FAR

Cropping Strategies

Nitrogen Application in Wheat

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FAR Cropping Strategies - Nitrogen Application in Wheat

Summary

- It is very important to measure the soil mineral N as it varied from 20 to 207 kg N/ha in these trials.
- The optimum N application increased yield by 50 to 60% in irrigated wheat but the response in dryland wheat was very variable.
- The optimum nitrogen use efficiency (NUE) was highest in irrigated feed wheat and lowest in dryland milling wheat.
- There is no economic benefit in applying N for protein in Conquest milling wheat if the N applied through stem elongation has maximised yield.
- Forecasting the N supply from mineralisation is an important area for further work.

Autumn sown irrigated feed wheat

Total N rate

- On average FAR N trials show 26 kg of N (soil mineral (0 to 60 cm depth) + applied) is required for each tonne of grain to maximise yield. For example, if the yield potential is 10 t/ha the N requirement is 260 kg/ha. (Soil mineral N is assumed to be 100% available. No account is taken of subsequent N mineralisation during the growing season).
- The actual amount of N required to maximise yield may vary from the guideline due to variability in N mineralisation. Knowledge quantifying the rate of N mineralisation due to variation in soil type, soil moisture, soil temperature and crop rotation is limited.
- Grain protein with optimum N for yield is about 11%. If grain protein is less than 10% it indicates insufficient N has been supplied to the crop. Regular monitoring of protein at harvest can provide a future guide to N requirement.

Timing

- In general there is no yield loss by delaying N application until GS32 during stem extension and then applying the N in two applications ²⁄₃ at GS32 and ¹⁄₃ at GS39.
- A small earlier (GS25 late tillering to GS30 pseudostem erect) N application (e.g. 40 kg/ha) can be beneficial if the spring soil mineral N is low (less than 60 kg N/ha to 60 cm depth) or if the crop has had poor establishment, tillering or for second wheat the root system has been damaged by take-all.

Effect of increasing cost of N

- The optimal N rate is not very sensitive to increasing N cost. For example, if the cost of N doubled, from $1.50/kg to $3.00/kg, at a grain price of $400/t, the most cost-effective rate of N reduces by only 20 kg/ha to 290 kg/ha (for a 11.3 t/ha crop). This is equivalent to an increase in NUE from 27.7 to 26.1 kg N/t grain.

Autumn sown irrigated milling wheat

Premium wheat cv Conquest

- On average 31 kg N (soil mineral + applied) is required for each tonne of grain to maximise yield.
- If adequate N has been applied to maximise yield through stem extension, the margin over N cost does not increase with a later GS59 protein dose of N. The grain protein content at maximum yield was in the top price bracket for all three trials; therefore there was no increase in margin by increasing the grain protein content further.
- There is evidence, from only one trial (with a soil mineral N of 90 kg/ha, from 0 to 60 cm), that bringing the first N application forward to GS30 increased yield while maintaining adequate grain protein content in cv Conquest.

Gristing wheat cv Amarok

- On average FAR N trials show 30 kg of N (soil mineral + applied) is required for each tonne of grain to maximise yield.
- For cv Amarok a 40 kg N/ha protein dose at ear emergence (GS59) (in addition to the N applied through stem extension to maximise yield) should ensure the minimum protein specification (11%) is met. If adequate N has been applied to maximise the yield, the margin over N cost does not increase with a protein dose of N.

Autumn sown dryland feed and biscuit wheat

- On average FAR N trials show 33 kg of N (soil mineral + applied) is required for each tonne of grain to maximise yield. This is based on two trials which were variable (21 to 46 kg N/t grain) so there is uncertainty with this guideline. Nitrogen was used more efficiently in the trial run on a deeper Wakanui silt loam possibly due to having access to more plant available water.

Autumn sown dryland milling wheat

- On average two FAR N trials show 38 kg of N (soil mineral + applied) is required for each tonne of grain to maximise yield.
- If adequate N has been applied to maximise yield through stem extension, the margin over N cost does not increase with a later GS59 protein dose of N. The grain protein content at maximum yield was in the top price bracket for the two trials.

Autumn Sown Irrigated Feed Wheat

Four N response trials on irrigated feed wheat from 2005 to 2009 were analysed. The average soil mineral N content in the trials was 91 kg N/ha with a range from 46 to 200 kg N/ha (Table 1). The average grain yield of the nil N control treatment was 7.7 t/ha, and for the optimum N treatment 12.1 t/ha, a 57% yield increase. The average optimum total N (soil mineral N + applied N) for the four trials was 307 kg N/ha (range 240 to 360 kg N/ha) for maximum yield (10.7 to 13.5 t/ha).

