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Managing nitrogen in rice

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Nitrogen (N) is an important nutrient required to achieve high rice grain yields. It is also a major input cost. Few rice farming systems in southern NSW now contain legumes, so there is a strong reliance on N fertiliser to maximise grain yield, water productivity and profitability.

As there is no soil N test suitable for rice, growers must rely on field history and experience to determine pre-permanent water N application rates. Determining the amount of N to apply to a field is a complex decision with many interacting factors and few definitive answers. There is a balance between applying sufficient N to maximise yield potential and applying excess, which can increase the risk of lodging or reduce yield due to cold-induced sterility. Experiments (Figure 1) in various locations over several seasons have helped determine the optimal N rate and timing for different rice varieties.

Figure 1. Nitrogen rate and timing experiment conducted at Yenda in the 2022–23 season.

Crop nitrogen requirements

A rice crop of a semi-dwarf variety requires sufficient N to be supplied before panicle initiation (PI) to reach its yield potential. Panicle initiation is when the panicle begins to develop in the base of the stem. At PI, the crop N status can be measured, and if deficient, fertiliser applied to the crop. Nitrogen uptake at PI, calculated from plant dry matter and N concentration, has a strong relationship with grain yield (Figure 2).

Grain yield for Reiziq⁽ᵇ⁾ increases with increased PI N uptake until plateauing at around 140 kg N/ha, and then it starts to decline above 170 kg N/ha (Figure 2). The cluster of points in Figure 2, with N uptakes above 100 kg N/ha and yields below 9 t/ha, were affected by low temperatures during the reproductive period in the 2020–21 season.

To maximise yield potential, N uptake levels between 100 kg N/ha and 140 kg N/ha should be obtained by PI (Figure 2). High grain yields can still be achieved with PI N uptake levels above 140 kg N/ha, but there is an increased risk of lodging and floret sterility. The 100–140 kg N/ha range allows for minor judgement errors in soil N levels.

