May 2022

UK FLOUR MILLERS

Review of how best to respond to expensive fertiliser nitrogen for use in 2022

Part four: Late N for Milling Wheat

Authors

Roger Sylvester-Bradley[1] & Sarah Clarke[2]

[1]ADAS Boxworth, Cambridge CB23 4NN

[2]ADAS Gleadthorpe, Meden Vale, Mansfield NG20 9PD

Technical reviewer

Sarah Clarke[2]

This review is the fourth part of a project that started in October 2021. This part was funded by UK Flour Millers.

CONTENTS

1. Executive Summary

To inform the need for extra N to meet milling specifications in 2022, Part 4 of this review considers historic trends in grain protein of wheat, responses of milling wheat crops to fertiliser N applied in spring and later in summer, and premiums paid for achieving protein levels that exceed fixed thresholds. Principal findings were that:

- Break-even price ratios between N and grain have recently increased from ~5 to ~10, causing optimal N applications for non-milling wheats to decrease by ~ 50 kg/ha
- Typically, milling wheat crops with reduced N optima deliver only ~11% grain protein
- To achieve 13% grain protein, milling wheat crops typically need ~120 kg/ha more applied N than is optimal for yield at a break-even ratio of 10
- A protein response of 1% can be achieved by applying ~60 kg/ha extra late N
- Extra N applied at GS39 causes small yield response up to ~40 kg/ha, but later applications do not
- Average extra N applied to UK milling wheats decreased from 34 to 24 kg/ha since 2010
- Recovery of extra N in grain is poor, varying from 25% to 33%
- Only ~40% of milling wheats entered in the YEN (2013-2020) achieved >13% protein
- Farms consistently differ in their success of achieving 13% protein in milling wheats
- AHDB Recommended List protein levels are helpful in predicting on-farm achievements
- 10-20% of farms that regularly achieve >14% grain protein may be over-supplying N. Tests of reduced N by omitting late N on a few comparable tramlines could show whether savings are possible

The review concludes that growers should temper their decisions on late applications of extra N in 2022 according to (i) the premium on offer for exceeding the protein threshold, (ii) whether they have reduced their spring N applications due to high prices in 2022, (iii) whether late N has usually been used in the past, and (iv) the farm's past success in meeting the criteria for premium payment, as follows:

Premium	**Farm's past success in meeting milling spec.**		
£/tonne	***Seldom***	***Sometimes***	***Usually***
~£10	Omit late N & hope!	Continue with usual past practice for milling wheats	Continue with usual practice for milling wheats
~£20	Only apply late N (60 kg/ha) if spring N applied was as in previous years. Otherwise, omit late N & hope!		
>£20		Apply 60 kg/ha late N even if not usual past practice	

Thus, some farms are recommended to ignore the influence of recent prices hikes on optimum N rates, as set out in Part One, and continue to focus on achieving grain protein levels in milling wheats which meet their buyer's criteria for premium payments.

2. Introduction

This is the fourth part of a multi-stage review of how the arable cropping industry can best respond to the recent sharp increases in prices and availability of manufactured fertilisers.

Part 1 addressed how nitrogen (N) rates should be changed because of increases in N fertiliser prices and the impact of these changes on crop yield for the major arable crops, wheat, barley, and oilseed rape. In addition to this report (Sylvester-Bradley and Kindred, 2021):

Part 2 assessed additional aspects of fertiliser management, including achieving milling and malting specifications, but also which crops, fields and N splits to prioritise; the influence of expected yield; any implications for management of organic materials; the value of precision N use; calculating the N price; management of other nutrients; and longer-term implications.

Part 3 examined implications for management of oats.

Part 4, as reported here, explores how late N applications should be managed for wheat varieties suited to the milling market, where the grain protein content affects the sale price.

Current issues of concern regarding late N applications are as follows:

- The price of fertiliser N has doubled since last year, the value of grain has also increased substantially, and is still increasing, thus the economics of N use, including late N use, have transformed since last year, and are still in a state of flux.
- On average, growers apply more N to milling wheat varieties than to non-milling wheats. Use of extra N has reduced over recent years (Anon, 2021), probably because fewer crops receive extra late N; the average difference is now equivalent to 60% of milling crops receiving 40 kg/ha extra N, which now costs ~£80/ha. The extra N is often applied late: as granules when flag leaves have just fully emerged (GS39) or as foliar sprays of urea during grain filling, when grains are milky ripe (GS75).
- Most growers committed to their choice of wheat variety before recent price changes, so some growers who chose milling varieties are concerned about whether it remains economically worthwhile to attempt to meet the market specification for milling
- Part 2 of this review concluded “in many cases it will still be economically justified to target milling quality, particularly if premiums are £30/t or more”
- Current price differences between feed and milling wheat (delivered November 2022) are ~£43/tonne (Farmers Weekly, w/e 05-05-2022)

