Nitrogen Recommendations for Grassland

AHDB Grass Campaign

Date

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1 INTRODUCTION

The rising cost of nitrogen (N) fertiliser, and possible limited supply in spring 2022, are causing concern across the livestock industry. The international fertiliser market has seen significant volatility since autumn 2021. Even the John Nix Pocketbook for Farm Management 2022 (52^{nd} edition) was out of date by the time it was published in Sept 2021 as it uses £275/tonne (t) for UK ammonium nitrate (34.5% N) for all its enterprise costings.

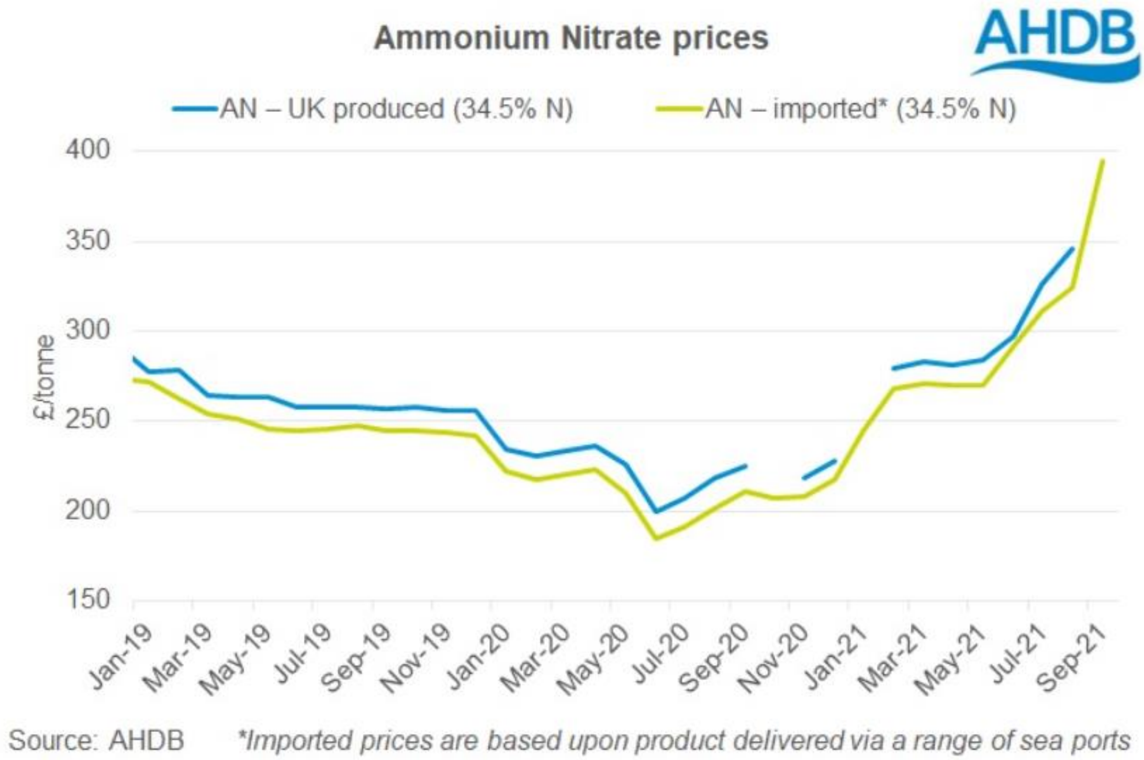

Figure 1. Great Britain Fertiliser Price Chart

In December 2021 ADHB commissioned ADAS to provide practical and accessible guidance on management of high-cost nitrogen fertiliser on grass (including grazed, cut, and hay).

