	5.0	3.0	6.1	3.6	7.3

Note: *10 mm/day evaporation is an estimate for daily evapotranspiration in January. Evapotranspiration rates can change significantly, depending on location and season, which can make a large difference to the fill up time at low flow rates and for large crop areas.

For example, if you have 15 ML/day supply on your 60 ha paddock and you need to lift your water level from 10 cm to 30 cm (a total increase of 20 cm), it will take you 13.3 days (13 days and 8 hours).

The above table will also help you to determine flow rates required for the area of rice you have sown to lift the water levels to 10 cm or 20 cm within a certain number of days.

For example, to lift your water level 20 cm in 10 days over 50 ha, you will need a flow rate of 15 ML/day.

Table 12. Water management of aerial sown rice. Also refer to figures 1 and 2 on pages 2 and 3.

Crop stage	Target water depth	Management practice	Comments
Establishment	3–5 cm	This is the ideal water depth to encourage seedling establishment and early tillering of aerially sown crops. However, water levels may be higher at initial flooding or as required for herbicide management.	Flushing, draining and immediately re-flooding of dry broadcast seed can improve establishment. (Figure 19)
Mid-tillering (3 shoots/plant)	5 cm	Shallow depth encourages tillering: very important if seedling number is low.	Plants in deep water will be taller but have less biomass than those in shallow water.
Late-tillering	5–10 cm	Tillering should almost be complete. Start to increase water height in readiness for higher water demand summer.	If water supply from the main delivery channel system is restricted, water levels on well-tillered crops can be increased more rapidly to achieve 15 cm at PI in preparation for high levels at microspore.
Panicle initiation (PI)	10–15 cm	Water levels are increased progressively after PI to ensure that the target water depths for microspore are achieved within 14 days after PI.	Deeper water at PI will encourage elongation of the air space and this will increase the height of the panicle above the soil surface. The water depth required to protect the panicle at microspore will then need to be deeper and this will be more difficult to achieve. Water depth at these crop stages should not exceed 50% of the height of the crop.
Microspore	25–30 cm		
Flowering to draining	5 cm plus	Maintain sufficient water depth to ensure permanent water is retained even in very hot weather; allow deep water to subside to a depth of around 5 cm.	Deep water can be maintained to utilise rice bays as storage, freeing up water supply to irrigate winter crops and pastures.

Table 13. Water management of drill sown rice before the application of permanent water.

After permanent water refer to Water management of aerial sown rice (Table 13) at the appropriate growth stage.

Flush number/crop stage	Management
First flush	Apply the first flush as soon as possible after sowing. Ensure seed soaking but water needs to be off as soon as possible.
Second flush – 2 leaf stage	The second flush should be timed before the soil around the seed becomes dry but the ground must be dry enough to traffic machinery for herbicide application. In crusting soils consider the soil moisture below the crusting layer.
3 leaf stage –permanent water	Once the rice seedling has successfully emerged, the time between flushes can be lengthened. Seedlings should be flushed before the moisture around the plant roots dry out. The earliest time permanent water should be applied is the 3 leaf stage. However, it can be as late as 10 days prior to PI if barnyard grass is under control.

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

Use the PI Predictor (http://pipredictor.sunrice.com.au/) determine the PI dates for each of your paddocks sown and record.

Determine the early pollen microspore (EPM) date for each paddock. This is the start of the cold sensitive reproductive period, which is 12–16 days after PI and record in a table.

Use the guide in Table 12 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 EPM date to determine when you should start filling to ensure water depths of 25–30 cm are achieved before EPM.

An example and template to record your own crops has been provided below in Table 15

Table 14. 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 Table 8)	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.

In some cases, flow through your irrigation inlet can be restricted by internal infrastructure and obstructions such as weeds or silt.

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

1. Sow different varieties or stagger your sowing dates and methods to spread out microspore.
2, Fill farm water storages leading up to PI to be used to assist paddock fill up after PI.
3. Fill up rice bays to 10–15 cm before PI. Note that deeper water before PI will inhibit tillering and promote taller plants. So if filling up before PI, keep depths even across the whole paddock. If the crop is well tillered a more rapid fill can be used. For further information, refer to Table 13.