Part 2 did not address that:

- The way that protein premiums are paid can differ between grain buyers, and the effects of payments structures may influence growers’ strategies for late fertiliser N use.
- Growers always face considerable uncertainty concerning the N amounts they should apply to optimise yield, due to the difficulties in predicting soil N supplies and fertiliser N recoveries by their crops. This leads to further uncertainties over the protein levels that they will achieve, hence the value of applying late, extra N
- Milling wheat premiums are paid according to moisture, specific weight, Hagberg falling number and admixture criteria as well as according to protein concentrations. This exacerbates the uncertainties of targeting the milling market.
- Farms appear to differ in the protein levels that they generally achieve, and the consistency of these.

3. Analysis Approach

3.1. Crop Responses to applied N

Part 1 of this Review analysed 46 experiments from the LearN Project (Kindred *et al*., 2018) which used feed wheat varieties, and Part 2 analysed 27 experiments from the LearN Project which used milling wheat varieties, to deduce normal crop responses in both yield and grain protein to total amounts of N applied (in spring, excluding 'late' applications).

These 'normal' or 'standard' responses were adjusted here to be compatible with the grain protein levels and responses given in recommendations in AHDB's Nutrient Management Guide (RB209).

Normal responses to additional, late N applications were deduced here from the nine experiments reported by Dampney *et al*. (2006).

3.2. Cost & Price Scenarios

Economic optimum fertiliser N rates were specified according to the break-even ratio (BER) of prices between N and grain. Current and historic prices were obtained from AHDB and Defra websites.

Effects of adding extra late N were estimated after making assumptions about the cost of fertiliser N, the price of feed wheat, the yield level achieved with optimal N supplied, the protein level required in the milling specification, the price premium on offer for achieving the milling wheat specification, the discount for not achieving the protein threshold, and the protein level resulting in rejection from the milling market**.**

3.3. Historic Trends and farm-to-farm uncertainties

Past trends were determined in fertiliser N applied (Defra, 2021), grain yields (Defra, 2021) and grain protein concentrations (AHDB, 2022).

Current variation was determined from analysis of the YEN database (from crops harvested from 2013 to 2020) which contained data describing 779 crops of milling wheat.

4. Results & Discussion

4.1. Crop Responses to applied N

4.1.1. Spring applied N

The shapes of curves fitted to yield and protein data from individual N experiments do not vary hugely, so summary curves were developed from experiments in the LearN Project (Fig. 1; Kindred *et al*., 2018). The vertical and horizontal locations of the protein curves were set to match values quoted in RB209 (AHDB, 2022) i.e. if BER=5, grain protein of non-milling varieties with optimal N for yield is ~11%, and at any one level of applied N, milling varieties have ~1% more protein than non-milling (or 'feed') varieties (Fig. 1). Thus, if milling varieties are fertilised optimally with prices at BER5, the extra N needed to achieve the milling specification of 13% must raise the protein level by ~1% and the quantity of extra N (applied in spring) needed to achieve this is 70 kg/ha.

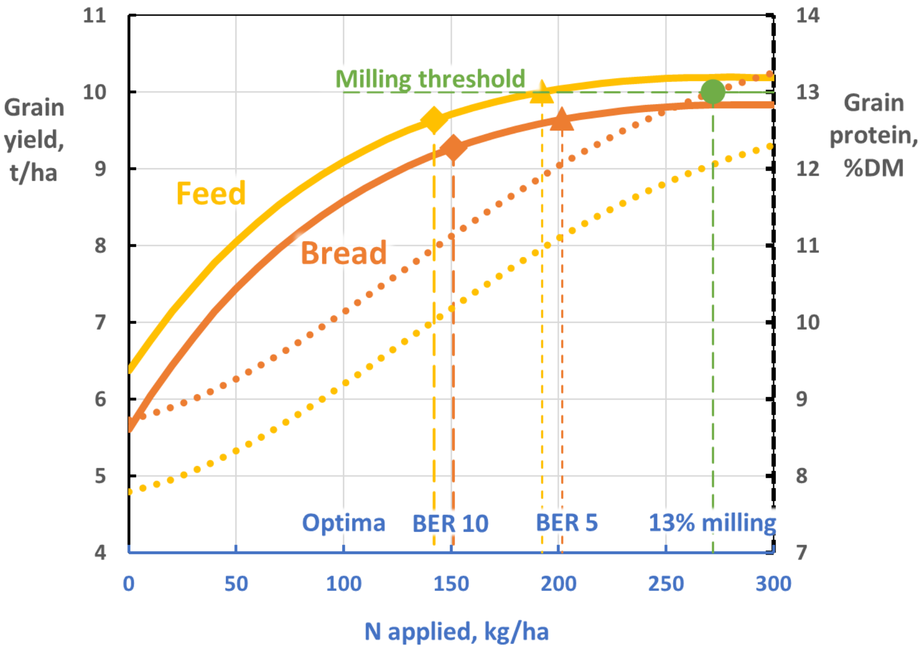

***Fig. 1** Effects of total fertiliser N applied in spring on grain yield (full lines) and grain protein (dotted lines) of feed (yellow) and milling (orange) wheat varieties based on curves adopted for AHDB's 'Nitrogen fertiliser adjustment calculator for cereals and oilseeds' and on RB209 advice about protein concentrations at N rates that optimise grain yield at break-even price ratios (N:grain; BER) of 5 (as in RB209) and 10 (as now).*