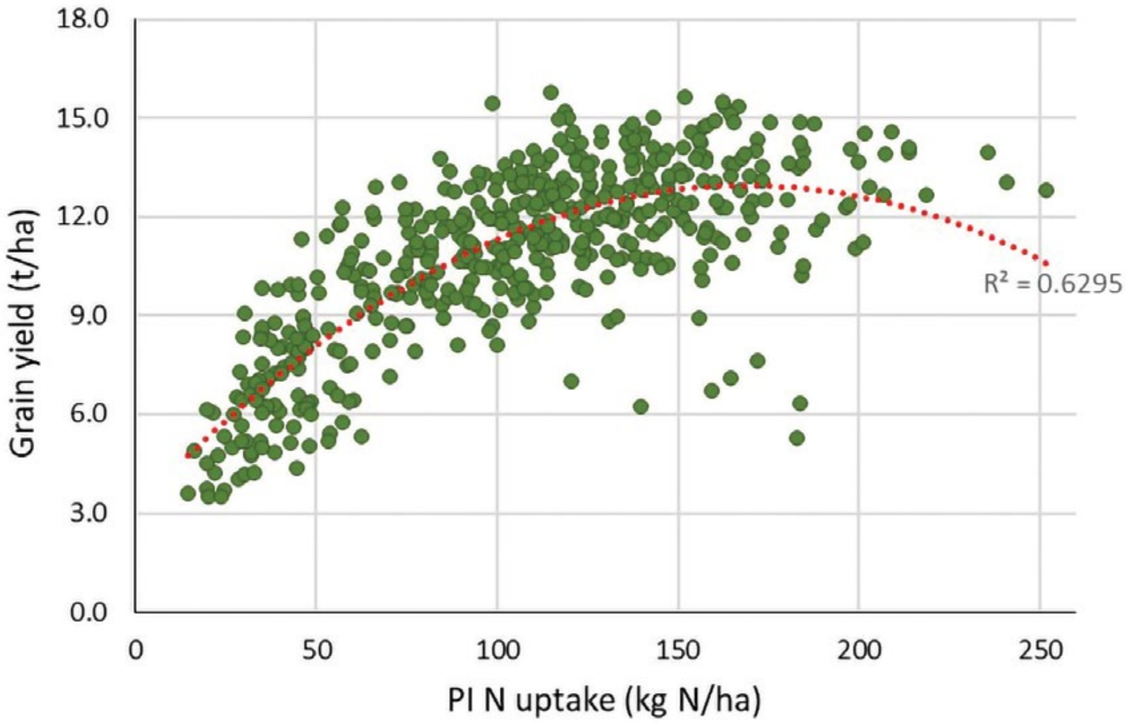

Figure 2. The relationship between panicle initiation nitrogen (PI N) uptake and grain yield for the semi-dwarf medium grain variety Reiziq⁽ᵇ⁾. Data are from over 600 plots in 52 experiments conducted over 8 seasons (2015–2023) in southern NSW.

Nitrogen deficiency during tillering greatly reduces grain yield potential in semi-dwarf varieties, which cannot be regained later. If Reiziq⁽ᵇ⁾ does not have N uptake above 80 kg N/ha by PI, then grain yield potential has already been limited, regardless of how much fertiliser is applied at PI. An exception to this is fields with high soil organic N levels, such as after a legume pasture, where high grain yields can sometimes be achieved with PI N uptake levels below 80 kg N/ha.

Permanent water nitrogen fertiliser requirements

The most efficient time to apply N to a rice crop is before applying permanent water (PW), regardless of the sowing or irrigation method (Table 1). Data from many N experiments illustrate the relationship between the rate of pre-PW applied urea and PI N uptake levels for Reiziq⁽ᵇ⁾ (Figure 3).

On average, to obtain a PI N uptake in the recommended range of 100 kg N/ha to 140 kg N/ha for Reiziq⁽ᵇ⁾ requires between 200 kg/ha and 360 kg/ha of urea pre-PW (Figure 3). Fields with a history of legumes and high soil N levels might require less N, while fields with a long cropping history or areas of recent cut that result in low soil N levels might require more.

Table 1. Nitrogen use efficiency ranges for different nitrogen application timing. These efficiencies are based on the best practice being used for each application method.

Timing	Sowing method	Nitrogen use efficiency	Comments
Pre-permanent water	Aerial and dry broadcast	40–60%	Lower efficiency if urea is spread on the soil surface than if drilled >50 mm deep pre-PW
	Conventional drill	50–70%	Best applied to dry soil close to PW application with no rain before PW
	Delayed PW	65–75%	DPW might need 25% less N pre-PW than aerial or dry broadcast
Mid-tillering	–	10–25%	If no urea is applied pre-PW, wait for plants to grow then apply it multiple splits over a month
Panicle initiation	–	30–35%	A full canopy reduces volatilisation losses and a large root system takes up N quickly

PW = permanent water, N = nitrogen.