The main objectives of this report were to:

- Summarise typical grass dry matter yield responses from the application of manufactured nitrogen (N) fertiliser and assess the relevance of the current AHDB N recommendations for grassland considering current fertiliser prices
- Evaluate alternative options to manufactured N fertiliser application
- Summarise how high-cost manufactured N fertiliser can impact on farm enterprise decision-making to help businesses that are reliant on grassland forage production to evaluate what alternatives there may be to using manufactured N fertiliser

2 GRASSLAND YIELD RESPONSE TO NITROGEN APPLICATION

When assessing whether manufactured nitrogen (N) fertiliser application rates to grassland should be adjusted due to a high fertiliser price, it is important to consider the typical grass dry matter (DM) yield response to N fertiliser and the basis for the current recommendations. Over a whole season, grass DM yield increases by about 20 kg dry matter per kg N applied, up to the recommended rate. However, this response can vary between 0 and 35 kg DM per kg N applied, depending on the time of year, the soil type and recent rainfall, i.e. site and grass growth conditions, which is normally reflected in the grass growth class (GGC), i.e. GGC is a simplified five level classification of a site's soil available water to support grass growth and thereby indicate its potential response to applied nitrogen. Temperature is considered. GGC is a function of soil type, summer rainfall and altitude (i.e. temperature). The better the GGC, the greater the efficiency of N use and the greater the DM yield response.

AHDB's Nutrient Management Guide (RB209) grassland N recommendations are based on knowledge of grass response to fertiliser nitrogen, under conditions where growth is not limited by supplies of certain other nutrients. Furthermore, they are based on the need to produce the amount of home-grown forage necessary to maintain a target level of production, rather than the optimal amount relative to the cost of fertiliser. Nevertheless, the current and previous recommendations have used "break-even ratios" to determine an economic optimum, which represents the amount of N fertiliser applied to the sward above which any additional yield was minimal before maximum yield was reached. For example, in the 8th (2010) edition of RB209 the economic optimum concept was set at a break-even ratio of 10:1 (10 kg of DM yield to 1 kg of N applied). These were determined from a selection of N response trials and used to set recommendations for Very Good/Good, Average and Poor/Very Poor GGCs.

The 2017 update and subsequent versions of RB209 have retained the same principles but adjusted the recommendations for cut and grazed grass based on the amount of grass DM yield required on farm. It therefore is of interest to determine the N_{10} application rate at which the Y_{10} 'economic optimum' yield is reached for a variety of sites, conditions and stages in the growing season. At current fertiliser prices of around £650/t for ammonium nitrate, and using a break-even ratio of 10:1, imported forage of similar quality to well managed and conserved silage grass would need to cost less than circa £200 per tonne of DM before any reduction in fertiliser applications could be economically justified.

2.1 Nitrogen Response Curves

Grass dry matter yield response to nitrogen is variable, both in terms of the shape of the response curve, the 'economic optimum yield' and the maximum yield achieved (Figure 2). This variability is determined by various growth limiting factors, including soil water availability, solar radiation and sward composition; and by the soil nitrogen supply (including the N-fixing activity of any legumes in the sward and soil microbes), which determines the yield when no N fertiliser is applied.

In many cases, the N_{10} optimum (the N application rate at a break-even ratio of 10:1) is not reached at any of the N rates applied, i.e. the relationship between N fertiliser applied and grass DM yield is linear up to the highest rate of N applied (Figure 2). For the curves presented in Figure 2, this is the case for all four cuts (stages of the growing season). However, in some instances the Y_{10} optimum yield (the grass DM yield at a break-even ratio of 10:1) is reached at less than 100 kg N/ha applied per cut, and maximum yield at less than 150 kg N/ha applied per cut, and this should be borne in mind when

N fertiliser prices are high. On each farm, it is important to consider what the growth potential is at the farm and individual field level.