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 pipes and incorrect sized pipes and bay outlets cause flow restrictions on farm. Consider replacing them, removing them or use 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.

Figure 22. These channels will restrict flow.

2. Keep an eye on the weather forecasts: colder minimum temperatures are often forecast 7–10 days out. Forecast temperatures can be found at http://www.bom.gov.au/nsw/forecasts/map7day.shtml.

   If the forecast is predicting minimum temperatures lower than 17 °C then get that water on as quickly as possible.
3. **Fixed price contracts and varietal premium**: Protect higher value crops by filling these up first. Paddocks with higher yield potential will also be higher value crops.
4. Variety: Less tolerance to cold stress will need deep water

Table 15. Cold tolerance ratings

Variety	Cold tolerance rating
Doongara, Topaz	1
Reiziq	2
Illabong, Langi	3
Koshi, Opus	4
Sherpa, YRK5, YRM70	5

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

Source: *Rice variety guide 2017–18*

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 EPM and the other is for shallow water at EPM. If you are doubtful of achieving 25–30 cm water depth you should consider adopting the lower N rate, and accepting a lower yield. Higher N rates will require deeper water as the crop will be more susceptible to cold-induced sterility.

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 23). Problems of shallow or too deep water depth can be easily detected and rectified using the depth indicators.

Figure 23. Examples of water floating and static depth indicators. Photos: John Fowler

Water quality

The tolerance of rice to salinity varies considerably with its stage of growth. 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 the sensitive seedling and reproductive stages.

Growers need to monitor the ponded water quality (ECpw) in rice bays regularly and frequently using a calibrated portable electrical conductivity meter. The key issue is the salinity level of floodwater in the rice bays, which might arise as a result of evaporation or salinity contributions from the soil or groundwater. Groundwater has higher salinity than channel supply water, so if using groundwater, mix with channel water or use only channel water, particularly at fill up to protect sensitive seedlings. If using groundwater on more saline soils it might be advisable to flush saline water out of lower bays as the season progresses, where possible, to lower salinity levels. No yield loss should occur from salinity below 2 dS/m (1280 ppm), but this depends on variety and the level of leaching in the particular field.

Figure 24. Flushing, draining and immediately re-flooding of dry broadcast seed can improve establishment. Photo: Troy Mauger

Water management

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.

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.

Midseason drainage

Midseason drainage 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 25).

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 acquatic weed chara, which can otherwise form a dense mat on the soil surface and significantly delay drainage before harvest.

Figure 25. Midseason dry down can alleviate straighthead (right). Photo: Tina Dunn

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 26. It is important to select representative panicles and squeeze the glumes to determine their stage of development. Photo: Tina Dunn

Table 16. 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

Precision agriculture

Precision agriculture (PA) is a farming management concept that uses spatial information to help manage the inter and intra field variability in crops. PA aims to optimise field level management with regard to:

- **Crop science:** by matching farming practices more closely to crop needs
- **Environmental protection:** by reducing environmental risks and footprint of farming
- **Economics:** by boosting competetiveness through more efficient practices.

Monitoring yields has suggested that production varies approximately 3–4 t/ha across each paddock ($1200+/ha variability). NDVI images, NIR test results, EM soil surveys, cut and fill maps and historical yield maps can be used to understand the factors causing crop variation. Soil variability issues should be addressed before sowing. Yield potential might already be lost if left until mid-season or PI.

Paddock levelling

Variable water depth across bays can significantly impact yield. Regularly levelling paddocks (every two years) to ensure minimum grades on each bay will limit the effect of inconsistent water depth (Figure 27).

Figure 27. A laser bucket can be used to ensure minimum grades on each bay to limit the effect of inconsistent water depth.
Photo: Chris Andrighetto

Elevation data can be collected by farmers who use RTK 2 cm accurate autosteer for pre-drilling fertiliser or planting (Figure 28). This data can be utilised to create digital elevation maps in order to identify which bays may require re-levelling. An analysis of yield against elevation can also offer an insight into the economic loss of poorly levelled bays.