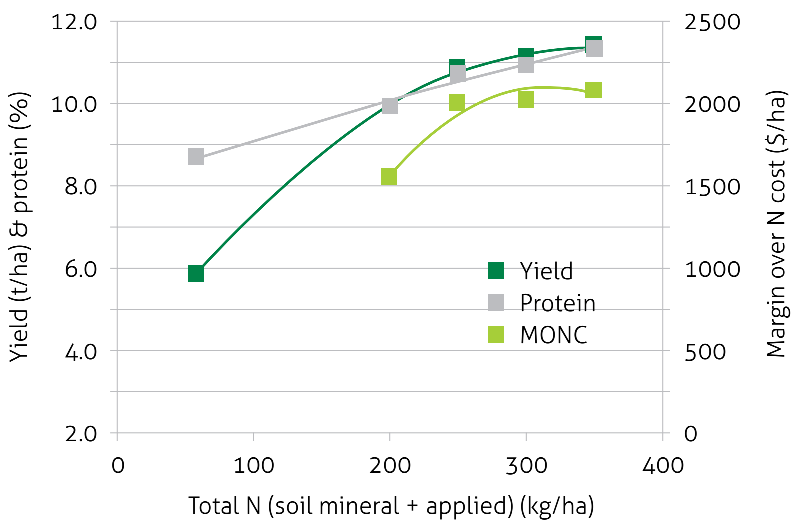
For the four trials the average applied optimum N rate was 216 kg N/ha. On average about 26 kg of N (soil mineral plus applied) is required for each tonne of grain to maximise yield.

TABLE 1

Summary of irrigated autumn sown feed wheat trials: cultivar, soil mineral N, the optimum N required for maximum yield (using a polynomial model) and the yield for nil N and optimum N rate, protein and nitrogen use efficiency (NUE).

Trial no	Cultivar	Soil mineral N (0-60 cm) (kg/ha)	Optimal N		Grain yield (t/ha)		Protein (%)	NUE (kg N/t grain)	
			Applied (kg/ha)	Total (kg/ha)	Nil applied N	Opt. applied N for max. yield		Nil applied N	Opt. applied N
1	Phoenix	57	273	330	5.9	11.3	11.1	9.7	30.1
2	Phoenix	60	240	300	5.5	10.7	-	10.9	28.0
3	Phoenix	46	194	240	9.2	13.5	10.9	5.0	17.8
4	Xi-19	200	160	360	10.3	12.9	10	19.4	27.9
	Average	91	216	307	7.7	12.1	10.7	11.2	25.9

FIGURE 1



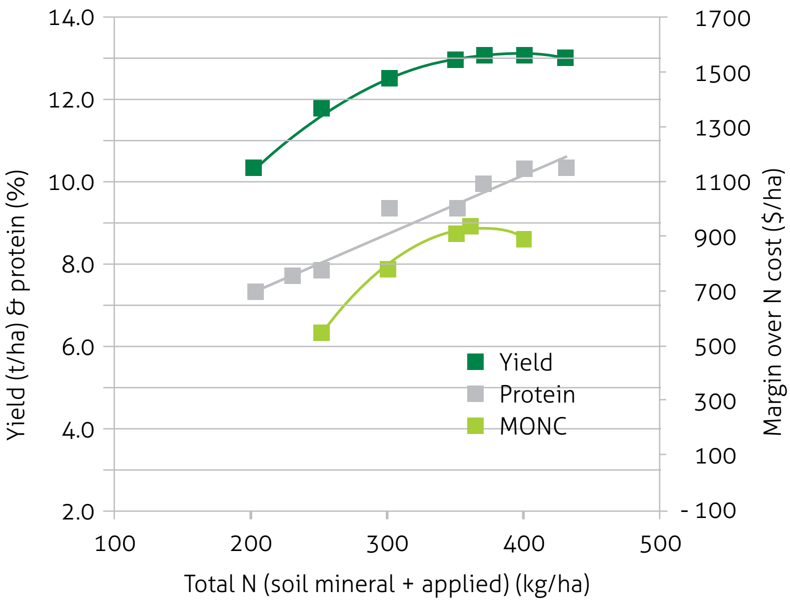
Effect of N (soil mineral + applied) on autumn sown wheat cv. Phoenix yield, protein and margin over N cost (mean of two application timings) for trial 1. Dorie, mid Canterbury, sown 13 May 2008, soil mineral N 57 kg/ha. Grain price $450/t and urea cost $1.50/kg N. N.B. to centre the data on the graphs the axis scales differ between figures.