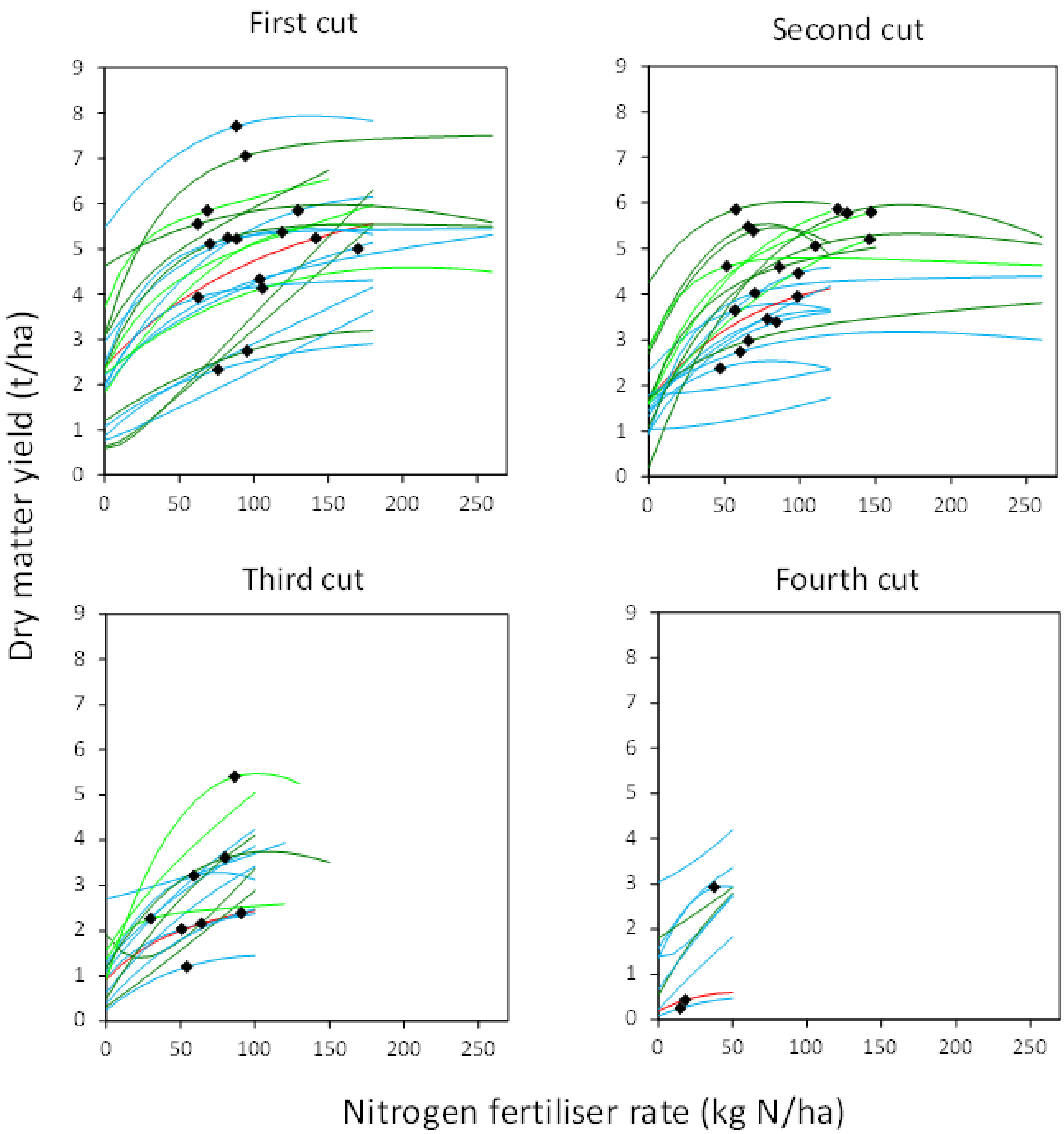

Figure 2. Fitted (linear + exponential) yield response curves by cut; colour coded by Grass Growth Class: Poor/Very poor, Average, Good and Very good. Diamonds represent grass yields at nitrogen optimum at a break-even ratio of 10:1. *Data was collated from twenty-two replicated, randomised block, field experiments using differential fertiliser N rates carried out in England, Wales and N.I. in the past decade (from Newell Price et al., 2016)*.

It is also worth noting that for whole season N response curves the Y_{10} optimum yield (N-opt) tends to be reached more often than not (Table 1). Nevertheless, in purely economic terms, and if the grass is required to support production (based on the stocking rate and required forage intake) the current

RB209 recommendations for N fertiliser applications are still valid. However, key factors to consider are the grass growth class and sward composition.

Table 1. Ranges of nitrogen (N) optimum fertiliser rate at a break-even ratio of 10:1 by cut and for the whole season and number of observations for which N-optimum was reached. Note: for the remaining observations N-opt was either not reached or exceeded the highest N-rate. *Data was collated from twenty-two replicated, randomised block, field experiments using differential fertiliser N rates carried out in England, Wales and N. Ireland. in the past decade (from Newell Price et al., 2016)*.

