



# Timing of nitrogen applications for rice

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## in a nutshell

- This report presents a summary of five years of experiments investigating a suite of timings for nitrogen fertiliser application
- Results indicate no significant differences in nitrogen responses among Australian rice varieties and optimum nitrogen requirement lies around 170–180 kg N/ha depending on the inherent soil nitrogen supply
- Five years worth of results show that the best yields are obtained when nitrogen application is split between pre-flood and panicle initiation applications
- A minimum pre-flood application of 90 kg N/ha in continuously cultivated bays is recommended to ensure adequate nitrogen supply during the vegetative growth stage of the crop to produce sufficient biomass to sustain a good yield
- A maintenance requirement of nitrogen at panicle initiation is recommended to ensure adequate nitrogen supply to the plant during the reproductive stages
- Mid-tillering nitrogen applications are warranted if an inadequate amount of pre-flood nitrogen was applied, early nitrogen application was not managed correctly, or the soil is inherently low in fertility

***The response of current commercial rice varieties to nitrogen has been shown to vary from year to year and site to site, hence making accurate nitrogen recommendations for rice crops a challenging task for researchers to achieve. Constant upgrading of fertiliser recommendations is especially necessary for rice because the properties of rice growing soils change enormously with time due to the intensity of cultivation. New rice varieties also need to be assessed for their response to current nitrogen strategies.***

Grower preference for many years, supported by some research results, was to apply nitrogen fertiliser as a heavy single dose before seeding (pre-flood), 5–10 cm below the soil surface. This practice remains popular in some districts of the rice growing area. Using the strategy, it is recommended to apply 120–180 kg N/ha pre-flood to achieve a target nitrogen uptake of 130–150 kg N/ha at panicle initiation, to obtain 12 t/ha yield, depending on the history of the paddock. However, pre-flood application of the crop's total nitrogen requirement carries a certain amount of risk.

## Risk of total nitrogen upfront

High nitrogen rates at pre-flood can increase the risk of cold damage to the developing pollen microspore, if low night temperatures occur during the crop's reproductive stage, thereby reducing the number of engorged pollen

grains per anther, increasing spikelet sterility, and reducing yield potential.

Recommended sowing time puts pollen development during late January and early February. Historical weather data illustrates that the average minimum temperature during this period is 17°C.

High nitrogen fertiliser doses pre-flood can prolong the vegetative development of the rice plant, thereby deferring the reproductive stage, and increasing the probability of encountering critical minimum temperatures of 15°C or less.

The extra biomass produced due to high rates of pre-flood nitrogen fertiliser could also increase the risk of exposing the rice plant to extreme temperatures during reproductive development.

As such, timing and rate of nitrogen application are critical for maximising yield and avoiding the risk of low temperature damage, because low temperature events during the reproductive stages are unpredictable.

## Years of fertiliser timing research

Research into the effect of the timing of nitrogen fertiliser application on yield has been ongoing for many years. Some findings have shown that total pre-flood application of nitrogen fertiliser improves yield as well as nitrogen fertiliser efficiency. However, other findings revealed that



split nitrogen application is as efficient as pre-flood application, and that heavy pre-flood applications could increase the risk of damage to the crop in cold seasons, and induce lodging at harvest.

Most of the previous work on nitrogen management in Australian rice systems has been focused on nitrogen requirements under continuously flooded conditions. However, many rice farmers in Australia are currently practising a midseason dry down to mitigate the occurrence of straighthead, a physiological condition which reduces the yield significantly.

In addition, time of sowing can alter the response of rice plants to nitrogen fertiliser applications. When sowing is delayed, there is a high risk of yield loss due to cold damage, as crop development is delayed and the early pollen development stage occurs after early February, especially in conjunction with high nitrogen rates. However, about 10–15% of rice farmers in Australia do not adhere to the recommended sowing windows due to a variety of reasons. Therefore, nitrogen management in paddocks with delayed sowing is a key to achieving good yields. Our knowledge on the effect of delayed sowing on nitrogen responses is fragmentary.

Since 2002, this project has investigated issues related to nitrogen management under different scenarios and developed nitrogen management options for newly released

varieties and for different water management systems. The project has also gathered information on the effect of other nutrients on rice productivity under different water management systems, and the influence of sowing date on nitrogen responses.

