The influence of late nitrogen applications on autumn sown milling wheat

M.D. Craighead and W.B. Burgess[1]

Ravensdown Fertiliser Co-op Ltd., PO Box 1049, Christchurch,
[1]55 Mountain View Rd., Timaru

Abstract

This paper describes the use of late nitrogen on autumn sown wheat to increase grain protein levels. The data are based on a series of experiments carried out at the Ravensdown Seadown farm, South Canterbury in the late 1980s and early 1990s. While late nitrogen can increase grain protein, the degree to which nitrogen is partitioned between grain yield and protein depends on the yield, nitrogen previously applied to the crop, the crop history or residual nitrogen, the cultivar of wheat grown, and the rate of nitrogen applied. The timing of the late nitrogen is less critical.

Additional key words: *grain protein, yield, residual nitrogen, cultivar*

Introduction

The quality of New Zealand milling wheat became as important as grain yield once New Zealand moved to a more open market policy in 1987 and had to compete with high quality imported wheat from Australia. Local mills now offer premiums or impose penalties based on quality criteria such as cultivar, grain protein, thousand grain weight, falling number and % screenings. To be successful, wheat growers must obtain high yields of high quality grain. Irrigation is now more critical as are improved management practices such as timely plant protection, correct cultivar selection, precise sowing dates, and seeding rates. However fertiliser, in particular extra and timely nitrogen application, remains a major factor for lifting grain protein levels. It is accepted that there is a good relationship between grain protein and baking attributes, particularly up to 12% protein. Although protein may not reflect all desirable baking attributes it is still seen as the most convenient measure of quality as it can be assessed quickly by near infra-red reflectance (NIR) at the weigh bridge.

This paper describes data from a series of trials that demonstrate how nitrogen affects grain quality and how these are the basis of our existing grower recommendations. A measure of their success is seen in the way grain protein levels continue to rise, caused by the changes in the way growers produce high milling quality wheat. We were able to assess a cross section of the growers' response through the annual Ravensdown/-United Wheatgrowers milling wheat competition.

Materials and Methods

The trials were carried out at the Ravensdown Seadown Farm in South Canterbury. The soils were Lismore stony silt loam, related to the yellow grey earth series, classified as Orthic Brown soils in the New Zealand Classification system of Hewitt (1992). Most trial data presented concern autumn sown crops. All trials were spray irrigated as necessary, in more recent years being monitored by Hydro Services Ltd., and appropriate plant protection practices used, including where necessary a plant growth regulator.

All treatments were replicated at least four times in a randomised block design. Header harvested yields were measured and grain nitrogen assessed by the kjeldahl method and converted to grain protein (x 5.7).

More specific details of the cv. Kotare and other wheat trials are given elsewhere (Craighead and Burgess, 1989; Craighead, 1995; Ravensdown Fertiliser Co-op, 1995).

Results and Discussion

Impact of timing and rates of nitrogen on yield and quality

Much of the work on raising wheat quality as measured by grain protein is centred on applying late nitrogen to milling wheat crops. Less emphasis is placed on the overall nitrogen status required to grow the crop. In 1986/87 a trial on a nitrogen deficient site using milling wheat cv. Kotare looked at the overall response to nitrogen on wheat yield and baking quality. In this trial nitrogen was applied at planting, tillering, stem extension and pre-booting and all combinations of these. Three sets of data were chosen from this work to demonstrate some of the important factors relating to grain protein.

Response of grain yield and protein to increasing rates of nitrogen. On a highly responsive site when the nitrogen application rate was gradually increased, grain yield initially increased rapidly (Fig. 1) due to improved vegetative growth leading to increased survival of existing tillers and hence increased ear numbers. The grain protein actually declined at this stage as the priority was to maintain vegetative growth. As nitrogen rate increased more nitrogen was available to prolong uptake or translocation to the grain and therefore grain nitrogen increased. The relative yield increase slowed due to competition between tillers for light and water, so progressively more nitrogen was available to the grain and the rate of protein accumulation increased. If nitrogen rates were further increased, protein may have declined due to excessive competition for assimilates or through lodging of the crop (Martin *et al.*, 1989). When the main effects were isolated in this trial (Table 1), nitrogen applied at any growth stage increased both grain yield and protein.