In trial 1 the maximum yield of 11.3 t/ha was obtained with a total N of 330 kg/ha. This trial had the largest response to applied N of 5.4 t/ha. Margin over N cost (MONC) reached a plateau at 310 kg N/ha (Figure 1). Therefore, the optimum N rate for the maximum economic benefit was 20 kg N/ha lower than for the yield maximum (94%). The maximum MONC has a wide plateau beginning to drop off more rapidly below about 280 kg N/ha.

The soil mineral N was highest in trial 4 and the yield gain with applied N was relatively low. Did it pay to apply the 160 kg N/ha to maximise yield in this crop? The maximum MONC was over $900/ha (Figure 2). Again, the economic optimal N rate was about 20 kg N/ha lower than the N rate for maximum yield. What was the effect on the margin of applying less than the optimal economic N rate? If the rate applied was 50 kg N/ha less than optimal the MONC would reduce by $100/ha for trial 4 and $140/ha for trial 1. Therefore, it is important to determine the correct N rate to maximise yield.

In trial 3 the crop had a higher yield potential of 13.5 t/ha but needed a total of only 240 kg N/ha to reach maximum yield. This trial was 10 kg N/t grain more N efficient than the other trials. The higher nitrogen use efficiency (NUE) may have been caused by more N mineralisation. The soil may have had a higher organic matter content, temperature or moisture enabling it to mineralise more N. A method of confirming the high N mineralisation in this trial is by measuring the N in the grain of the nil N treatment (140 kg N/ha) plus an estimate of the N in the remaining biomass (42 kg N/ha) and subtracting the spring soil mineral N (46 kg N/ha). An estimate of the N uptake from mineralisation over the season can then be calculated (136 kg N/ha). Nitrogen mineralisation is difficult to forecast and contributes the biggest uncertainty to N management. However, more recently FAR funded research has started to look at rapid methods of measuring the different soil carbon pools which is related to the N mineralisation capacity of the soil.

FIGURE 2



Effect of N (soil mineral + applied) on autumn sown wheat cv. Xi-19 yield, protein and margin over N cost for trial 4, Wakanui, mid Canterbury, sown 27 May 2005, soil mineral N 200 kg/ha. Grain price $450/t and urea cost $1.50/kg N.

N application timing

Previous work conducted in first wheat paddocks following a break crop (2005 FAR Cereals Strategy Workshop) has shown that there is no yield loss by delaying N application from late tillering until stem elongation. Applying ⅔ N at GS32 and ⅓ at GS39 is in general a sound practice provided the soil fertility is reasonably good and the crop root system has not been impaired by soil born disease, poor establishment or water logging.

An example of earlier N requirement was in trial 1 cv. Phoenix, where with a low soil mineral N of 57 kg/ha, there was a yield advantage of about 0.5 t/ha achieved by bringing the first application forward to GS30. Therefore, if soil mineral N is low, the yield potential can decrease by delaying the first N application. This clearly demonstrated the value in having deep soil N test results.

TABLE 2

Optimal N rate (kg/ha) (soil mineral plus applied) for maximum margin over N cost at a range of grain prices and N cost (urea) based on a N response trial with Phoenix wheat with a maximum yield of 11.3 t/ha.

		Grain price ($/t)				
		200	300	400	500	600
N cost ($/kg)	1.0	290	300	310	310	320
	1.5	280	300	310	310	320
	2.0	270	290	300	310	310
	2.5	250	280	290	300	310
	3.0	240	270	290	300	300

How does the optimum N rate change with a changing price of grain and cost of N?

If the cost of N doubled from $1.50/kg to $3/kg at a grain price of $400/t the optimal N rate for maximum MONC reduces by only 20 kg/ha to 290 kg/ha (Table 2). A grain price increase of $100/t to $500/t justifies an additional 10 kg N/ha at a N cost of $2/kg and over.

Autumn Sown Irrigated Premium Milling Wheat (Conquest)

The average soil mineral N content in the trials was 87 kg N/ha with a range from 60 to 110 kg N/ha (measured to 60 cm depth) (Table 3). The average grain yield of the nil N treatment was 6.9 t/ha, and for the optimum N treatment 10.7 t/ha, a 55% yield increase. The average optimum total N (soil mineral + applied) for the three trials was 328 kg N/ha (range 270 to 390 kg N/ha) for maximum yield (9.7 to 11.5 t/ha). For the three trials the average applied optimum N value was 242 kg N/ha. On average about 31 kg of soil mineral N plus applied N was required for each tonne of grain to maximise yield.