With prices at BER10, optimum applied N is reduced by ~50 kg/ha and grain protein levels are ~1% less than at BER5. Thus, the challenge for managers of milling wheat varieties in 2022 is to judge whether it is worth applying sufficient extra supra-optimal N (i.e. ~120 kg/ha if spring-applied) to achieve the milling specification of 13% (Fig. 1).

4.1.2. Late applied N

The most thorough and recent UK experiments on effects of late-applied N on milling wheat varieties were harvested in 2003-2005 and reported by Dampney et al. (2006). Average responses across the nine experiments are shown in Fig. 2, and individual responses to late applications of foliar urea are shown in Fig. 3. Results here were similar across sites (Fig.3) and are in keeping with results of experiments in the 1980s (e.g. Sylvester-Bradley et al., 1987) and 1990s (e.g. Dampney et al., 1995) hence it is expected that responses of more recent crops of milling wheat to late N applications will remain principally the same.

In summary, Fig.2a shows that small increases in yield are caused by applying extra AN at GS39 but no yield increases can be assumed from applying more extra N than ~40 kg/ha or from later applications of foliar urea; in fact, multiple applications of foliar urea can cause slight yield reductions.

All means of applying late N increase grain protein (Fig. 2b) and the responses are similar or slightly larger than protein responses to spring-applied N (Fig. 1). Protein responses to AN at GS39 do not extend at rates greater than 40 kg/ha N whereas protein responses to extra N applied as foliar urea continue at rates exceeding this (Fig. 2b). Thus, if a crop is predicted to need more of a protein lift than ~1%, it is possible to achieve this by applying larger rates of late N – say ~60 kg/ha per % protein – as foliar urea sprays, but with the risk of small yield reductions.

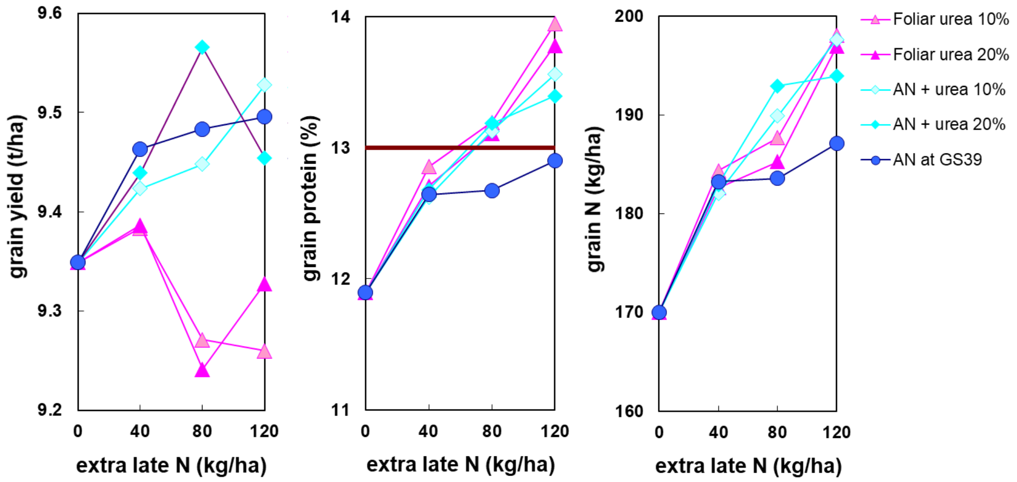

Fig. 2 ***Average effects of extra late N on (a) grain yield, (b) grain protein and (c) grain N offtake from nine experiments harvested from 2003 to 2005. Late N was applied as ammonium nitrate granules (AN) or foliar urea in sprays at 20% (w/v) or diluted (10%).***