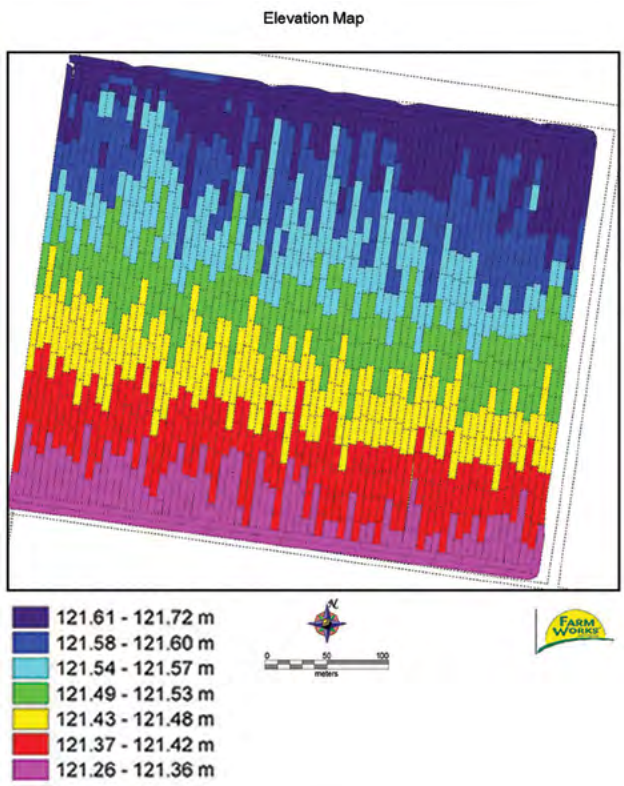


Figure 28. Elevation maps can be used to identify which bays need re-levelling.

Yield data capture

Yield mapping is critical because it allows proper analysis of issues on your farm (e.g. fertiliser responses in cut/fill zones, water depth/ irrigation issues, etc; Figure 29). Preparation is the key to collecting meaningful data collection at harvest:

- Ensure hardware components are in good working order including testing the yield monitor at the start of the harvest.
- Use a formatted data card (with predefined paddocks listed, boundaries and/or guidance lines for each season) preferably with enough space to record the entire harvest's yield data.
- Ensure the yield monitor is calibrated both pre-harvest and against post harvest delivery tonnages

- Calibrate the moisture sensor against the moisture meter.
- Ensure the height switch is set up and working correctly and turns off when raising the header front at end of runs.
- Ensure the right header front width has been entered into the monitor and that a full comb is harvested at each run (ideally use GPS guidance if available).
- Record harvested tonnes for each paddock to enable post-harvest calibration, if required.
- Where possible avoid using multiple headers to harvest the same paddock.

Analyse data

Use yield data to measure variations in yield and responses to management practice changes (i.e. levelling, fertiliser applications etc.) to see if a positive (yield and economic) response has been achieved. Start by reviewing whether there is a strong correlation with cut and fill zones.

Aerially or satellite sourced technology can be used to produce NDVI images of rice crop growth. These images show variation in crop growth, often from cut and fill areas. It is important to note that NDVI is not a measure of plant N, and an NIR test is still required to properly calculate N topdressing requirements. The zones of variation on the NDVI images are ideal to sample for the NIR test.