Last season (2006–07) was the final year of the project. The key findings of each season's work and the conclusions of the five seasons' worth of work are presented in this article.

### Trials 2002–03

Three field experiments were conducted in the 2002–03 season at Leeton, Jerilderie and Hay, comparing newer varieties Paragon and Quest with their older counterparts Amaroo and Millin.

The nitrogen treatments consisted of three nitrogen rates (0, 90 and 240 kg N/ha) applied at pre-flood, and the same three nitrogen rates applied at pre-flood with topdressing of 90 kg N/ha at panicle initiation.

Results of the trials were very variable with no clear cut guidance on nitrogen recommendations for the newer cultivars.

Quest showed consistently higher yields in most situations compared with the other three cultivars (Table 1).

Millin, Paragon and Quest yields were optimised around 180 kg N/ha and split application of 90 kg N/ha pre-flood

**Table 1: Average grain yield (t/ha) of four varieties at different nitrogen treatments in Jerilderie, Leeton and Hay in 2002–03 season**

Location	Tmt #	Nitrogen rate (kg N/ha)		Grain yield (t/ha)			
		pre-flood	panicle initiation	Amaroo	Millin	Paragon	Quest
Jerilderie	1	0	0	7.58	10.15	9.16	10.31
	2	0	90	10.64	11.60	10.98	10.53
	3	90	0	11.64	13.83	11.34	12.29
	4	90	90	13.21	11.64	11.24	12.84
	5	240	0	10.84	10.13	11.30	9.01
	6	240	90	7.73	11.67	9.62	10.13
Leeton	1	0	0	9.81	7.42	8.77	7.43
	2	0	90	10.73	9.82	10.07	10.57
	3	90	0	11.07	11.56	11.11	12.58
	4	90	90	11.85	10.42	12.52	12.60
	5	240	0	13.52	11.36	9.75	12.32
	6	240	90	12.17	11.39	12.00	10.77
Hay	1	0	0	6.00	5.24	6.33	5.06
	2	0	90	9.02	6.53	6.17	5.03
	3	90	0	9.70	8.70	9.86	7.95
	4	90	90	11.36	10.65	9.98	8.19
	5	240	0	12.12	10.19	10.51	10.51
	6	240	90	11.60	9.83	11.10	10.11