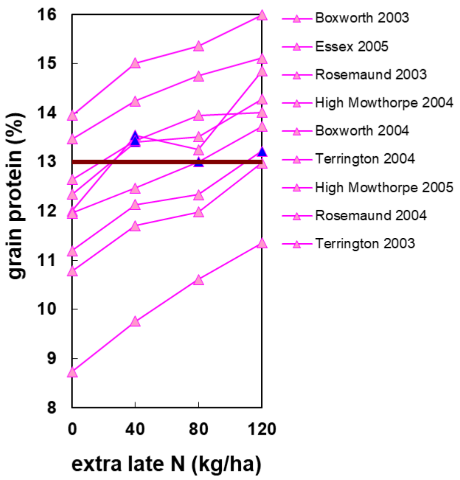

Fig. 3 ***Effects of extra late N (applied as 10% foliar urea at GS75) on grain protein in nine experiments harvested from 2003 to 2005.***

Fig. 3 shows that effects of late urea sprays on grain protein were quite consistent across the nine experiments but that the protein levels achieved without late N were very variable so that extra N raised grain protein from below to above 13% in only three cases by applying 40 kg/ha extra N and in five cases by applying 120 kg/ha extra N. It is thus clearly important that farms make good assessments of protein levels resulting from just their spring N applications.

4.1.3. Environmental impacts:

Effects of late N applications on total N in harvested grain are also shown in Fig. 2c. When averaged over N rates these can be summarised as recoveries over all N rates of: 21.6% for AN at GS39, 27.3% for 10% foliar urea, 24.5% for 20% foliar urea, 26.2% for AN + 10% urea, and 27.1% for AN + 20% urea. The overall average recovery of late-applied N was 25.3%; but average recovery was 33% from applying only 40 kg/ha. Clearly these recoveries are poor, and they show substantial inefficiencies in applying extra N late to milling wheat crops, with 75% of applications potentially adding to environmental impacts. Research in the 1990s showed that the main inefficiencies were through deposition of sprays on the soil, through ammonia volatilisation, and through N left in straw (Cross, 1992; Hopkinson, 1998; Turley *et al.*, 2001).

4.2. Cost & Price Scenarios

Prices that growers paid for the fertiliser N that they are using in 2022 varied hugely; some bought it before the recent price hike and others after. Some can store or re-sell their fertiliser (thus profiting from any price increase) whilst others cannot. There are strong arguments, depending on the ease and legitimacy of re-selling and longer storage, that all fertiliser at any time, even that already on the farm, should be valued at the cost of its replacement. Current prices (see here) are £2.28 and £1.95 / kg N for ammonium nitrate (AN) and urea respectively.

Current prices for milling and feed wheat (from Farmers Weekly, 13-5-22, for November delivery) are £358.50 and £315.50 respectively. Hence the current BER for milling wheat fertilised with AN is 6.34. However, BERs have varied through the season from less than 5 to more than 10. To illustrate (in Fig. 4) the effects of using a range of rates of applying extra late N, either as AN at GS39 or as foliar urea at GS75, a scenario was created that makes the following assumptions:

N cost:	£2.00	/kg N
Feed wheat value:	£300	/tonne
Break-even price ratio:	6.7	
Yield level:	9.00	t/ha
Protein premium:	£40	/tonne if over main threshold
Max protein causing rejection:	12.5	%DM
Discount:	£2.00	/tonne for every 0.1% below Main threshold
Main threshold:	13.0	%DM
Upper enhancement:	£0.00	/tonne for every 0.1% above Main threshold to Upper limit
Upper limit:	NA	%DM

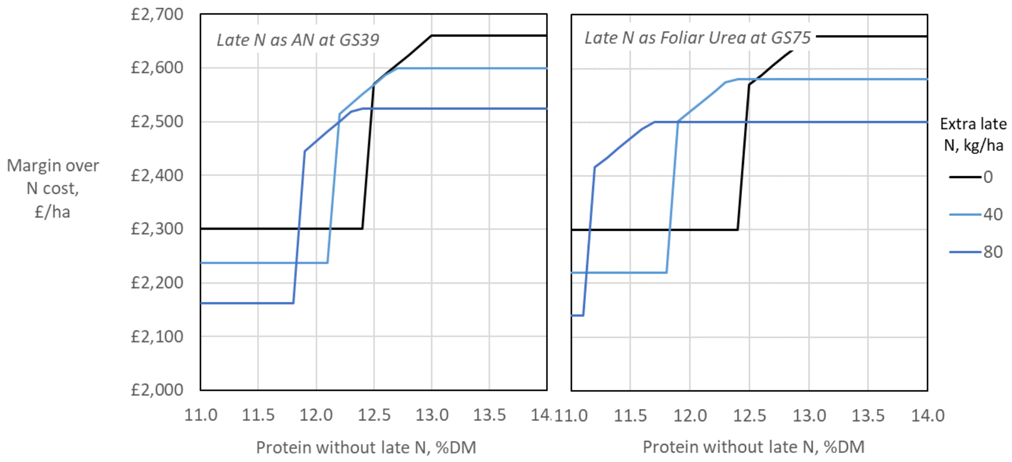

Fig. 4 Effects on margin over N cost of applying extra late N either as AN at GS39 (a) or as foliar urea at GS75 (b) for the step-slope-step payment scenario and other assumptions given in the text.