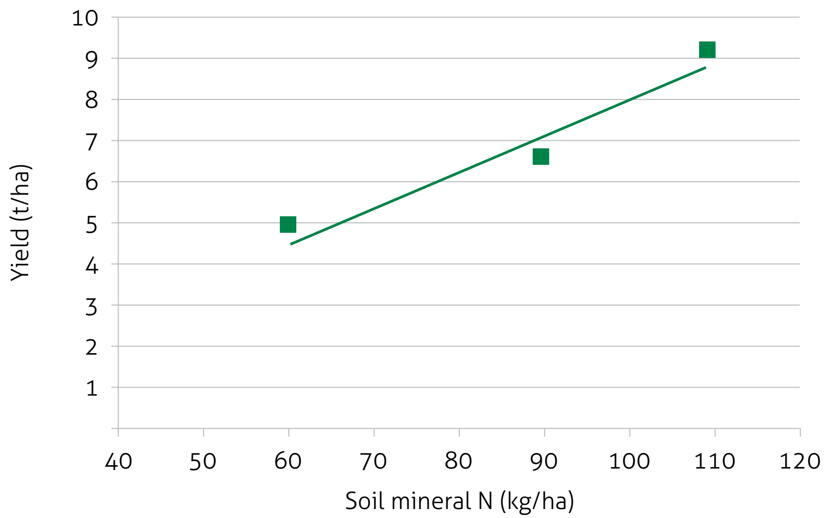
There was a strong relationship between soil mineral N (nil applied N treatment) and yield (Figure 3). The yield increased with increased soil mineral N content. This shows the value of deep N soil measurement.

TABLE 3

Summary of autumn sown Conquest N trials: soil mineral N, the optimum N required (using a polynomial model) and the yield for nil N, optimum N rate, protein and nitrogen use efficiency (NUE).

Trial no	Soil mineral N (0-60 cm) (kg/ha)	Optimal N		Grain yield (t/ha)		Protein (%)	NUE (kg N/t grain)	
		Applied (kg/ha)	Total (kg/ha)	Nil applied N	Opt. applied N for max. yield		Nil applied N	Opt. applied N
1	110	160	270	9.1	10.9	13	14.3	24.8
2	60	265	325	4.94	9.74	13.9	12.1	33.4
3	90	300	390	6.66	11.54	13.6	13.5	33.8
Average	87	242	328	6.9	10.7	13.5	13.3	30.6

FIGURE 3



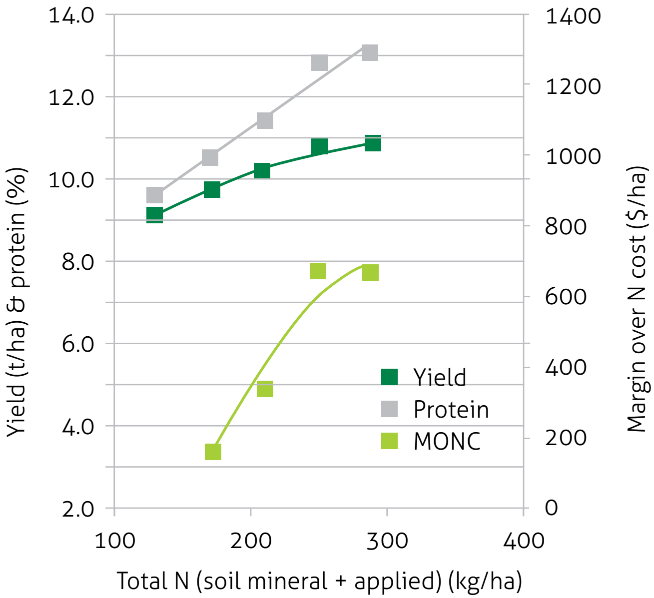
Relationship between soil mineral N (measured to 60 cm depth) and yield for three trials cv. Conquest

Nitrogen rate

There was generally a consistent and significant increase in yield from increasing total N up to approximately 290 to 350 kg/ha (including soil mineral N) in three trials (one trial shown in Figure 4). The margin was maximised at a N rate slightly lower than that which maximised yield. As expected increased N rates improved the protein content of the grain. However, it was not cost effective to apply additional N to increase protein above the N rate that maximised yield. Further, as the grain protein content was high (13% and above) at the maximum yield there is unlikely to be a quality benefit from applying additional N to achieve a higher protein content.