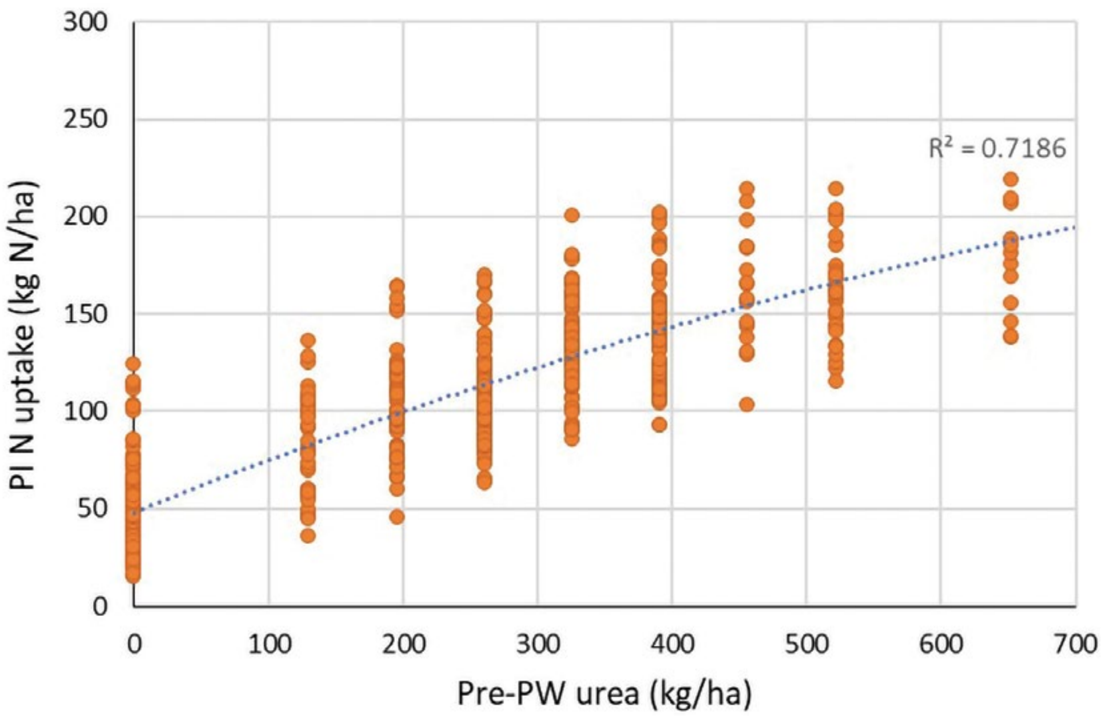

Figure 3. Nitrogen uptake levels at panicle initiation (PI) in Reiziq[(h)] when applying a range of pre-permanent water urea rates in commercial rice fields. Data are from 600 plots in 52 experiments conducted over 8 seasons (2015–2023) in southern NSW.

The level of PI N uptake at each urea application rate (Figure 3) varies considerably. This variability is due to several factors including soil organic N level, soil type, topsoil depth, N mineralisation rates and N application practice. Land forming cut and fill can also greatly affect these factors. Imagery and PI tissue test results from previous rice crops grown in the field are valuable resources when determining pre-PW urea requirements.

When applying pre-PW urea, the fertiliser must be applied evenly with no overlaps or gaps. Overlaps and uneven urea applications create large differences in rice growth that cannot be amended later in the season and can lead to grain yield loss, lodging, variability in maturity and poor grain quality.

Mid-tillering nitrogen to manage field variability

Variability in soil N supply is common, particularly after land forming has moved topsoil. When a blanket rate of N is applied to a field, variability in crop growth often results. Although applying N during tillering is not recommended as it is relatively inefficient (Table 1), if there are areas of the crop that are not expected to reach a PI N uptake of 80 kg N/ha, a mid-tillering top-dressing of the poor growth areas might be required.

Using normalised difference vegetation index (NDVI) imagery collected during tillering can help to identify the poor growth areas that might require N application 2 or 3 weeks before PI. It is important to validate the imagery for plant population and weeds and be aware that water deeper than 80 mm can affect NDVI values during tillering, as the water covers leaves.

Applying N during tillering can also be beneficial if the field has been drained for a prolonged period during early tillering or sufficient N could not be applied pre-PW due to rain.

Panicle initiation nitrogen application

Once a crop has reached PI, it will have taken up most of the N available from the soil and fertiliser applied before PW and during tillering and used it to produce biomass.

Panicle initiation offers the opportunity to efficiently apply N to the rice crop if required, as many surface roots quickly take up the N and the crop canopy reduces N losses to the atmosphere (Table 1). Another advantage of applying N at PI is being able to measure the crop's growth using the PI tissue test and then making an evidence-based decision on how much fertiliser to apply.

The biggest limitation to applying N at PI is it can only increase grain yield by a small amount. In the V071⦶ experiment conducted in 2022–23 (Figure 4), even when no urea was applied pre-PW, applying 261 kg/ha urea at PI could only increase yield by 2 t/ha. Applying 261 kg/ha urea at PI did not increase grain yield to anywhere near the level achieved by applying 261 kg/ha urea pre-PW. The poorer the crop growth at PI, the larger the grain yield increase that can be achieved (Figure 4).