This is equivalent to the ‘step, slope, step’ payment system analysed by Sylvester-Bradley & George (1987b) who compared this to other systems such as ‘one-step’, ‘two steps’, and ‘continuous’ adjustment. They found only minor effects on profits of employing these different payment systems, so effects of alternative payment systems are not explored further here.

This ‘step, slope, step’ scenario shows that over most of the range over which grain protein varies, application of extra late N reduces profit because it does not affect grain sale price. Profit is only increased by the application of extra N to crops which otherwise would have achieved between 11.0 and 12.5% protein (Fig. 4). Profits would have suffered from use of late N on crops with lower or high protein levels than these. Hence the importance of considering the predictability of protein levels after spring N has been applied.

4.3. Trends and farm-to-farm uncertainties

4.3.1. National trends

Total fertiliser N used on wheat has not changed for 40 years (Fig. 5). Grain yields continued to increase until the mid-1990s. There is a suspicion that grain protein levels decreased in the early 1990s whilst the trends in N use and yield differed, but this did not persist; no longer-term trend in grain protein is evident over the last 20 years.

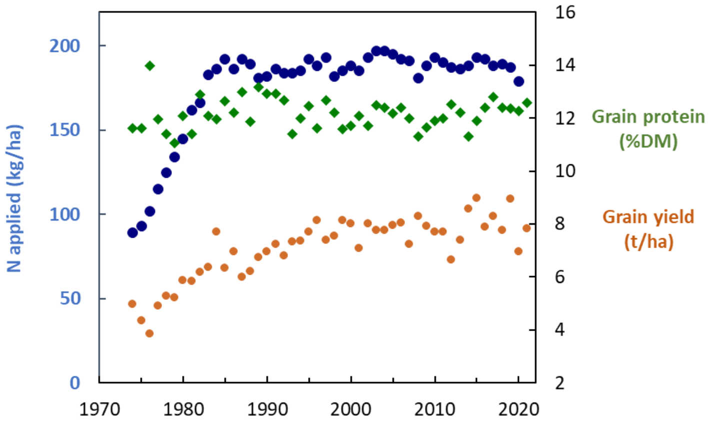

***Fig. 5** National trends in fertiliser N applied overall to winter wheat (blue; Anon., 2021), its grain yield (orange; Defra, 2021) and grain protein (green; AHDB, 2021).*

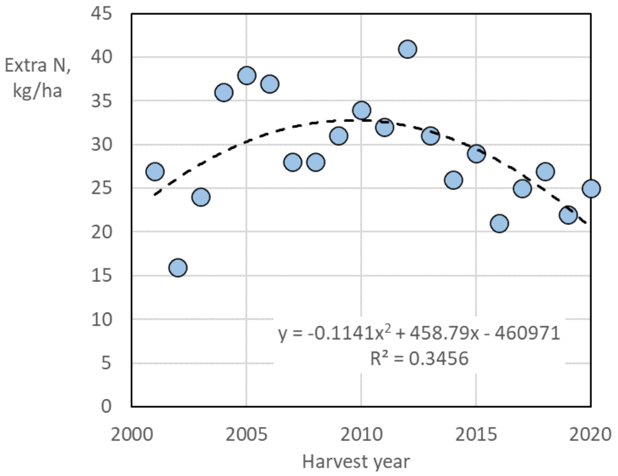

***Fig. 6** National trend in the difference between fertiliser N applied to milling and non-milling wheat (Anon., 2021). The quadratic trend is highly significant.*

However, the difference in N use on milling wheats compared to non-milling wheats has decreased by 10 kg/ha over the last ten years from 34 kg/ha in the late 2000s (Fig. 6). This difference may arise from any of many possible causes beyond less extra N being applied to boost protein of milling varieties; for example, soil conditions (e.g. soil N supplies from previous cropping) selected for the two wheat types may be changing, or growers' perceptions of yield levels and hence N demands of modern wheat types may be changing. Access to additional datasets and further work would be needed to evaluate probable causes of this trend, but suffice it to say that, given that applications of less than 40 kg/ha of late N are relatively impractical, these data support the conclusion that only a minority of milling wheat crops receive late N applications and this minority has decreased in recent years.

4.3.2. Uncertainties in protein levels

The relatively small range of grain protein over which profits are affected by late N applications arises from market specifications that use one or a few fixed protein levels to trigger milling wheat premium payments and emphasises the importance of knowing what protein levels to expect when deciding on the need for late N applications.