	1st Cut	2nd Cut	3rd Cut	4th Cut	Whole season
N-opt (kg N/ha)	62 to 170	47 to 147	30 to 91	15 to 38	110 to 406
Dry matter yield at N-opt (t/ha)	2.3 to 7.7	2.4 to 5.9	1.2 to 5.7	0.3 to 2.9	7.0 to 16.9
Number of observations N-opt reached	16	19	8	3	19
Total number of observations	22	22	16	10	22

On poor and very poor GGC sites (e.g. light and shallow soils above 300 m altitude) the yield response to N is often flatter and the risk of applying more fertiliser than is justified is higher. Similarly, if the sward is dominated by less productive grassland species the dry matter yield response to N fertiliser may not be as high as the recommendations predict. Including clover in a sward or sowing multi-species swards that include legumes can allow reductions in fertiliser N use for only a small or moderate reduction in yield, if legume content in the sward remains at an effective level. In some instances, particularly under moderate drought conditions, yields can be unaffected or even increased through establishing multi-species swards (e.g. Finn et al., 2013; Haughey et al., 2018).

Grass DM yield response to applied manufactured fertiliser can therefore vary significantly depending on the GGC of the site and the position on the response curve (Table 2). In Defra project IF00121, DM yield responses at annual rates of applied N less than 100 kg N/ha were lowest at sites D7 and E10, which had high clover contents. Where 200-300 kg N/ha was applied, the lowest DM yield responses were at A1 (over 300 m altitude) and D7 (high clover). DM yield response rates ranged from 6 to 36 kg DM per kg N applied, depending on site factors and the point on the response curve (i.e. amount of N applied). At the Nitrate Vulnerable Zone (NVZ) '*N max*' rate of 300 kg N/ha/annum (340 kg N/ha/annum is permitted for 3 cuts or more per year), responses ranged from 11 to 34 kg grass DM per kg N applied.

Table 2. Grass DM yield response to manufactured fertiliser N in different sections of the response curve. A1, A2, C5, C6, C7, D7, D8, E9, E10, F11 and F12 are the different experimental sites involved in Defra project IF01121: "Validation of *Fertiliser Manual* (RB209) recommendations for grasslands".

N fertiliser range (kg N/ha)	kg grass DM per kg N applied									
	A1	A2	C5	C6	D7	D8	E9	E10	F11	F12
0-100	23	26	36	33	15	26	34	18	31	28
100-200	18	21	32	27	9	22	34	21	24	24
200-300	13	15	25	19	9	17	33	22	15	18
300-400	7	9	15	6	9	12	25	22	6	7
0-300 (N max)	18	21	31	26	11	22	34	20	23	23

2.2 Evaluating Cost Benefit of N Fertiliser

The cost benefit of applying N has been assessed by comparing the cost of 1 kg fertiliser (based on ammonium nitrate fertiliser prices ranging from £250/t to £850/t for 34.5% N) to the relative feed value (RFV) of grass using three different DM response rates (approximately representing Very poor, Poor/Average and Good/Very good GGC).

The relative feed of grass is calculated by comparing it to the cost of concentrate feed equivalent for the same DM and nutritional value. A concentrate blend cost of £260/t was used; section 4.2.1 shows how this has been calculated. An allowance for fertiliser spreading cost has also been included, see Appendix 1 for full details.