Early topdressing of nitrogen (GS2 or GS5) increased yield through increased ear numbers; hence protein increases must have been a result of later remobilisation of nitrogen from upper leaves and the stem (Scott *et al.*, 1992). Nitrogen at GS8 did have some influence on ear numbers and yield when nitrogen was not applied at GS2, however the GS8 nitrogen had a greater impact on grain protein. Stevenson and Daly (1991) also found early N reduced the response to late N. When the individual effects on yield and protein are examined, the benefit of using nitrogen at GS2 or GS8 increased as the amount of N applied at GS5 was increased. Martin *et al.* (1992) found grain yield and protein increased with increasing nitrogen irrespective of when the N was applied, but within a cultivar, yield was inversely related

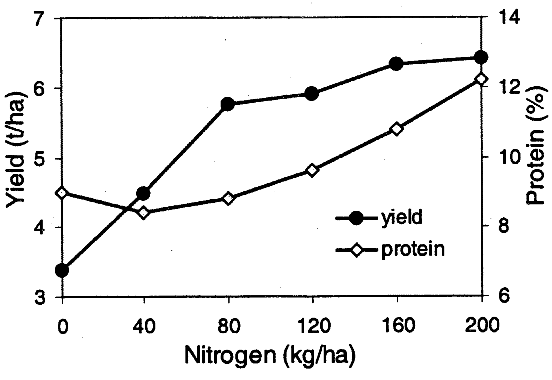

Figure 2. Response to n applied at Feekes GS5 on wheat cv. Kotare in 1986/87

Table 1. Effect of timing and rates of N on yield and quality of wheat cv. Kotare.

Timing (Feekes scale[1])	N applied kg/ha	Yield t/ha	Grain protein %
Planting	0	5.62	9.44
	23	5.83	9.63
	$LSD_{p<0.05}$	0.11	0.21
GS2[2]	0	5.32	9.34
	40	6.14	9.73
	$LSD_{p<0.05}$	0.11	0.21
GS5	0	4.60	8.55
	40	5.62	8.71
	80	6.23	9.88
	120	6.46	10.99
	$LSD_{p<0.05}$	0.25	0.30
GS8	0	5.54	9.16
	40	5.92	9.90
	$LSD_{p<0.05}$	0.11	0.21

[1]Large 1954, [2]GS = growth stage

to grain protein.,The degree to which late N will raise grain nitrogen will depend on the base fertility, whether from earlier fertiliser N applied, (Fig. 2) or that derived from mineralised soil N, the amount depending on the soil type and its previous crop history (Table 2).

While Fig. 2 clearly showed nitrogen was partitioned between yield and grain protein, management practices also have an impact (Table 2). Following a history of

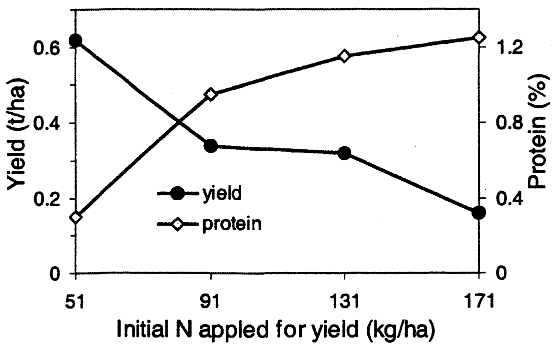

Figure 2. Response in yield and protein* of wheat cv. Kotare to an extra 40kg of late N. (* base yield and protein 4.94t, 8.3%; 5.82t, 8.7%; 6.22t, 9.80%; 6.60t, 10.85% respectively.)

Table 2. The effect of crop history and management on grain yield and protein % on the autumn sown wheats cv. Batten, Domino and Monad, (results are the mean of two N treatments, 183 and 229kgN/ha).

Previous season's history	Yield (t/ha)	Grain protein (%)
1. Peas - reasonable N fertility, good structure	10.4	11.2
2. barley - poor N fertility, disease, weed burden	4.1	12.7
3. annual grass - low N fertility, grass weeds	6.5	11.4
4. fallow/swedes - reasonable N fertility	10.7	11.5
$LSD_{p<0.05}$	1.2	0.8

barley and annual grass, weeds were more dominant, particularly annual grasses, and it needed a threshold of nitrogen before the crop could utilise enough nitrogen to compete against the weeds. Disease carryover was also an issue following barley. Other workers have quoted locality, cultivar and season as influencing grain quality (Douglas, 1987; Stevenson, 1987; Martin *et al.*, 1989; Millner *et al.*, 1994), in part due to crop history and soil type and in part moisture and temperature differences (Martin *et al.*,1989; Salinger *et al.*,1995), and disease (Daly and Dyson, 1987; Martin *et al.*,1989).

Work at Seadown using different cultivars has shown variable responses to late N; generally those bred for high yield have a relatively lower protein. However when the same amount of nitrogen is applied late, they generally give a higher protein response/kgN applied than those cultivars bred for high protein, although their final protein level is usually still lower than cultivars with a higher initial protein.