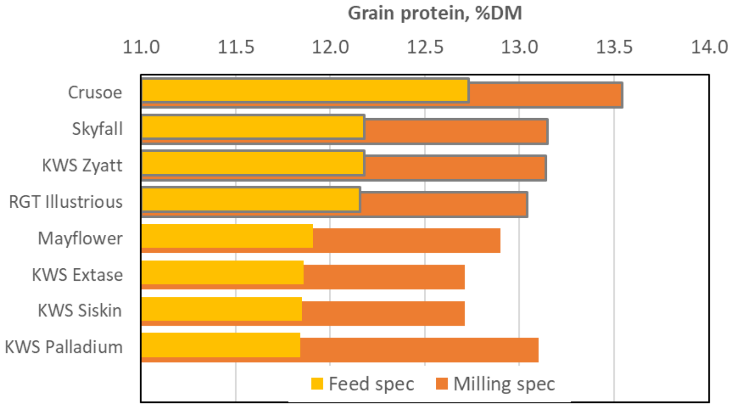

Fig. 7 ***Grain protein levels of Group 1 (outlined) & Group 2 varieties of winter wheat quoted in the AHDB Recommended List for 2022. N applied for the 'Feed specification' is as recommended for Group 3 or 4 varieties by RB209, and N applied for the 'Milling specification' aims to achieve 13% protein content in the highest yielding variety using combinations of extra late N applied as granules in May and/or a foliar spray at GS75.***

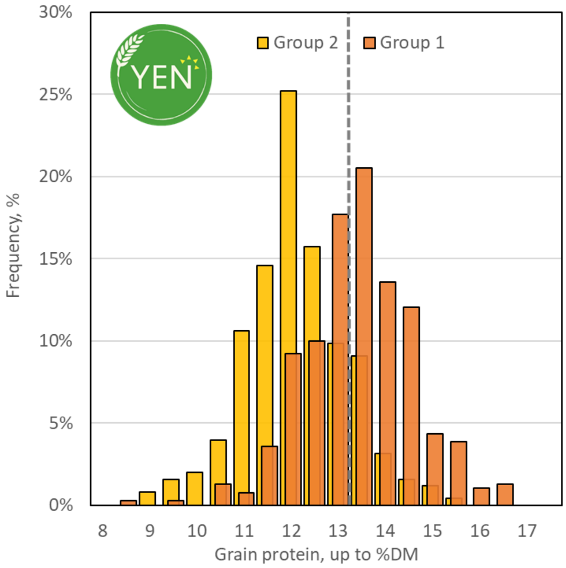

Fig. 8 ***Frequency distributions of grain protein amongst 644 milling wheat crops entered in the YEN (Yield Enhancement Network) between 2013 and 2020. The dotted line divides crops with <13% from crops with >13% grain protein.***

Variation is partly genetic as shown by results of AHDB Recommended List experiments (Fig. 7); Group 1 varieties all have greater protein levels than Group 2 varieties. Effects of extra late N in these experiments average quite consistently at ~1%, except for KWS Palladium which appears to respond significantly more than other varieties, by +1.26%.

These genetic effects can be seen in the context of total variation in protein level of milling wheat crops by examining data from the YEN (Figs. 8 & 9) which show that only 57% and 16% of Group 1 and Group 2 crops respectively achieved >13% protein. On top of the difference between Groups, variation due to husbandry and growing conditions is also clearly substantial, with the range in protein contents of individual crops of both Groups extending from 9% to >15% (Fig. 8).

In exploring this environmental variation further, a clear difference in average protein level was found between farms (Fig. 9). All farms with consistent high protein levels grew Group 1 varieties, but not all farms that entered Group 1 varieties achieved consistently high grain protein. All farms that always entered Group 2 varieties achieved protein levels consistently less than 13%. Farms with inconsistent grain protein levels tended to enter a mix of Group 1 & 2 varieties (except for Farm J). Farms growing high protein varieties tended to apply more N in total (average trend +16 kg/ha/% protein). Thus, most farms are clearly able to predict and manage their grain protein levels and they should keep good records of these to guide and improve future N management.