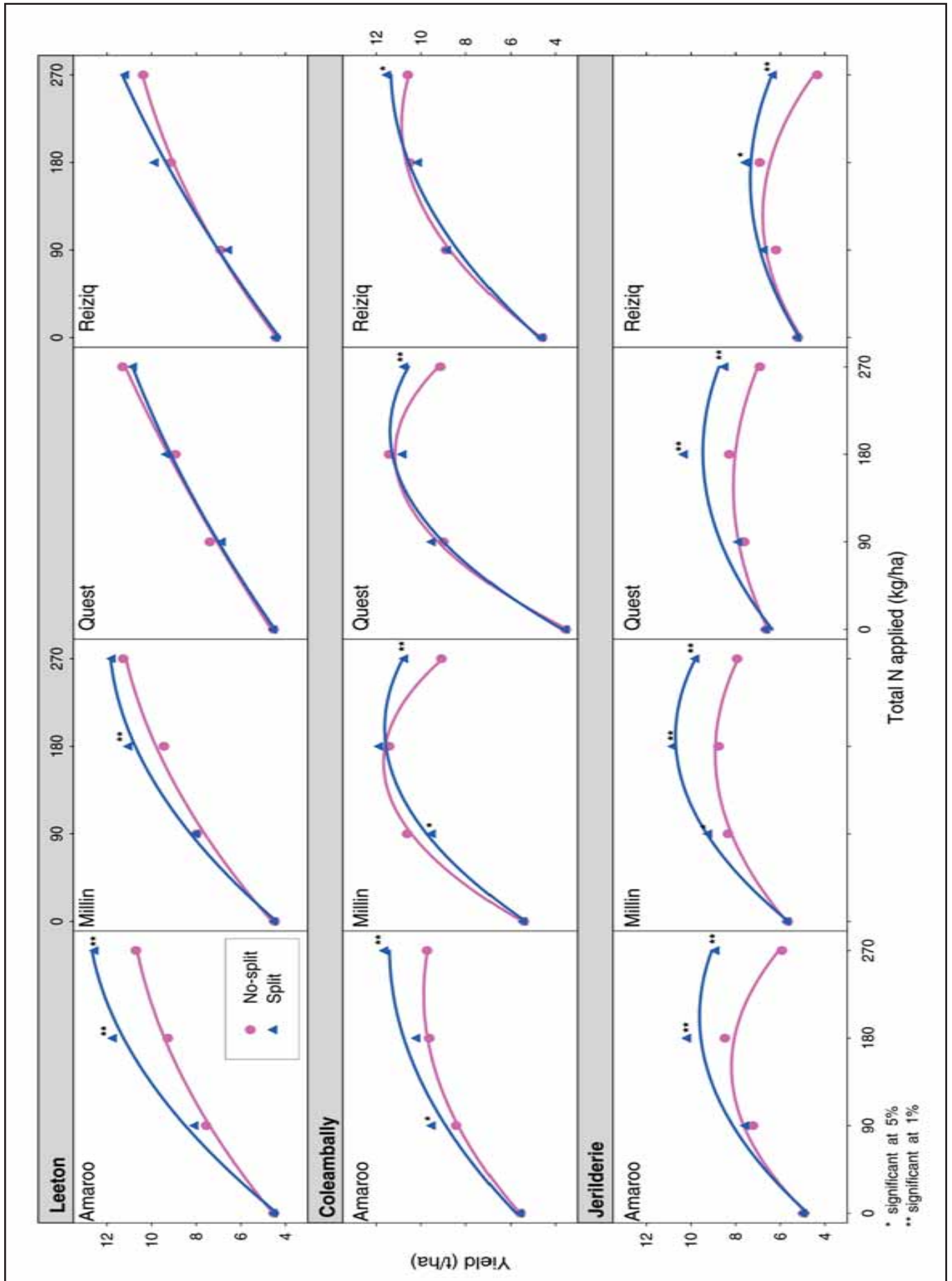
LSD (5%)

0.63 to compare the response of a variety to different nitrogen treatments within a location

0.52 to compare the response between varieties to the same nitrogen treatment within a location

2.35 to compare any two data points irrespective of variety, nitrogen treatment and the location

Note: PFN = Pre-flood nitrogen application, PIN = nitrogen application at panicle initiation





and 90 kg N/ha at panicle initiation showed higher yield compared with other treatments on most occasions, indicating the benefit of topdressing at panicle initiation.

All the varieties showed reasonably higher yields at higher nitrogen rates, even at the 330 kg N/ha rate. Higher yields at high nitrogen rates were expected as there was no extended spells of low temperatures (<15°C) during the microspore development stage which would have occurred during the last three weeks of January 2003 for all varieties and locations.

Overall, the results demonstrated the importance of applying nitrogen fertiliser at pre-flood to produce sufficient biomass especially in paddocks with low inherent nitrogen. However, the results also showed that when adequate nitrogen is provided at pre-flood, split application of nitrogen at panicle initiation is better than if the total amount of nitrogen is applied at pre-flood. For example, treatment 4 which has split application (90+90) gave the best yield in most occasions.

Results of the trials conducted in this season indicate that the optimum nitrogen requirement of the four cultivars in the trials lies around 180 kg N/ha depending on the inherent soil nitrogen supply.

### Trials 2003–04

Three nitrogen trials were conducted at Leeton, Jerilderie and Coleambally in the 2003–04 season. Responses of four varieties (Amaroo, Millin, Quest and Reiziq) to four nitrogen levels (0, 90, 180 and 270 kg N/ha) and two nitrogen timing treatments (a. total nitrogen at pre-flood and b. 2/3 nitrogen pre-flood and 1/3 panicle initiation) were investigated.

All three sites showed a similar temperature patterns and experienced spells of minimum air temperatures below 17°C during the periods 18–20 January and 22 January to 7 February. Some nights even experienced temperatures below 10°C. Of the three sites, Jerilderie experienced the lowest minimum air temperatures.