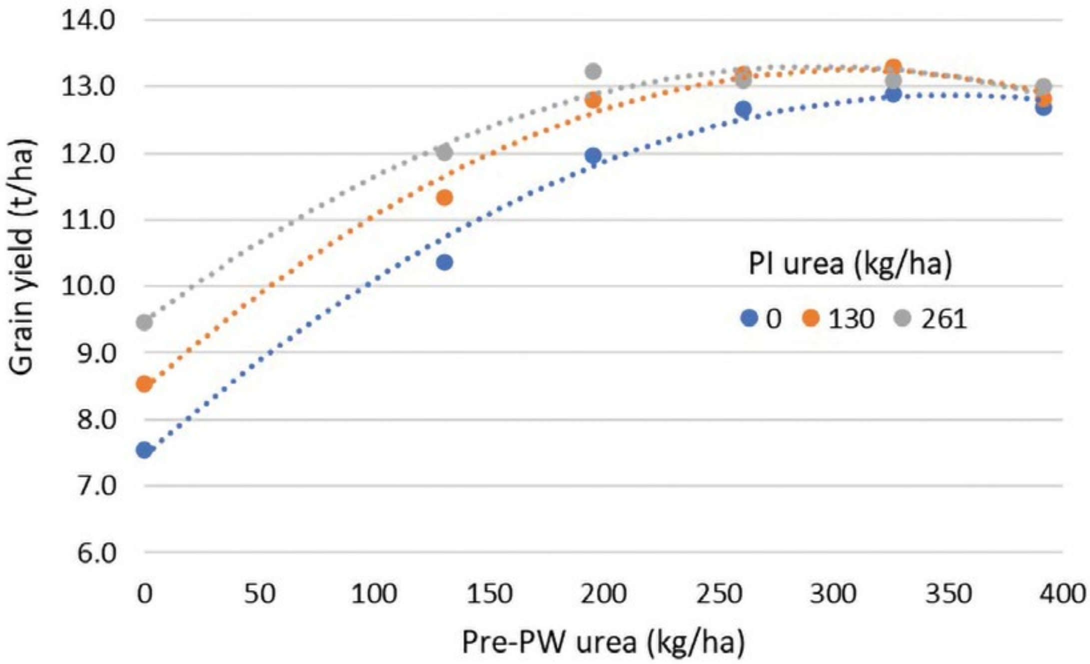

Figure 4. The effect of pre-permanent water and panicle initiation urea (kg/ha) on grain yield (t/ha) of V071⦶ in an experiment in 2022–23.

The PI top-dressing window ranges from when PI is first identified until 10 days after PI. The more N deficient the crop, the closer to PI the N should be applied to maximise potential yield. Normalised difference red edge (NDRE) imagery of the field at PI is valuable to show rice growth differences and provide a guide for zone sampling for the PI tissue test. Normalised difference vegetation index imagery is of little use for rice at PI as the crop biomass is very high, which saturates the NDVI reading, therefore it does not show the true extent of plant growth variability throughout the field.

Pre-permanent water nitrogen requirements for other varieties

The semi-dwarf medium grain rice varieties (ReiziqⓅ, V071Ⓟ, SherpaⓅ and OpusⓅ) all show similar grain yield responses to PI N uptake and pre-PW urea (Table 2). The range of recommended pre-PW urea application rates is therefore the same for all these varieties except OpusⓅ, which has a reduced target rate as it is not desirable in the market to have high grain protein in this short grain variety (Table 2).

The other varieties listed in Table 2 have a reduced recommended PI N uptake and pre-PW urea rate range compared to ReiziqⓅ. ViandⓅ is a late-sown semi-dwarf medium grain variety that is susceptible to lodging when high levels of N are available early in the crop's growth. TopazⓅ, Doongara and Langi are all semi-dwarf long grain varieties and require high levels of N to produce high grain yields, but they have increased sensitivity to cold during the reproductive periods, which is increased by high levels of N in the crop. Langi is also susceptible to lodging when high rates of N are applied pre-PW.