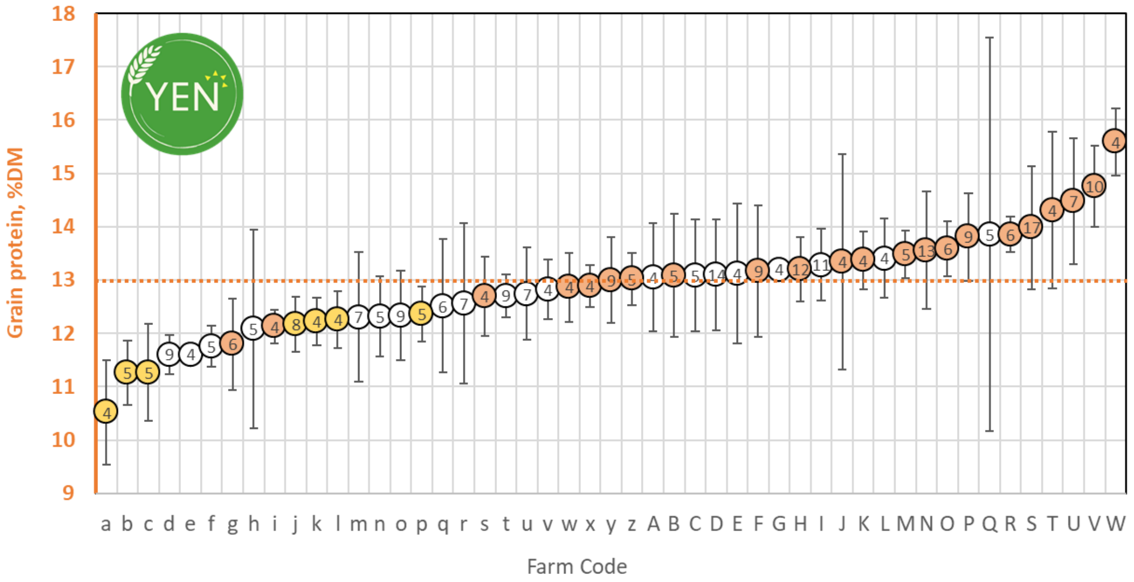

***Fig. 9** Average (circles) and variation (bars; 2xSD) in grain protein for each of 49 farms with four or more Group 1 or Group 2 wheat crops entered in the YEN between 2013 and 2020. The number of entries from each farm is shown in each circle. Orange and yellow circles mark farms which consistently grew Group 1 or Group 2 varieties respectively.*

Around 20% of farms entered crops with consistently high grain protein (>13%); these farms, especially farms U, V & W which entered crops with >14% protein, are likely to be over-supplying their crops with N and could benefit from testing whether crop N supplies can generally be reduced. The 25% of farms entering crops with consistently low grain protein (<12%) are probably under-supplying N; they are justified in applying sufficient extra N to provide protein levels which would attract a premium only if the premium on offer is large, say >£20/tonne. Farms such as a, b & c are unlikely to achieve a 13% protein threshold, so cannot justify applications of extra late N unless vary large premiums are on offer, or unless they wish to test whether yield responses might also be economic.

About half of all farms entered crops with grain protein levels close to the milling premium threshold of 13%. These are the farms for which decisions on the need for extra N are crucial. YEN data do not identify whether these farms actually used late N, so further investigation would be required to show whether their N strategies were economically advantageous. But for farms with an equally uncertain prospect of achieving the protein threshold in 2022 it is probably worth applying extra late N if the milling quality premium is good or very good.

5. Conclusions

Conclusions from this review are summarised in Table 1, which suggests that best decision-making approaches on late N use for milling wheat crops in 2022 depend on: (i) the premium on offer for exceeding the protein threshold, (ii) whether they have reduced their spring N applications due to high prices in 2022, (iii) whether late N has usually been used in the past, and (iv) the farm's past success in meeting the criteria for premium payment.

Table 1. Summary of conclusions on applying late N to milling wheat in 2022.

Premium	**Farm's past success in meeting milling spec.**		
£/tonne	***Seldom***	***Sometimes***	***Usually***
~£10	Omit late N & hope!	Continue with usual past practice for milling wheats	Continue with usual past practice for milling wheats
~£20	Only apply late N (60 kg/ha) if spring N applied was as in previous years. Otherwise, omit late N & hope!		
>£20		Apply 60 kg/ha late N even if not usual past practice	

As concluded in Part 2 of this Review, because of their inherently lower yield and the supra-optimal N applications needed to produce sufficient grain protein, premiums are generally necessary to incentivise production of wheat crops that meet the milling specification. However, yields and quality premiums only need to be modest (e.g. £10/tonne) for production of milling wheat to be more profitable than production of feed wheat.

With expensive fertiliser N it is still usually better to fertilise milling varieties to achieve 13% protein than to apply the new smaller optimum N rates for grain yield (see Part 1). It is only when quality premiums are small (e.g. £10/tonne) and BER is greater than 9, that it ceases to be worthwhile (in terms of margin over N cost) to apply sufficient N to achieve the milling specification.

However, these conclusions should be tempered by the past success of each farm in growing crops that attract a quality premium (based on *all* criteria: protein, Hagberg falling number, specific weight, moisture, admixture). If premiums are not achieved consistently over seasons, or where there is a risk of low HFN or specific weight, then the recent fertiliser price increases may now have moved the risk/benefit balance to a point where targeting milling quality cannot be justified.

Considering the converse, farms that always achieve >13% protein are likely to be supplying more N than is necessary and could profit from reducing their N use. If they are now finding fertiliser N costs to be high, they could easily find it worth testing field areas or tramlines with less N applied (e.g. by omitting late N) than previously and comparing the differences in grain yield and grain protein, hence margin over N.