Cultivars showed significant variation in grain yield with Millin showing highest yield at each nitrogen level compared with the other three varieties, and Reiziq giving the lowest yield (Figure 1).

At Leeton, all cultivars showed a continuous upward trend in yield with increasing nitrogen application and may not have reached the maximum yield despite the application of a relatively high rate of total nitrogen fertiliser (270 kg N/ha). At Coleambally and Jerilderie, the optimum nitrogen requirement of all the four cultivars was somewhere around 180 kg N/ha.

The differences in yield responses at three locations may be due to varying levels of cold exposure during the microspore stage. Yield decrease with increasing nitrogen application at Coleambally and Jerilderie therefore, could be attributed to cold damage during microspore. Whereas, the microspore stage of plants at Leeton may have occurred before the low temperature spell. Sterility percentages also confirm the variation of levels of cold damage at the three locations.

Split application treatments at or above 180 kg N/ha resulted in higher grain yield compared with corresponding no-split treatments at all three sites. In most instances, the yield

differences were significant (Figure 1). These differences were most prominent at Jerilderie. Some split nitrogen application treatments resulted in nearly 2.0 t/ha yield advantage over the corresponding pre-flood application.

Amaroo showed better responses to split application over total pre-flood application at all three sites. Reiziq only showed significant responses to split application over pre-flood application at the 180 kg N/ha rate at Leeton and the 270 kg N/ha rate at Jerilderie.

Lodging was minimal at all locations, even at 270 kg N/ha. This may be due to zero rainfall during the harvesting season. This shows that the rice crop can stand without lodging at high nitrogen levels if a rainfall event does not occur during the harvest season.

Results also showed that nitrogen uptake at panicle initiation was significantly varied between cultivars, sites and nitrogen treatments. Optimum nitrogen uptake at panicle initiation (to produce maximum grain yield) was between 145 and 170 kg N/ha for the four varieties at Coleambally and Jerilderie. Across the three sites, the results suggest that nitrogen uptake at panicle initiation beyond 150 kg N/ha is detrimental when plants are exposed to low temperature spell during the pollen microspore stage, and this was particularly evident at Jerilderie.

An additional trial was also conducted at Yanco in 2003–04 season to evaluate the response of Amaroo to four nitrogen levels (0, 90, 180 and 270 kg N/ha) and three nitrogen timing treatments (a. total nitrogen at pre-flood, b. 2/3 pre-flood and 1/3 panicle initiation and c. 1/3 pre-flood and 2/3 panicle initiation).

Results indicated a significant yield increase due to nitrogen fertiliser application (Figure 2). However, the yield increase above the 90 kg N/ha rate was not significant. The trend of increasing yield with increasing nitrogen application rate seen at the Leeton trial in the same season was not evident at the Yanco trial, even though the temperature regimes during the pollen microspore development stage were the same at the two locations.

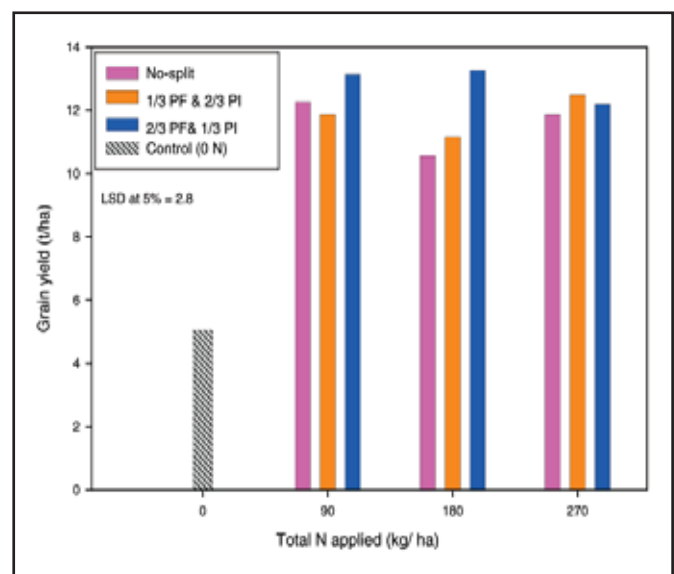


Figure 2. Yield responses to different timing strategies of nitrogen application at Yanco in 2003–04 season (PF = pre-flood, PI = panicle initiation).