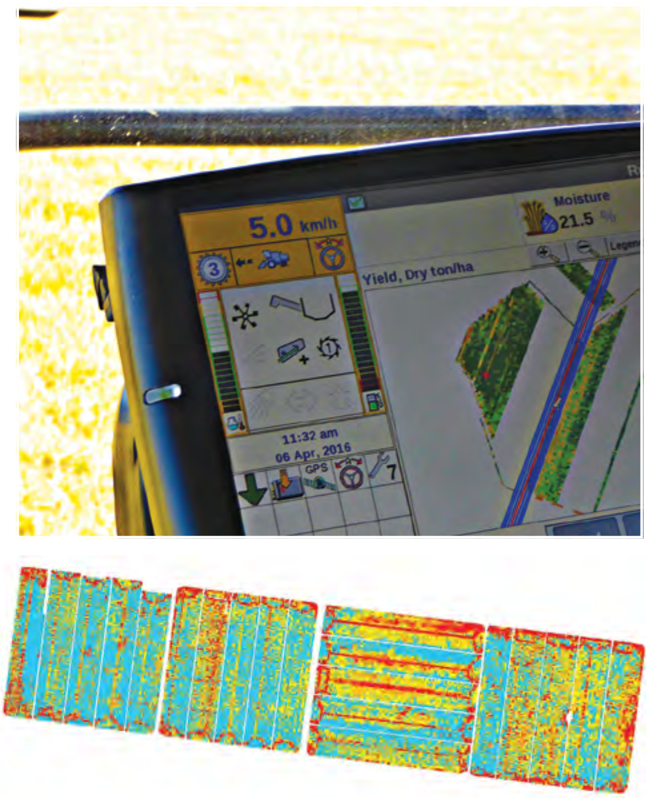


Figure 29. Create yield maps from data collected on a yield monitor to define paddock management zones.

Define paddock management zones

An electronic cut and fill map is a critical dataset for any rice farmer wanting to implement variable rate (VR) crop management. Cut and fill zones often correlate with rice yield. Define cut and fill zones, typically 2–4 zones per paddock (5–10 cm increments).

Farmers with multiple years of yield data should review all maps and look for consistent trends. However, it is likely that the maps will vary between seasons. If clear production zones cannot be found, then there would be little value in pursuing variable rate management.

Once management zones have been identified from clear trends in layers of collected data, writing the prescription for the variable rates is the next step. The combination of yield maps , paddock knowledge, cut and fill maps and targeted soil sampling can help define fertiliser rates to unlock yield potential. Prescriptions for VR can be done by using a mapping program or by engaging a service provider to manage your data and build VR application maps.

VR fertiliser programs have been shown to close the variability in yield and can offer a 10–15% productivity increase.

Do not use yield data from non-rice crops in an attempt to define rice management zones as they respond differently to soil/water influences. Paddock knowledge should always be integrated into the paddock zoning process.

Soil monitoring and conditioning

Strategic GPS- referenced (0–10 cm) soil tests based on previous year's rice yield map and/or cut and fill zones are important to develop a targeted crop nutrition program.

Topsoiling is essential when levelling new country as it has the ability to dramatically minimise the detrimental effects of cut. Cut areas that are not top-soiled often need a doubling of nutrients, but this depends on the amount of cut. As much as 150–300 kg N/ha and 40 kg P/ha might be needed each season to bring cut areas to the same nutrient level as undisturbed areas. These areas can also respond to Zn application. Applying animal (pig, cow and chicken) manures can improve soil structure and fertility in cut areas.

Actively manage soil acidity and sodicity with targeted lime and gypsum applications based on soil pH maps and EM38 maps.

Crop monitoring

Monitoring crops throughout the season is essential to ensure the yield variation is due to nutrients, and not to other factors such as weeds or uneven plant populations.

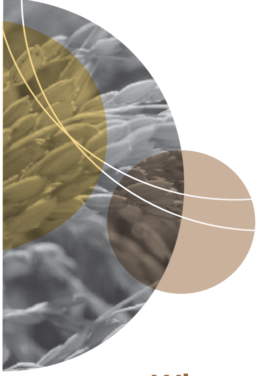
On-farm trials

Testing management practices are made simple for farmers with GPS capabilities. Simple test strips (Figure 30 on page 34) should be used to quantify crop/economic response to a wide range of management including fertiliser programs and soil conditioning with lime and gypsum (if cultivated in).