Extra late N is used inefficiently and recent research (Shewry *et al*., 2020) has indicated that the same protein content is not a consistent indicator of the performance of a grain sample in breadmaking across all varieties. Hence there may be advantages to breadmakers of developing grain testing and processing procedures that allow them to use grain containing less protein hence with a smaller environmental footprint.

5.1. Possible further research

The need for extra N in order to meet milling specifications has been controversial for many years (e.g. Sylvester-Bradley & George, 1987b), hence a subject of continued research. Much improved data are now available. For example, the AHDB Recommended List provides robust protein data for each wheat variety (both milling and feed) both with and without extra late N, and these levels vary substantially. Nevertheless, their predictive value in guiding N fertiliser decisions is not currently recognised in RB209 recommendations; this should be considered.

Some further questions that may merit further investigation are as follows:

- Can breadmaking varieties be bred to require less or nil extra late N?
- Can N applied specifically for breadmaking be developed to have reduced environmental impacts?
- What is the fate of the many milling wheat crops that achieve inadequate protein for the breadmaking market?
- Can the predictability of protein levels in wheat be improved by recognising the distinct differences between farms?
- Can sophistication of the way protein premiums are operated reduce the proportion of crops that are grown for breadmaking but are never made into bread?
- Can relationships between producers and processors of milling wheat be improved such that a reduced proportion of milling crops are rejected for breadmaking?
- For example, after improvement of the 'combinable crops grain passport' (see here) can information flows between producers and processors of milling wheat be enhanced such that everyone in the chain benefits, right through from plant breeder and farmer to consumer?

6. Acknowledgements

Funding from UK Flour Millers is gratefully acknowledged.

Many thanks to AHDB for providing historic dataset from the Cereal Quality Survey used in Fig. 5..

Development by ADAS of the YEN Database is gratefully acknowledged; its use in Figs. 7 & 8 will be reciprocated by sharing these Figs. with YEN participants though YEN News.

7. References

AHDB (2016) *The Nutrient Management Guide (RB209).* Accessed here Nov 2021.

AHDB (2021). *Cereal Quality Survey.* Accessed here May 2022.

Anon (2021). *The British Survey of Fertiliser Practice (2021). Fertiliser use on farm crops for crop year 2020.* Defra, London, 114pp.

Cross, R.B. (1992). Crop recoveries and soil residues from nitrogen applied as prills or sprays to boost grain protein concentrations of winter wheat grown for breadmaking. *Aspects of Applied Biology* **30**, *Nitrate and Farming Systems,* 431-434.

Dampney, P.R.M., Salmon, S.E., Greenwell, P. & Pritchard P.E. (1995). *Management of breadmaking wheat: effects of extra nitrogen on yield, grain and flour quality.* HGCA Project Report 109.

Dampney, P.M.R., Edwards, A. & Dyer, C. J. (2006). Managing nitrogen applications to new Group 1 and 2 wheat varieties. AHDB Project Report No. 400. Pp. 122. Accessed here

Defra (2021). *Agriculture in the United Kingdom data sets.* Accessed here May 2022

Hopkinson, J. (1998). *Uptake and utilisation of nitrogen applied to the foliage of winter wheat.* PhD Thesis, University of Nottingham, England. 230 pages.

Kindred, D.R., Clarke, S.M., Sylvester-Bradley, R., Hatley, D., Roques, S., Morris, N., Knight, S., Langton, D. & Blake-Kalff, M.A. (2018). *Using farm experience to improve N management for wheat (LearN)* AHDB Project Report No. 596, Pp.82. Accessed here Nov. 2021.

Shewry, P.R., Wood, A.J., Hassall, K., Pellny, T.K., Riche, A., Hussein, A., Hawkesford, M.J., Griffiths, S., Penson, S., Tucker, G. & Bake, C. (2020). *Low protein wheat for bread making.* AHDB Project Report No. 621. Pp. 36. Accessed here

Sylvester-Bradley, R. & Clarke, S. (2009). *Using grain N% as a signature for good N use.* HGCA Project Report No. 458, 61 pp. Accessed here

Sylvester-Bradley, R., Marriot, N., Hayward, C.F. & Hook, S.C.W. (1987a). Effect of urea sprays during ripening on the breadmaking quality of winter wheat. *Aspects of Applied Biology* **15**, *Cereal Quality*, 283-288.

Sylvester-Bradley, R. & George, B. (1987b). Effect of quality payments on the economics of applying N to winter wheat. *Aspects of Applied Biology* **15**, *Cereal Quality*, 303-318. Accessed here.

Turley, D.B, Sylvester-Bradley, R. & Dampney, P.M.R. (2001). *Foliar applied nitrogen for grain protein and canopy management of wheat.* HGCA Research Review No. 47. London, HGCA. 32 pp. Accessed here.