Results from the 2007/08 and 2008/09 FAR N trials showed that as a general principle the optimal N rates for yield and protein content also gave kernal weight well above the minimum specification.

FIGURE 4



Response of irrigated Conquest milling wheat to N applied ²/₃ at GS32 and ¹/₃ at GS39, Methven mid Canterbury, sown 19 May 2007, soil N 130 kg/ha. Grain price: 2011-12 milling contract. Urea cost: $1.50/kg N.

N application timing

A trial at Ashburton in 2009-10 had an earlier N timing treatment of ²/₃ at GS30 (7 Oct) and ¹/₃ at GS32 (27 Oct). This earliest N timing (first N application 20 days earlier than next treatment) gave the highest yield and margin over N cost and a lower but acceptable protein content (Table 4) even with a soil mineral N of 90 kg/ha. Conquest has inherently small grain having 1000 kernel weights (KW) that are typically 40-45 g (autumn sown CPT results). If the crop is N-starved then the earlier senescence will terminate grain filling prematurely and KW will be low. Conversely crops with excessive early N may generate more grains per unit area than can be adequately filled. Because of its relatively inflexible grain size Conquest needs sufficient early N to get good tiller survival for optimum yield but not so much as to cause excessive tillering. The results from the 2009-10 Ashburton trial do show a marginally lower KW for higher early N vs later N, but KWs were all well above specification (38 g/1000 grains).

TABLE 4

Influence of N timing on heads/m², yield, protein, kernel weight and margin over N cost in cv Conquest, at Ashburton, mid Canterbury, sown 18 June 2009, soil mineral N 90 kg/ha (applied N 260 kg/ha). Grain price: 2011-12 milling contract. Urea cost: $1.50/kg N.

N Timing	Heads/m²	Yield (t/ha)	Protein (%)	KW (g/1000)	MONC ($/ha)
90 (soil)	399	6.7	10.6	44.3	0
²⁄₃ GS30 (7 Oct), ¹⁄₃ GS32 (27 Oct)	535	11.54	13.6	44.8	2,009
²⁄₃ GS32, ¹⁄₃ GS39 (18 Nov)	458	9.71	14.9	45.8	1,158
²⁄₃ GS32, ¹⁄₃ GS39, 40 kg/ha *GS59	432	9.43	16.2	45.8	1,043

*part of the 260 kg N/ha

Autumn Sown Irrigated Gristing Wheat (Amarok)

The average soil mineral N content in the trials was 113 kg N/ha with a range from 20 to 207 kg N/ha (Table 5). The average grain yield of the nil N treatment was 7.6 t/ha, and for the optimum N treatment 11.7 t/ha, a 54% yield increase. The average optimum total N (soil mineral N + applied N) for the three trials was 335 kg N/ha (range 320 to 370 kg N/ha) for maximum yield (7.7 to 14.1 t/ha). For the six trials the average applied optimum N value was 222 kg N/ha. On average about 30 kg N (soil mineral plus applied) is required for each tonne of grain to maximise yield.

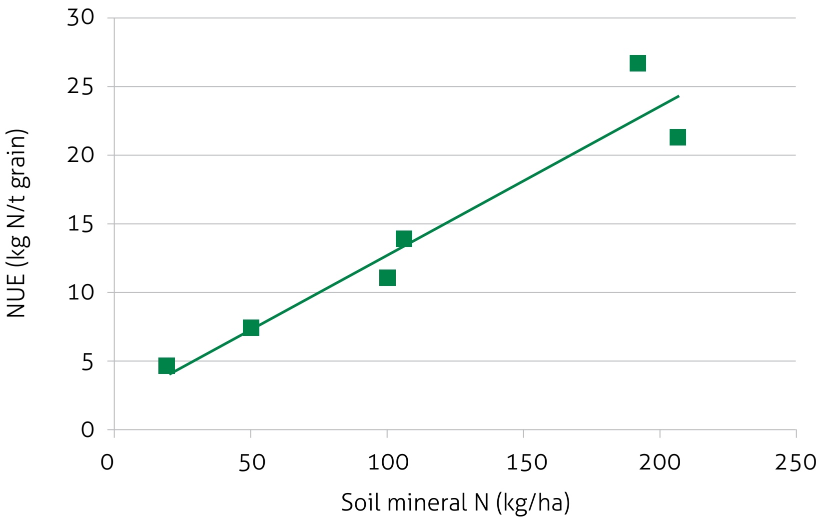
There was a strong relationship between soil mineral N and NUE (Figure 5). Nitrogen use efficiency decreased with increasing soil mineral N. As the yield increased the quantity of N required for each unit of additional yield also increased.