At the 180 kg N/ha rate, the split nitrogen application of 2/3 pre-flood and 1/3 panicle initiation showed significant yield advantage over the other two timing treatments. There were no differences in the timing treatments at 90 and 270 kg N/ha. Total pre-flood application resulted in lower yield at all three application rates compared to that of split nitrogen application treatment of 2/3 pre-flood and 1/3 panicle initiation. The performance of the other split application treatment (1/3 pre-flood and 2/3 panicle initiation) was not consistent.

The results suggest that the split nitrogen application is beneficial over no-split application if sufficient nitrogen is available to plants during their vegetative phase.

### Trials 2004–05

A trial was conducted at Jerilderie during the 2004–05 rice season to evaluate the responses of Amaroo to four nitrogen levels (0, 90, 180 and 270 kg N/ha) and four timings of nitrogen application (a. total at pre-flood, b. 2/3 pre-flood and 1/3 panicle initiation, c. 2/3 pre-flood and 1/3 mid-tillering and d. three equal splits at pre-flood, mid-tillering and panicle initiation).

There was marked variation in response to nitrogen timing and rate among the treatments. Even though there was an extremely low temperature spell during the first week of February, all treatments with split nitrogen application showed continuous yield increase with increase in nitrogen fertiliser rate (Figure 3). However, the no-split treatment showed a significant yield decline above 90 kg N/ha and resulted in lowest yield among the four treatments. The results lead to the conclusion that exposure of plants with high biomass to low temperatures during the first week of February may have contributed to low yield in no-split treatment above the 90 kg N/ha rate. In addition, high availability of nitrogen during the vegetative phase may have delayed the young microspore stage and thus the critical stage would have coincided with the low temperature spell.

The results suggest that application of the total amount of nitrogen at pre-flood is detrimental in seasons with low temperature spells during the microspore stage especially at high nitrogen rates.

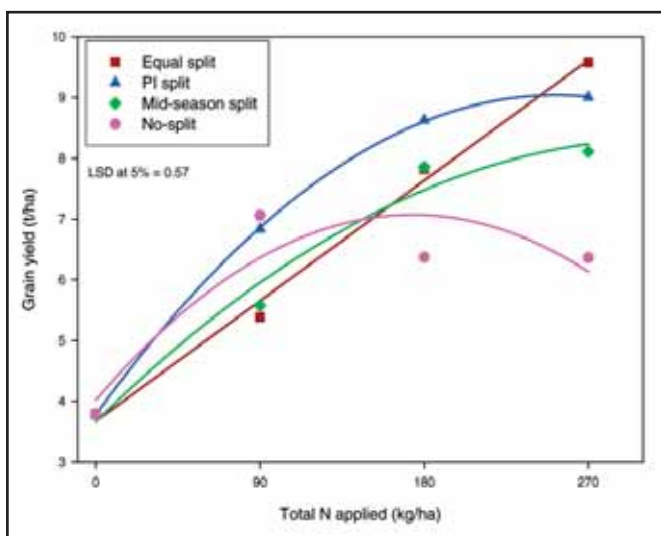


Figure 3. Yield response to rate and timing of nitrogen application at Jerilderie in 2004–05

Two timings for split application were investigated and the results suggest that a second application at panicle initiation is better than one at mid-tillering. Earlier investigations also showed the same result. The low efficiency of nitrogen topdressing at mid-tillering could be attributed to high losses of applied nitrogen through denitrification, as the plants are not quick enough to absorb applied nitrogen due to their small root mass at mid-tillering.

### Trials 2005–06

During the 2005–06 rice season, three trials were carried out at Leeton, Jerilderie and Wakool to quantify the nitrogen requirement of the new long grain variety YRL 125 and its older counterpart Langi. The trials further assessed the response of current rice cultivars to split nitrogen application. Four nitrogen levels (0, 90, 180 and 270 kg N/ha) and two nitrogen timing treatments (a. total nitrogen at pre-flood and b. 2/3 pre-flood and 1/3 panicle initiation) were evaluated.