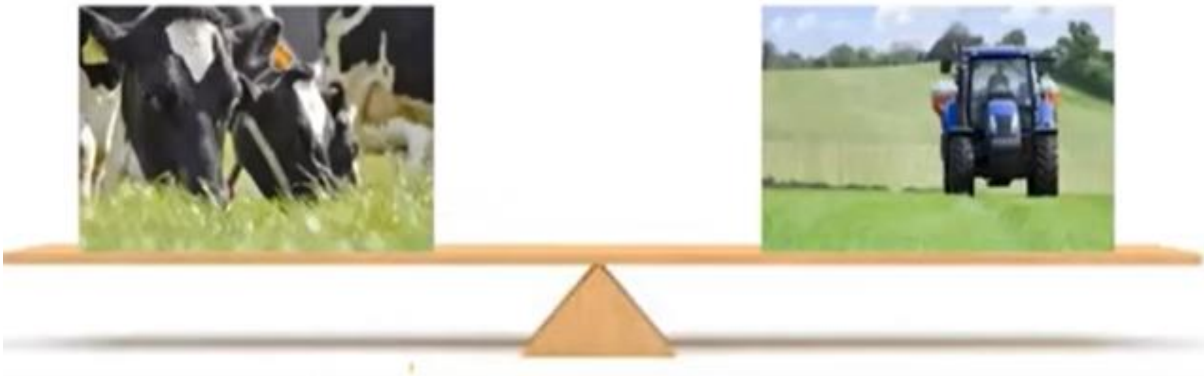

Figure 3. Relative feed value of grass compared to cost of fertiliser, balanced at 1:1

Values greater than 1.0 mean grass feed value is greater than the fertiliser cost. Values less than 1.0 mean the grass feed value produced is less than the cost of applied fertiliser.

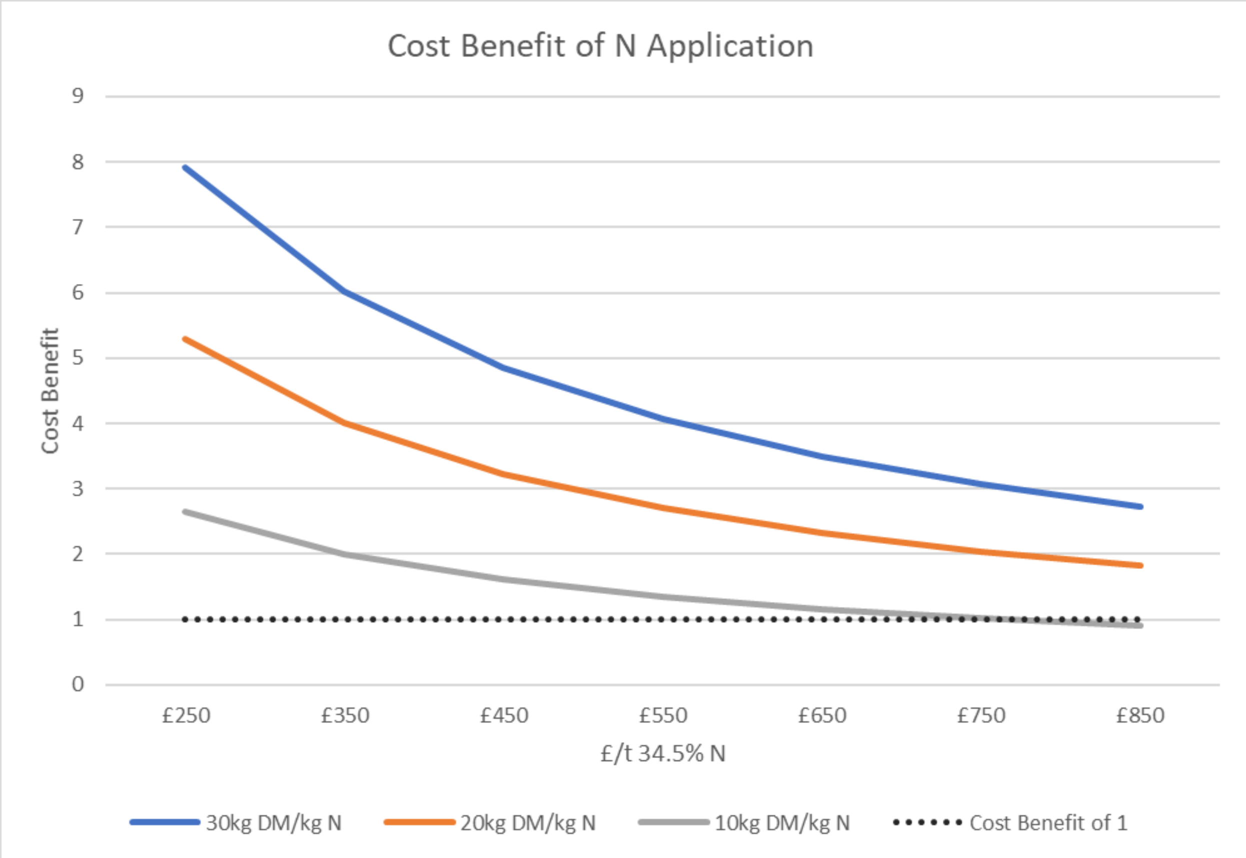

Figure 4. Graph showing the cost benefit of N application at three different grass growth response rates.