TABLE 5

Summary of autumn sown Amarok trials: mineral N in the soil profile, the optimum N required for maximum yield (using a polynomial model), the yield for nil N and optimum N rate, protein and nitrogen use efficiency.

Trial no	Soil mineral N (0-60 cm) (kg/ha)	Optimal N		Grain yield (t/ha)		Protein (%)	NUE (kg N/t grain)	
		Applied (kg/ha)	Total (kg/ha)	Nil applied N	Opt. applied N for max. yield		Nil applied N	Opt. applied N
1	100	230	330	9.1	13.5	10.3	11	24.4
2	20	340	360	4.5	12.4	11	4.5	29.0
3	192	108	300	7.2	7.7	11.6	26.7	39.0
4	207	163	370	9.8	12.1	10.9	21.1	30.6
5	108	222	330	7.8	10.6	11.6	13.8	31.1
6	52	268	320	7.3	14.1	10.7	7.1	22.7
Average	113	222	335	7.6	11.7	11.0	14.0	29.5

FIGURE 5

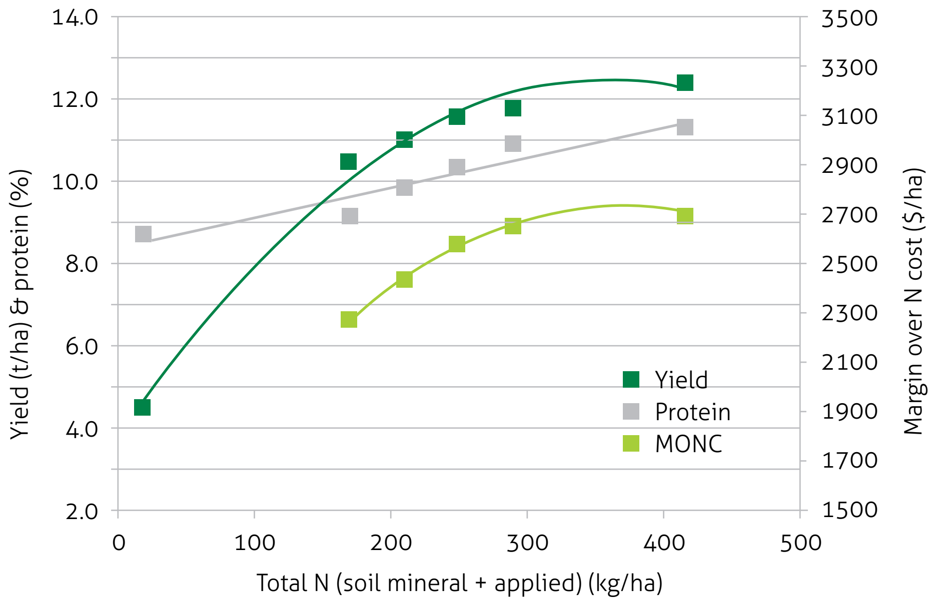


Relationship between soil mineral N and NUE for six trials cv. Amarok

Nitrogen rate

Figure 6 shows the typical yield response to N. There was an increase in yield from increasing total N to about 350 kg/ha (including soil mineral N). The margin over N cost was maximised at about the N rate that maximised yield. As expected increased N rates increased the protein content of the grain. It was not cost effective to apply additional N to increase protein above the N rate that maximised yield. However, additional N may be needed to achieve the protein specification in contrast to milling wheat cultivar Conquest.

FIGURE 6



Response of irrigated Amarok gristing wheat to N at Dorie mid Canterbury, sown 9 May 2006, soil N 20 kg/ha. Grain price: 2011-12 milling contract. Urea price: $1.50/kg N.

N application timing

Of the three timing treatments at a total of 290 kg N/ha (soil mineral N + applied), on a trial with cv. Amarok, yield was highest with ²/₃ N at GS32 and ¹/₃ at GS39 (Table 6). With a soil mineral N of only 20 kg/ha it would be expected that an earlier application than GS32 would increase the yield. There was one treatment with an early application of ²/₃ GS30, ¹/₃ GS32 and 40 kg/ha at GS59 but it was at a lower rate of 250 kg N/ha. This treatment yielded 0.37 t/ha higher than an equivalent N rate but later GS32, GS39 and GS59 treatment.

In this trial, protein content increased by 1.2% by shifting a proportion of the N later but yield and MONC decreased. However, to meet the milling protein specification and maintain high yield the higher N rate as scheduled by the wheat calculator was optimal (N timing 92 kg/ha mid-tillering, 120 kg/ha GS32, 133 kg/ha GS39 and 51 kg/ha at ear emergence).