There were significant differences in yield among the treatments. However, two cultivars showed similar nitrogen responses at all three sites. Unlike previous rice seasons, all sites showed a trend of continuous yield increase with increasing nitrogen rates, except with the total pre-flood application (no-split) at Jerilderie and Wakool (Figure 4). This may be due to favourable weather conditions during the season and no damaging low temperatures at the pollen microspore stage.

At all three sites, the split nitrogen application of 2/3 pre-flood and 1/3 panicle initiation resulted in higher grain yield compared with the no-split treatment, at rates beyond

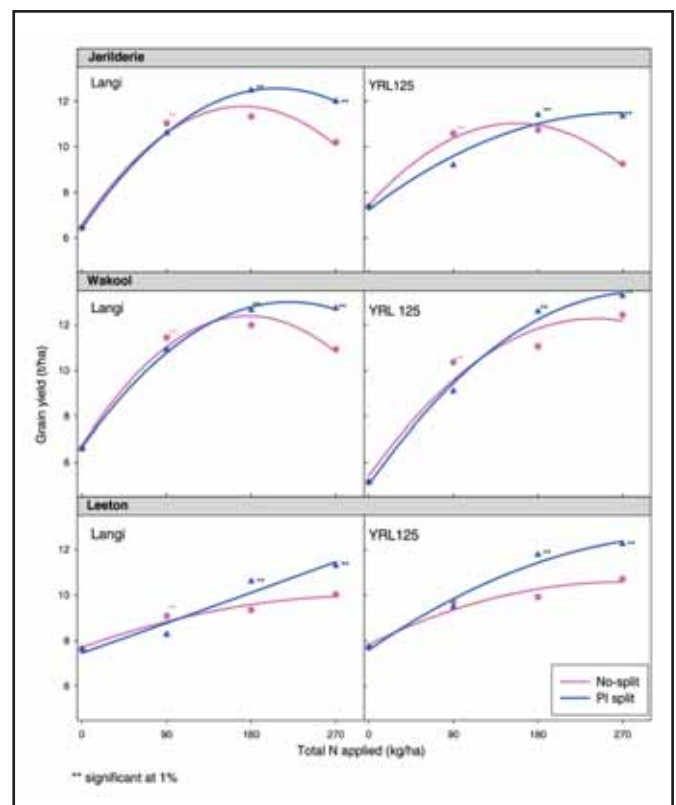


Figure 4. Yield response of YRL 125 and Langi to applied nitrogen at three experimental sites in 2005–06 (LSD at 5% = 0.30 to compare the response of a variety to different nitrogen treatments within a location).



90 kg N/ha. Even though the season did not experience low temperature spells during critical growing stages, these findings are parallel to the findings of previous rice seasons which experienced cooler weather spells.

The season's results suggest that split application of nitrogen is beneficial over total pre-flood application even in years with no low temperature spells during critical reproductive phases.

### Effect of midseason dry down 2005–06

Another two trials were conducted in 2005–06 season at Griffith and Wakool to investigate the effect of timing of nitrogen application on the performance of rice in bays with midseason dry down.

Air and water temperature data collected at 30 minute intervals indicated that the season was quite warm, without distinctive low temperature (below 15°C) spells compared with the two previous rice seasons. However, temperatures within the bays exceeded 40°C during the dry down period mainly due to very high ambient temperatures during the period, and the complete dryness of the soil surface in the bay. Had the hot weather continued for another couple of days, the plants would have suffered severe stress and recovery would have been a difficult task. This suggests that it is advisable to carry out the midseason dry down during the first half of December to avoid the periods of highest risk of hot weather, which are towards the end of December.

The yield responses to different rates and timings of nitrogen for the two sites are shown in Figure 5. It shows a continuous upward trend in yield with an increase in nitrogen application rate as expected in a normal season without low temperature events. Results also indicated that the yield responses to nitrogen treatments were highly significant ( $p < 0.001$ ).

The treatment with total nitrogen application pre-flood (no-split) showed the lowest yield for all nitrogen rates beyond 90 kg N/ha at both experimental sites. The treatment with split nitrogen application of 2/3 pre-flood and 1/3 just before re-irrigation after the midseason dry down showed the highest yields at nitrogen rates beyond 90 kg N/ha, followed by the split application of 2/3 pre-flood and 1/3 at panicle initiation.