Trials more suited to each bay level include regrading and water management. On farm trials should consider the following:

1. Simple test strips within the same bay should be used to quantify crop/economic response to a management factor, primarily fertiliser and soil conditioning (lime and gypsum, if cultivated in).
2. Trial design and location holds the key to success – viewing historical yield maps and land forming maps offers insights into paddock and bay selection that are consistent in their yield performance.
3. These data sets can also help design trials to deliberately run through areas of high and low performance.
4. Select bays that are wide enough for each treatment to include three passes of the header and avoid bays with significant variation in water depth as this can confound your trial results.
5. Where possible, run each trial strip the entire length of the paddock. At a minimum, trials should be no less than 100 m long.
6. An option for minimising water depth influence is to split the bay in half across the bay rather than a split along the centre run-line.
7. Certain trials will be more suited to bay level comparisons (i.e. water management), however multiple replicates would be required in order to obtain confidence in results from these trials as more confounding factors are introduced to the trial when comparing different bays.

Figure 30. Using test strips can quantify crop and economic response to management programs. Photo: Andrew Whitlock



Production of quality rice

What quality attributes do we want in a rice variety and how do we measure these?

In the NSW DPI quality evaluation program, rice quality is measured objectively and subjectively to determine the best variety for a desired quality. Following are some of the parameters to determine rice quality.

High whole grain yield

Whole grain yield (WGY) is the percentage of grain left after removing the hulls and bran layer. Paddy rice is assessed after milling to determine the percentage of whole grain in the sample. This is the first quality requirement for the paddy. The paddy is test milled and the quality team assesses the breakage percentage.

No chalk

Chalk is an undesirable property in rice (except for Arborio) as it affects not only whole grain yield, but also cooking properties, colour and translucency. The high temperature during grain filling has been associated with higher chalkiness in grain. In quality evaluation, image analysis is used to measure and calculate the chalk percentage.

Good colour with high translucency

Polished grain can appear yellow or grey in colour. 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 high temperature during grain fill. A spectrophotometer is used in the quality evaluation program to measure the colour, and overall colour is expressed as a whiteness, redness and yellowness value.

The 'right' shape

The ratio of length to width describes variety shape, and is used for determining the class of a rice i.e. short, medium or long grain. Mixing different varieties during harvesting and not cleaning the header properly when changing variety can cause a mix of size and shape of grains. Inadequate nutrition and pest infestations also cause poorly shaped grains.

No cracks

Cracks can cause rice to break during milling thereby affecting the whole grain return. The cracks can also form in the milled grains and cause a significant loss in quality. Various agronomical and post harvest factors affect cracking.

The right 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 to the instrumental methods to measure cooking quality, sensory evaluation is also used to determine more realistic cooking and sensorial properties.

What can growers do to improve grain quality?

Australian rice is prized for its superior quality and caters for niche markets. Hence, the focus on quality should be maintained at every step of the supply chain. While variety is the major factor affecting quality (i.e. appearance, milling quality and cooking characteristics), grower management plays an important role. The choice of variety and grower practice such as sowing rate, nutrition, irrigation, draining and time of harvest greatly influence rice quality.

Rice is primarily consumed as a whole grain. Hence, SunRice has implemented quality payments and a premium price for high WGY. A premium/discount of $2.00 per tonne per percent (or part thereof) variation from the seasonal average for the variety will be applied in a linear scale starting at 2.5% above and below the average. For example, if the variety average for whole grain yield is 60%, discounts will start for that variety at 57.5% and premiums at 62.5%. Using the seasonal average, WGY as a base point takes into account the seasonal weather and other influences outside the grower's control. Researchers are working towards a better understanding of grain quality as all the factors that affect WGY are unknown.

Grain moisture decline. The rate grain dries during ripening determines the percent whole grain. Weather conditions, sowing time 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 and grain moisture can fall at 0.5% per day for moist soils and at 1% per day for dry soils. Farmers need to monitor grain moisture closely under these conditions.

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

Harvest at a moisture level as close to 22% as possible. WGY will be maximised by harvesting at 18–22% moisture (Figure 28). Once the grain is delivered and stored under a controlled dry down process the chance of stress cracking (Figure 30) 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.