At a grass growth response rate of 30 kg DM/kg N and 20 kg DM/kg N, the cost benefit doesn't drop below 1.0 even when ammonium nitrate (AN) fertiliser (34.5% N) reaches £850/t. At a response rate of 10 kg DM/kg N the cost benefit is much lower at all fertiliser prices and drops below 1.0 when the price of AN fertiliser reaches approx. £700/t.

3 FORAGE COSTS

3.1 Cost of Home-Grown Forage

When considering the cost of applying manufactured N fertiliser to grass and forage crops, it is important to assess this within the overall cost of producing home-grown forage. It is also important be aware of these costs when comparing home-grown forage production costs with the price of bought-in feeds. The AHDB forage cost calculator was updated in Jan 2022 using current fertiliser prices and up-to-date contracting costs to work out the cost of production of several home-grown forage options (Table 3).

The calculations are based on the following fertiliser costs

- Nitrogen (34.5% N) at £655/t = 190p/kg N
- Triple Super Phosphate (46% P_2O_5) at £552/t = 120p/kg P
- Muriate of Potash (60% K_2O) at £560/t = 93p/kg K

All fertiliser requirements and supply of nutrients from manure have been calculated using the AHDB Nutrient Management Guide (RB209). Costs of mechanical operations such as fertiliser and manure spreading, spraying, establishment and harvesting have been taken from John Nix Pocketbook 2022. The forage cost calculations also include a rent equivalent cost (if owned, the land could be let rather than farmed) and the cost of establishment as appropriate. Many situations will also require farmyard manures or slurry to be spread. Guidance information has also been taken from Field Options crop costings.

Full costings & assumptions are contained in Appendix 2 & 3.

Table 3. Home-grown forage production costs

Forage Type	Expected Yield (t DM/ha)	Manufactured Fertiliser (MF) Only (£/tonne DM)	MF plus nutrients from Organic Manure (£/tonne DM)
Grazing only	12.6	74	73
First cut silage	6.9	117	102
Silage plus grazing	11.3	110	101
Three cut silage	14.0	140	125
Maize silage	12.0	115	97
Wholecrop	13.5	123	110
Permanent pasture	7.2	67	67

John Nix Pocketbook 2022 quotes grazed grass cost as £51/t DM and grass silage cost of £101/t DM however this does not take into account a rent equivalent and is based on a fertiliser cost of £275/t for UK 34.5% nitrogen (N), £400/t for 46% phosphate (P_2O_5) and £250/t for 60% potash (K_2O). These fertiliser prices would have been accurate at the time of writing the 2022 update in early 2021, which was published in September 2021.

Table 3 shows that grazed grass is by far the cheapest home-grown forage on the farm. Conserving the grass as silage increases the cost per tonne of DM significantly and the reduced yields from second and third cuts increases the average cost per tonne of DM further. Where yields of 40 tonnes of fresh weight (FWt) can be achieved, forage maize, grown predominantly with nutrients from organic manures, has a lower cost of production per tonne of DM (N.B. Organic manures should not be used to provide more than 50 – 60 % of the nitrogen requirement of a crop due to year-to-year variability in manure nutrient supply).

For the forage options considered, the contribution of nutrients from slurry and manure, even after taking account of spreading costs, reduces the cost per tonne of DM significantly. The other major influence on forage cost production is the DM yield of the crop / grass. The higher the DM yield per ha, the more likely it is that it will have a lower cost per tonne of DM.

All the forage cost calculations contained in Table 3 can be amended to suit individual farm circumstances including farm specific costs and yields. To do this, the template spreadsheet can be downloaded from the AHDB website.