Timing of late nitrogen for quality. All timings of late nitrogen significantly raised grain protein level but there was no significant difference between any of these timings (Table 3). There was a suggestion of decreasing yield the later topdressing was left, presumably because the plant had already started remobilising nitrogen from its upper leaves and stem to the grain. This has been noted in other trials at Seadown. Smith *et al.* (1989) suggested 80% of a heading N application was taken up and retained by the head, indicating a preference for

Table 3. Timing of 40kg of late N on wheat cv. Monad, 1993/94

Growth stage (Feekes)	Grain yield t/ha	Grain protein %
Control	9.06	11.71
GS7	8.83	12.51
GS8	8.75	12.26
GS9	8.85	12.24
GS10	8.64	12.36
GS10.5	8.56	12.54
$LSD_{p<0.05}$	0.60	0.45

All treatments received 247kg/ha of initial N fertiliser N rather than that from remobilization. Work by us and others (Stevenson and Daly 1991) showed that applying the quality N slightly earlier than ear emergence can increase grain yield. Archer (1988) found nitrogen at early stem extension, flag leaf emergence or milky ripe stage gave similar responses (0.5-0.7%) in grain protein when 40kgN/ha was applied. Tillering N did not increase protein and later N was less likely to give a yield increase. Hence optimum timing will vary according to when previous N applications were applied and the fertility carryover (crop history) as previously mentioned. We would recommend fertiliser nitrogen in a solid form be applied by GS9 and certainly no later than ear emergence.

Rates of late N for quality. Grain protein increases with the rate of late N as demonstrated for two cultivars in different seasons (Table 4). Once sufficient nitrogen is applied to maximise the yield response, then additional late nitrogen can be translocated directly to the grain (Scott *et al.*, 1992).

Table 4. Effect of rate of late N (GS8-9) on grain protein (%) in autumn sown milling wheat.

N rate (kg/ha)	cv. Tancred 1991/92 (grain yield 9.4t, earlier N applied 148kg/ha)	Cv. Monad 1993/94 (grain yield 8.9t, earlier N applied 247kg/ha)
0	9.96	11.71
20	10.76	12.42
40	10.87	12.24
60	11.39	12.87
$LSD_{p<0.05}$	0.85	0.65

The responses here are not as linear as those found by Cooper and Blakeney (1990), Stevenson and Daly (1991) or Millner *et al.* (1994), perhaps because their yields were lower and previous nitrogen inputs were applied earlier and at a lower rate.

Late nitrogen – solid or liquid urea?

Although solid urea has been compared with liquid urea and foliar fertilisers on several occasions the results tend to be somewhat variable. Two trials demonstrate some typical results (Table 5) showing that there is little difference between application forms. Grain protein data can also be misleading, unless yield is also taken into account (given here as protein yield). Where slight yield declines are noted with late N when adequate N has previously been applied to maximise yield, this is probably due to reduced grain size, competition for light in the canopy and lodging. These were certainly issues with the trial using cv. Monad in 1993/94.

Stevenson and Daly (1991) found 20kg/ha of foliar N as urea at ear emergence to be as effective as 40kgN/ha as solid, while Cooper and Blakeney (1990) have shown solid ammonium nitrate (40kgN/ha) to be more effective than a similar amount of foliar urea applied at anthesis. Soil and climatic conditions would influence these results. Soil moisture content can limit soil N uptake and in hot, dry conditions with low canopy cover, the risk of ammonia volatilisation losses from soil applied urea can also be high. It appears solid fertiliser is best for pre anthesis application and foliar best if applications are post anthesis (Gooding and Davies, 1993). The biggest issue with foliar urea is the risk of burning the flag leaf and hence risk of premature grain filling. The

Table 5. Effect of similar rates of solid vs liquid urea on wheat yield and protein.

cv. Tancred 1991/92 (earlier N applied 148kg/ha)			Cv. Monad 1993/94 (earlier N applied 296kg/ha)		
20kgN @ GS8	Protein (%)	Protein yield[1] (kg/ha)	50kgN @ GS9	Protein (%)	Protein yield (kg/ha)
Nil	9.96	929	Nil	12.61	1157
Solid	10.76	1063	Solid	13.11	1157
Liquid	11.03	1053	Liquid	13.44	1154
$LSD_{p<0.05}$	1.09	110		0.88	78

[1]Protein yield = grain yield x % grain protein

risk is greater in sunny weather conditions. Experience in Canterbury suggests single applications should not exceed 20-22kgN/ha as 10%N solution, to minimise burn risk. In their review, Gooding and Davies (1993) suggested a maximum of 15kgN/ha as foliar urea, applied at or after anthesis, Archer (1988) suggested 25kgN/ha in 500L of water in the UK, while even 10% urea solutions can pose a risk in warmer Australian conditions (Cooper and Blakeney 1990). Water volumes above 200L/ha are generally impractical. Hence if foliar applications are to be used, they suit crops needing small top ups to supplement residual carryover of nitrogen from previous dressings. These conditions are more likely to occur with spring rather than autumn sown crops.

Conclusions

Although late applications of nitrogen to wheat have a significant effect in raising grain protein, the effectiveness depends on many factors. These include the initial paddock fertility, the amount of early nitrogen applied for yield and hence the partitioning of nitrogen, the rate of late nitrogen, the cultivar of wheat, crop management and climatic effects. The timing and form of late nitrogen may be less important.

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