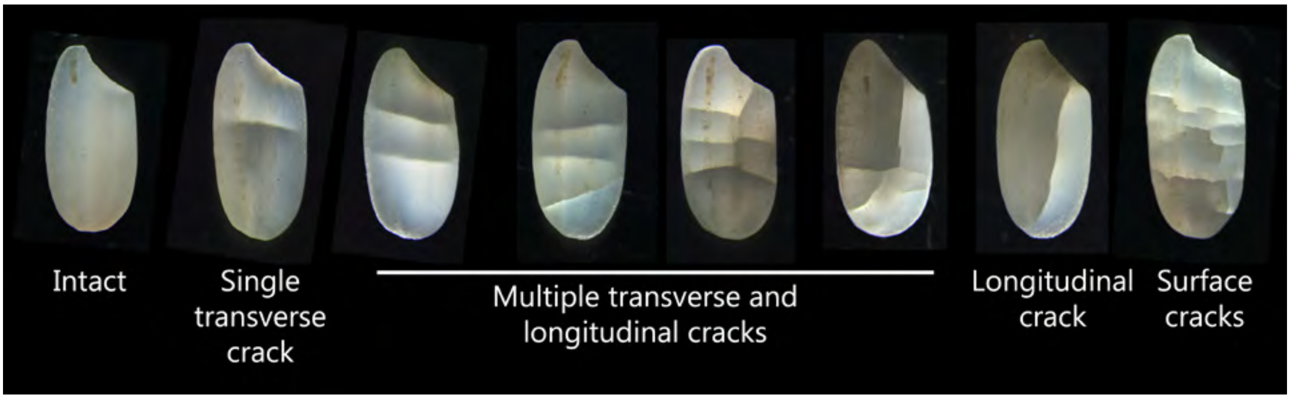


Figure 31. Stress cracking and subsequent broken grains can be prevented by harvesting at the correct moisture level. Photo: NSW DPI.

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 sometimes have spikes of hot weather with high daily evaporation and this will cause grain cracking and decline in WGY, especially if harvest moisture is below 20%.

Aim for a uniform crop. Fields with good layout and levelling will allow even establishment and water control, which will result in a uniformly maturing crop at harvest time.

Varietal harvesting order. If at similar moisture contents, medium grain varieties, Reiziq$^{\text{⦶}}$, Sherpa$^{\text{⦶}}$, Illabong and Viand$^{\text{⦶}}$ should be harvested before long grain varieties, as their rate of decline in WGY is faster. Harvesting Reiziq$^{\text{⦶}}$ and Langi should not be delayed because of the risk of shedding. Delaying harvest can lead to lodging and stress cracking problems with Koshihikari and YRK5.

Nitrogen management. WGY will be maximised by growing rice at the optimum N levels 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.

Draining. Draining at the right time is very important for achieving high grain quality. Draining too early might result in the crop haying off, which will cause a decline in WGY, grain quality and total yield. Draining too late could mean the paddock is too wet and harvest will be delayed beyond the optimal moisture content for highest grain quality (Table 16 on page 31).

Quality assurance

Consumers expect rice to be true to type, clean, and free from discolouration, off-flavours, chemical residues and foreign matter. Farmers have a responsibility to harvest and deliver paddy grain that can meet the standards for food safety and quality. There are quality assurance programs in place within the NSW rice industry to ensure that those standards are met.

There are a number of quality specifications that can affect your harvest return. These include contamination with foreign material (high penalties for glass, metal, fertiliser and insect contamination), discolouring, excessive trash, high moisture, stackburnt paddy and shot and sprung paddy.

Taking care in harvester setup and monitoring operations throughout harvest as well as attention to detail with harvest equipment cleaning, is vital to ensure minimum discounts apply to payments. Clean all 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 of 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.