3.2 Impact of Increased Fertiliser Costs on Grazed Grass Production Costs

As has already been discussed, the cost of N fertiliser rose rapidly in autumn 2021 due to increasing gas costs. If the cost of N fertiliser had remained at the £275/t quoted in John Nix the cost of grazed grass would have been £50/t DM not £74/t DM (Table 3). This assumes all other production costs remain constant – there will have been increases in late 2021 going into 2022.

On each hectare of grazing, this is a difference of £302/hectare (ha), so for a farm with a 40 ha grazing platform, this equates to an increase in fertiliser cost of £11,880 compared to 2021. This is without considering the increased cost of producing conserved forage for winter feed.

4 ALTERNATIVE OPTIONS TO APPLYING NITROGEN

The dry matter yield response of grassland to applied N, as summarised in Section 2; the current high cost of bought in feed; and high output prices for dairy and meat products (see figures 5 & 6), mean that, even at £655/t for ammonium nitrate, it is still cost effective to continue purchasing and applying manufactured N. However, the high cost of fertiliser and other inputs combined with the increased cost of replacement breeding animals (beef, sheep and dairy) means that the working capital required to operate a livestock business has increased significantly in recent months. In turn this has a significant impact on cashflow, particularly where businesses were not able to forward buy fertiliser prior to the rapid price rise.

Consideration is therefore given below to a variety of alternative strategies that could be employed if a farm business **is** thinking of reducing N applications despite the strong evidence that applying fertiliser N is still cost effective. The impact on the whole business should be carefully evaluated before any change is made.

The cost of production of home-grown forages (Section 3) gives a base from which to compare alternative options although these should be tailored to the farm situation. All the following options assume the application of manufactured fertiliser N to the grassland area is reduced with the consequence of reduced yield of grass/conserved forage.

4.1 Purchased Forage

If less conserved forage is made, because of lower N application, additional forage could be purchased from elsewhere. Cost, availability, and quality of forage vary hugely – to demonstrate this, the variety of forage currently being advertised for sale across the country on 'Sell My Livestock' is as follows:

- Silage £12-45/bale (£80-300/t DM for a 500kg bale @ 30% DM)
- Hay £18-45/bale (£70-176/t DM for a 300kg bale @ 85% DM)
- Haylage £8-35/bale or £75/t (£33-145/t DM for a 400kg bale @ 60% DM)
- Maize Silage £35-40/t (£100-115/t DM @ 35% DM)
- Wholecrop £45/t (£112.50/t DM @ 40% DM)
- Fodder Beet £20-32/t (£111-177/t DM @ 18% DM)

In some cases, the cost of buying in forage may be lower than the cost of producing home-grown forage. In this instance, the farmer needs to weigh up the risks of buying in forage that may be of lower quality than home-grown forage. The availability and cost of purchased forage and the cost of haulage in 2022 and subsequent years also need to be considered carefully – surpluses may not be available.

4.2 Cost of Alternative Feeds

If insufficient home-grown forage is produced and forage is not available to purchase locally then livestock diets would need to be substituted with purchased feed. This could be through a cereal based concentrate / blend feed or alternative by-product feed such as brewer's grains.

4.2.1 Concentrate/Blend

Wheat and rapeseed have been used in this example to show the megajoule (MJ) of metabolizable energy (ME) and crude protein (CP) equivalent needed to make up a shortfall in forage.

Commodity price @ 21st Jan 2022

- Feed wheat £212/t
- Rape meal £336/t

Grass silage quality target for dairy

25% DM, 11.5 MJ ME/kg DM, 15% CP/kg DM

Blend quality and cost (simple example excluding minerals, etc.)

87.2% DM, 13.5 MJ ME/kg DM, 15.3% CP/kg DM

88% wheat @ £212/t

12% rapeseed @ £336/t

= £227/t FW (corrected to 100% dry matter = £260/t of DM)

Assuming that metabolizable energy and crude protein in the dry matter are approximately the same for the feed/blend and the grass silage, it would cost £260 to replace 1 tonne of silage DM (4t Fresh Weight @ 25% DM) with purchased concentrate feed. This is more than double the highest cost of production per t DM of grass silage (section 3.1) even at current fertiliser prices, with no allowance for nutrients from organic manures. Additionally, there would be a limit as to how much concentrate / blend could be fed without the risk of digestive disorder.