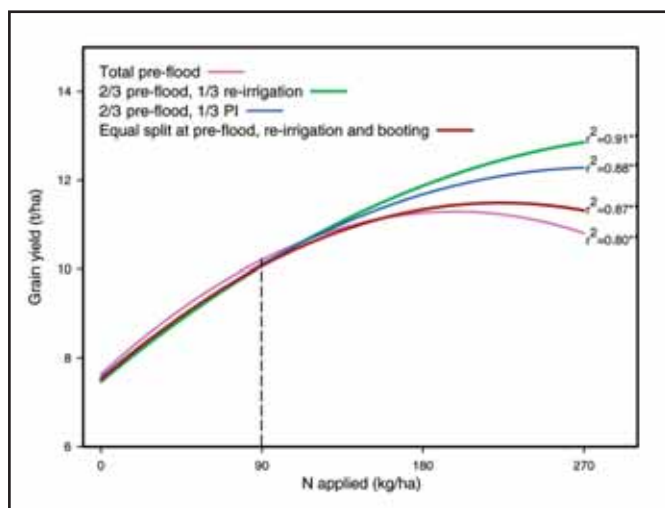


Figure 5. Yield responses to different rates and timings of nitrogen application at Griffith and Wakool (combined data for the two sites), where midseason dry down was practised.

methods gave about 1–2 t/ha yield advantage over the no-split treatment.

### Trials 2006–07

In the 2006–07 season, a field trial was conducted at Jerilderie to evaluate the responses of Reiziq to different rates and timings of nitrogen application in continuously flooded and midseason dry down bays.

Five nitrogen rates (0, 60, 120, 180 and 240 kg N/ha) and three timings of nitrogen application (a. total at pre-flood, b. 2/3 pre-flood and 1/3 just before re-irrigating after the midseason dry down, and c. 2/3 pre-flood and 1/3 panicle initiation) were used in the experiments.

Results indicate that split nitrogen topdressing at panicle initiation was the best nitrogen timing treatment under continuously flooded conditions, whereas topdressing just before re-irrigation gave the best yield in bays with midseason dry down (Figure 6).

Under both conditions, total pre-flood nitrogen application resulted in yield decline with increasing nitrogen application after the 90 kg N/ha rate. This may be attributed to exposure of plots with excessive biomass to a low temperature spell during the first week of February which would have coincided with the critical young microspore stage. The high initial nitrogen rates of the no-split treatment would have encouraged the development of biomass during the vegetative phase.