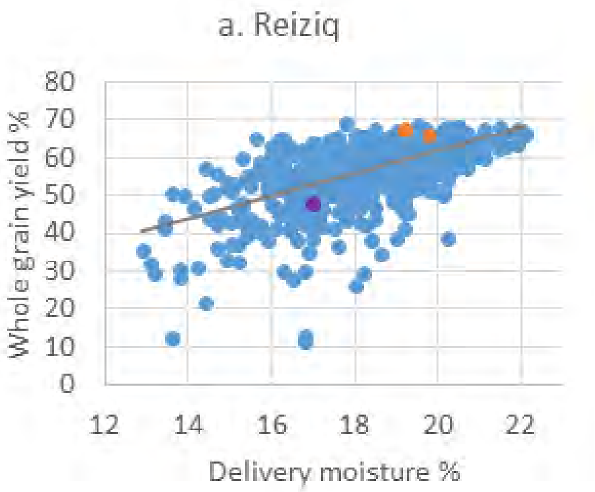


Figure 32. Effect of delivery moisture on whole grain yield of Reiziq⁽ᵇ⁾ in the 2016–17 season.

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.

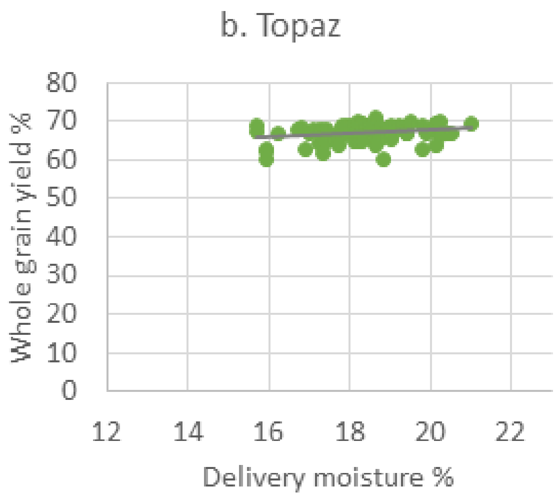


Figure 33. Effect of delivery moisture on whole grain yield of Topaz⁽ᵇ⁾ in the 2016–17 season.

The whole grain yield of long grains is more consistent than medium grains as the effect of lower delivery moisture is not as detrimental. The effect of moisture on the short grain varieties is less than on medium grains (Figure 32) and more severe than for long grains (Figure 33).

Grower example 1:
Excellent whole grain yield

Variety: Reiziq⁽ᵇ⁾ (whole grain yield average 2016–17: 56.1%)

Grower whole grain yield: 65.7–67.4%

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⁽ᵇ⁾ (whole grain yield average 2016–17: 56.1%)

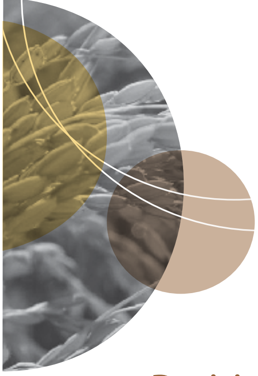
Grower whole grain yield: 47.6%

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.



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 $cenario (http://ricescenario.sunrice.com.au./) is a web-based tool you can use to enter your own numbers to help in making water purchase, crop mix and risk management decisions. If your computing skills are not great, work within this book by using the following hard copy templates from Rice$cenario (page 40).

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 40. 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 from GRDC.

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 17 and 18 on pages 39 and 40) 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 17. 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 18. Example gross margin for drill sown Reiziq⁽ᴾ⁾, Langi and Opus⁽ᴾ⁾.
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⁽ᴾ⁾ Langi and Opus⁽ᴾ⁾ 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 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 20. Example gross margin for dry broadcast Reiziq⁽ᴾ⁾, Langi and Opus⁽ᴾ⁾. 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⁽ᴾ⁾ Langi and Opus⁽ᴾ⁾ at the time of writing.
** Yield is based on the 5-year average for each variety.
*** Contract rates are used.

Budget sensitivity tables

Table 21. A sensitivity budget showing gross margin per hectare for the example crop in Table 20 for dry broadcast Reiziq[Φ] 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 22. A sensitivity budget showing gross margin per hectare for the example crop in Table 20 for dry broadcast Reiziq[Φ] 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 23. A sensitivity budget showing gross margin per hectare for the example crop in Table 20 for dry broadcast Reiziq[Φ] 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			
Yield			

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			
Yield			

Rice growing guide

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