Koshihikari is a tall, short grain variety that is highly susceptible to lodging and lower levels of N should be applied pre-PW.

Table 2. Variety panicle initiation nitrogen (PI N) uptake targets, pre-permanent water urea requirement ranges and factors limiting higher pre-permanent water N application rates.

Variety	Panicle initiation nitrogen uptake (kg N/ha)	Pre-permanent water urea (kg/ha)	Limiting factor
ReiziqⓅ	100–140	200–340	–
SherpaⓅ	100–140	200–340	–
V071Ⓟ	100–140	200–340	–
OpusⓅ	100–130	200–300	Protein
ViandⓅ	90–120	180–260	Lodging
TopazⓅ	90–120	180–260	Cold risk
Doongara	90–120	180–260	Cold risk
Langi	90–120	180–260	Lodging and cold
Koshihikari	70–90	100–150	Lodging

Nitrogen efficiency

The more efficiently N is used, the more cost effective and profitable rice growing is.

The highest N use efficiency occurs when N is positioned in the soil before, or when, PW is applied (Table 1). The N attaches to the clay particles and most remains in the soil until it is used by the plant.

Nitrogen is applied by either drilling urea into the soil before PW for aerial or dry broadcast sowing, or spreading urea onto the dry soil surface before PW is applied for conventional drill or delayed permanent water (DPW) managed crops.

The N use efficiency of urea when it is applied pre-PW is lower for aerial sown crops than for conventional drill and DPW crops (Table 1) because of the losses that occur before the plant is large enough to start using the N. Spreading urea onto the dry soil surface (Figure 5) before filling up for DPW crops is the most efficient, as the plants have a large root system and are actively growing, so they quickly take up the N that is washed into the soil and use it to produce plant biomass (Table 1).

Applying N at mid-tillering is not desirable due to its lower efficiency, but it might be required if insufficient N was applied pre-PW and crop growth is very poor. This happened in the 2022–23 season, which was very wet, and crops were sown without N. Mid-tillering N applications to poor growth areas identified by NDVI imagery are also valuable to even-up within-field variability.

Applying N at PI is not as efficient as at pre-PW, but is valuable as the crop growth and N content can be measured. This allows for accurate N top-dressing rate recommendations and cost-effective N application.

Figure 5. The most efficient nitrogen use in rice is when urea is applied to the dry soil surface before applying permanent water to a delayed permanent water crop.

Least efficient nitrogen application practices

Several practices should be avoided when applying N fertiliser as they result in large N losses. These losses are both a direct cost from the lost fertiliser and potentially reduced yield when the crop receives insufficient N to reach maximise yield. Practices that should be avoided include:

1. Spreading urea into a flooded field when plants are very small (up to 70% loss; Figure 6). The N does not move into the soil and the plants cannot take it up before much of it is lost to the atmosphere through volatilisation.
2. Sowing urea with seed or into the soil before flush irrigations when drill sowing (up to 50% loss). The wetting and drying of the soil from flush irrigations lead to large N losses by nitrification followed by denitrification.
3. Spreading urea onto wet soil before applying PW (up to 30% loss). The N is not washed into the soil when PW is applied, and N is lost from the flood water through volatilisation.
4. Spreading rather than drilling pre-PW urea for aerial sown crops (up to 20% loss). If urea is spread on the soil surface rather than drilled >50 mm deep, N can be lost before it can be used by the plants.

Nitrogen loss is highly variable due to many factors such as temperature, soil pH, the time between N application and PW, the time between irrigations, fertiliser placement and rate.

Figure 6. Applying urea into a flooded field when the plants are small is inefficient with much of the nitrogen lost through volatilisation before it can be taken up by the plants.

Conclusion

Adequate N supply is critical for rice crops to achieve optimum grain yields. The correct rate, timing and placement of N fertiliser for each variety enables efficient fertiliser use, high grain yield, water productivity and profitability.

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