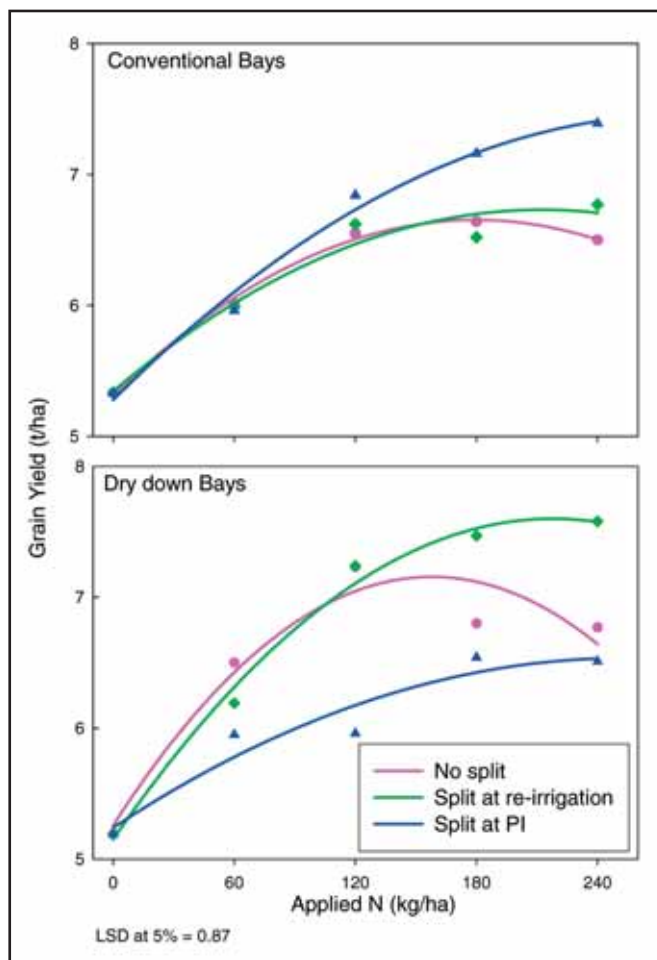


Figure 6. Yield response to different nitrogen treatments at Jerilderie in 2006–07 season.



## What does it all mean?

Overall, the five seasons' results indicate that split application of nitrogen is better than total pre-flood application as a nitrogen management strategy for Australian rice crops.

The split strategy lowers the risk of cold damage due to uncertain low temperature events during the critical pollen microspore (early pollen development) stage. It reduces lodging that can occur at high pre-flood nitrogen application rates and it increases grain yield – even during seasons without low temperature spells during the critical reproductive phase.

These results lead to speculation that rice roots are unable to take up nitrogen placed below the soil surface during its reproductive growth stages, especially after the formation of a superficial root mat – even though most of the pre-flood applied nitrogen is available in lower layers of the soil. As a result, the nitrogen requirement of plants during the reproductive phase is not fully met when the entire nitrogen application is placed in the soil before sowing. This speculation is worth investigating in future research work.

## Split nitrogen application

Adequate quantities of nitrogen should be available during the vegetative growth of the rice crop so as to produce sufficient biomass to sustain a good yield. Therefore, it is advisable to apply minimum of 90 kg N/ha if rice is to be grown on continuously cultivated bays. A maintenance requirement of nitrogen during the reproductive phase could be applied at panicle initiation. The results suggest that it is necessary to have a biomass accumulation of more than 4.5 t/ha at panicle initiation to achieve a target yield of 10 t/ha.

The findings of this work are contrary to earlier findings where the practice of applying total nitrogen requirement of the crop pre-flood showed a yield advantage over the split nitrogen application – in years without low temperature spells during the critical reproductive phase.

## Mid-tillering application

Results of this most recent work suggest that application of nitrogen during mid-tillering is not as effective as application at panicle initiation. This may be due to lesser root mass available at that stage to utilise topdressed nitrogen rapidly, to impede losses through denitrification. However, if an inadequate amount of pre-flood nitrogen is applied, the early nitrogen is not managed correctly, or if the soil is inherently low in fertility, an application of nitrogen at mid-tillering may be necessary.

While visual observations have been used in the past to decide about a mid-tillering nitrogen application, investigations should be carried out to quantify the nitrogen requirement at that stage based on plant biomass and nitrogen uptake, as practiced at panicle initiation.

## Midseason dry down

The research showed that just before re-irrigation is the best time to apply a nitrogen topdressing in paddocks subjected to midseason dry down. This may be due to minimisation of nitrogen losses through denitrification compared with topdressing being carried out at other stages. In addition, some of the nitrogen fertiliser applied just prior to re-irrigation could enter cracks in the soil that developed during dry down, thus further reducing the potential for denitrification. Further research is necessary to quantify the reduction of nitrogen losses through this practice. This option also gives an opportunity for farmers to apply the fertiliser using tractors and ground spreaders rather than using aerial contractors, as the bays are fairly dry.

## ....the conclusions

The following conclusions could be made from the findings of this work.

- Split nitrogen application of 2/3 pre-flood and 1/3 panicle initiation could result in better yield than nitrogen applied at other stages in continuously flooded bays.
- Minimum application of 90 kg N/ha at pre-flood is required in fields with low nitrogen status, to sustain a good grain yield.
- There are no significant differences in nitrogen responses among Australian rice varieties and optimum nitrogen requirement lies around 170–180 kg N/ha depending on the inherent soil nitrogen supply.
- It could be recommended to carry out nitrogen topdressing just prior to re-irrigation in bays with midseason dry down.
- It would be wise to practice midseason dry down during the first half of December to avoid hot weather during the later half. ☀️

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