TABLE 6

Influence of N timing with an application of 270 kg N/ha on wheat cv Amarok yield, protein and MONC, at Dorie, 2006 (Grain price: 2011-12 milling contract. Urea price: $1.50/kg N).

N Timing	Yield (t/ha)	Protein (%)	MONC ($/ha)
20 (soil)	4.5	8.7	
2/3 GS32 (180 kg), 1/3 GS39 (90 kg)	12.1	10.3	2,791
2/3 GS32 (153 kg/ha), 1/3 GS39 (77 kg/ha), GS59 (40 kg/ha)	11.7	10.9	2,627
1/3 GS32 (90 kg/ha), 1/3 GS39 (90 kg/ha), 1/3 GS59 (90 kg/ha)	11.5	11.5	2,533
Wheat calculator (396 kg N/ha)	12.4	11.3	2,708

TABLE 7

Influence of N timing and rate on wheat cv Amarok yield, protein and MONC, Dorie, sown 26 May 2005, soil mineral N 207 kg/ha (Grain price: 2011-12 milling contract. Urea price: $1.50/kg N).

Applied N (kg/ha)	N Timing	Yield (t/ha)	Protein (%)	MONC ($/ha)
	207 (soil)	9.8	9.0	
83	2/3 GS32, 1/3 GS39	11.6	10.2	611
123	2/3 GS32, 1/3 GS39, 40 kg/ha GS59	11.8	10.8	616
163	2/3 GS32, 1/3 GS39	12.1	10.9	669
203	2/3 GS32, 1/3 GS39, 40 kg/ha GS59	12.0	11.4	573

Is it worthwhile applying additional N at ear emergence?

In a trial where yield was maximised with the standard N timing, applying an additional 40 kg N/ha at ear emergence, following a previous 163 kg N/ha, did not increase yield however protein increased by 0.5% from 10.9% to 11.4% to meet the milling specification (Table 7). The MONC decreased as there is no premium for the higher protein % and the expenditure on N will increase.

Dryland Feed Wheat

Two N response trials on dryland feed/biscuit wheat were analysed. The average soil mineral N content in the trials was 101 kg N/ha with a range from 60 to 142 kg N/ha (Table 8). The average grain yield of the nil N control treatment was 6.7 t/ha, and for the optimum N treatment 7.5 t/ha, a 12% yield increase. The average optimum total N (soil mineral N + applied N) for the two trials was 225 kg N/ha (range 200 to 250 kg N/ha) for maximum yield (5.4 to 9.7 t/ha). For the two trials the average applied optimum N value was 124 kg N/ha. On average FAR N trials show 33 kg of N (soil mineral + applied) is required for each tonne of grain to maximise yield. This is based on two trials which were variable (21 to 46 kg N/t grain) so there is uncertainty with this guideline. Nitrogen was used more efficiently in the trial run on a deeper Wakanui silt loam possibly due to access to more plant available water.

The yield response to applied N was quite low in these trials. In trial 1 although the maximum yield was obtained with an applied N rate of 190 kg/ha the MONC was highest at 90 kg N/ha ($134/ha). There was only a small MONC in trial 2 of $54/ha.

In trial 2 there was a 0.3 t/ha yield advantage from the earlier application timing of ²/₃ at GS30 and ¹/₃ at GS32 compared with ²/₃ at GS32 and ¹/₃ at GS39.

TABLE 8

Summary of dryland feed and biscuit wheat trials: mineral N in the soil profile, the optimum N required for maximum yield and the yield for nil N and optimum N rate, protein and nitrogen use efficiency.

Trial no	Cultivar	Soil mineral N (0-60 cm) (kg/ha)	Optimal N		Grain yield (t/ha)		Protein (%)	NUE (kg N/t grain)	
			Applied (kg/ha)	Total (kg/ha)	Nil applied N	Opt. applied N for max. yield		Nil applied N	Opt. applied N
1	Phoenix	60	190	250	4.3	5.4	-	13.9	46.3
2	Claire	142	58	200	9.2	9.7	9.8	15.4	20.6
	Average	101	124	225	6.7	7.5	9.8	14.6	33.4

Dryland Milling Wheat

Two N response trials on dryland milling wheat were analysed. The average soil mineral N content in the trials was 57 kg N/ha (Table 9). The average grain yield of the nil N control treatment was 5.6 t/ha, and for the optimum N treatment 7.8 t/ha, a 39% yield increase. The average optimum total N (soil mineral N + applied N) for the two trials was 290 kg N/ha for maximum yield. For the two trials the average applied optimum N rate was 232 kg N/ha.

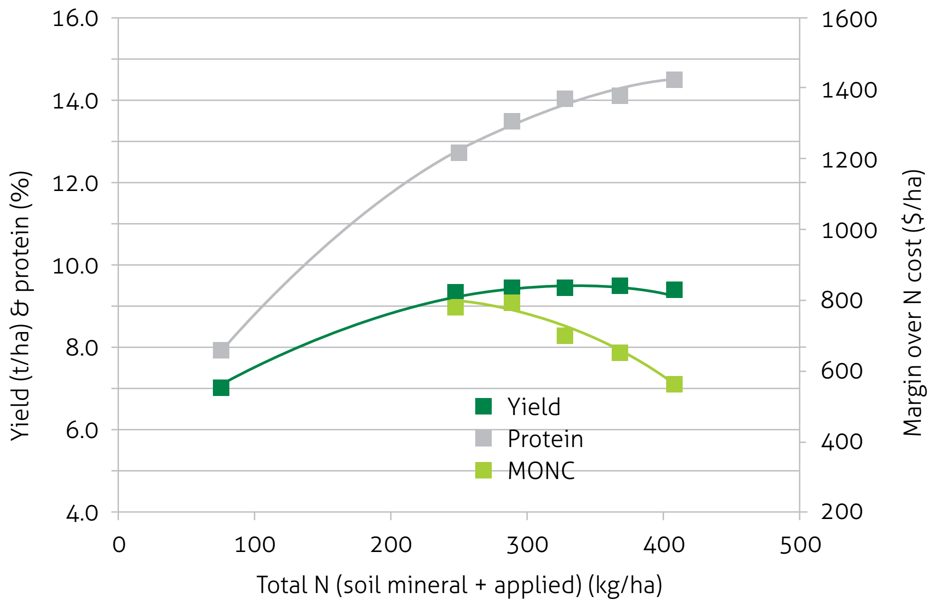
In trial 1 the crop with a maximum yield of 9.2 t/ha reached a maximum yield at a total N of 300 kg/ha. Margin over N cost (MONC) was highest at 250 kg N/ha (Figure 7). Therefore, the optimum N rate for the maximum economic benefit was 50 kg N/ha lower than for the yield optimum (83%). The response curves for the dryland trials are very flat compared with the irrigated trials and therefore the rate of N for maximum economic return is much lower than for maximum yield.

TABLE 9

Summary of dryland milling wheat trials: mineral N in the soil profile, the optimum N required for maximum yield and the yield for nil N and optimum N rate, protein and nitrogen use efficiency.

Trial no	Cultivar	Soil mineral N (0-60 cm) (kg/ha)	Optimal N		Grain yield (t/ha)		Protein (%)	NUE (kg N/t grain)	
			Applied (kg/ha)	Total (kg/ha)	Nil applied N	Opt. applied N for max. yield		Nil applied N	Opt. applied N
1	Vanquish	75	225	300	6.8	9.2	13.2	11.0	32.6
2	Conquest	40	240	280	4.4	6.4	13.1	9.1	43.7
	Average	57	232	290	5.6	7.8	13.1	10.0	38.1

FIGURE 7



Effect of N (soil mineral + applied) on autumn milling wheat cv. Vanquish yield, and MONC (N $1.50/kg; grain price from 11-12 milling contract) for trial 1.

TABLE 10

Influence of N timing and rate on wheat yield, protein and MONC cv Amarok, dryland, Chertsey, 2004.

Total N (kg/ha)	N Timing	Yield (t/ha)	Protein (%)	MONC ($/ha)
108	108 (soil)	6.8	9.7	
250	1/3 GS30 (47 kg/ha), 2/3 GS32 (95 kg/ha)	8.6	11.9	514
290	1/3 GS30 (47 kg/ha), 2/3 GS32 (95 kg/ha), GS59 (40 kg/ha)	8.6	12.2	443
330	1/3 GS30 (47 kg/ha), 2/3 GS32 (95 kg/ha), GS59 (80 kg/ha)	8.5	12.5	349

N application timing

In a trial with cv Amarok there was no economic benefit from applying a protein dose of N at ear emergence (GS59) in addition to the quantity required to maximise yield at stem elongation (GS30 to GS32) (Table 10).

Notes:

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ADDING VALUE TO THE BUSINESS OF ARABLE FARMING

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