4.2.2 Brewers Grains

The price quoted by KW Trident in the Farmers Weekly (updated 27/1/22) for Brewers Grains (20t bulk blown within 50 miles of store) was £50/t FW (£200/t DM).

The nutritional content of the product is 20-26% DM (25% assumed), 11.7 MJ ME/kg DM and 20-26% CP. It would cost £200 to replace 1 tonne of silage DM (4t FW @ 25% DM) with purchased Brewers Grains. This is still a significantly higher than the cost of production of grass silage although the financial value of the higher protein content hasn't been allowed for.

4.3 Reduce Whole Farm Stocking Rate

To reduce reliance on manufactured N applications, without purchasing additional feed, stocking rate across the whole farmed area would need to be reduced.

Figure 5 compares prices of all inputs to outputs (milk and meat) on dairy farms and shows that inputs and outputs have, generally, increased at a similar rate over the last 12 months.

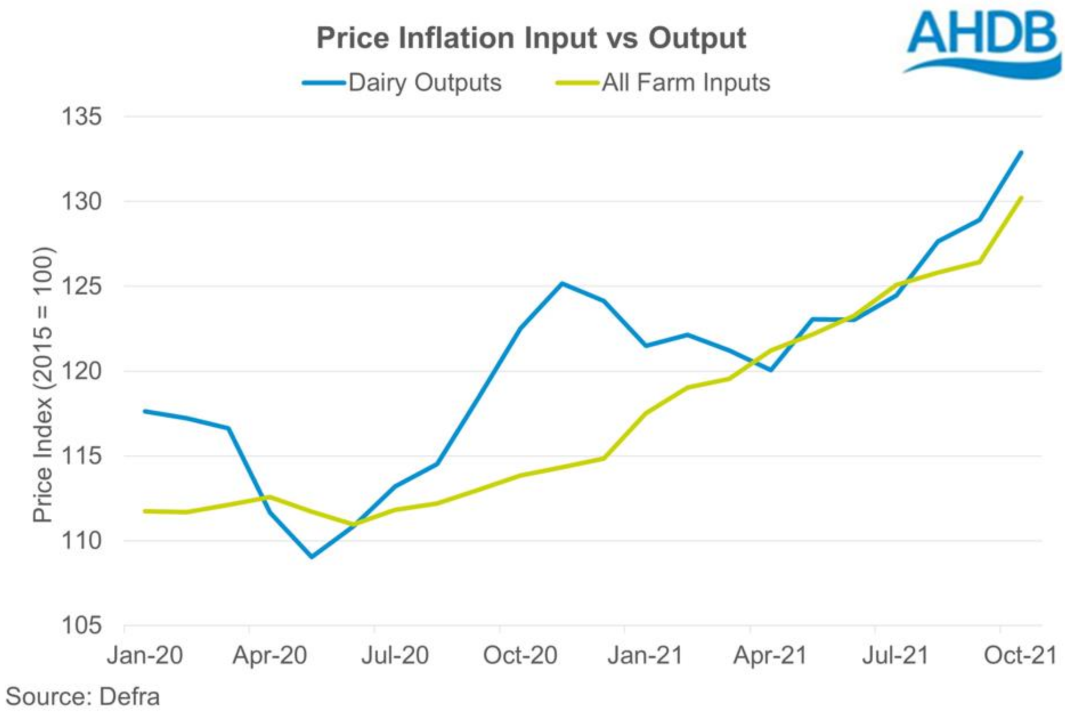

Figure 5. Dairy output and all farm input prices compared since January 2020.

While the cost per tonne of manufactured N fertiliser has increased, the value of beef and lamb sales from livestock farms is also significantly above the five-year average (Figures 6 and 7). The financial impact of any decision to reduce stocking rate to reduce N application would need to be calculated for the individual business but is unlikely to make financial sense at current output prices. Reducing turnover could reduce overall farm profit if fixed costs change little, even though variable costs would be lower. Additionally, livestock costs may be higher when restocking in the future.

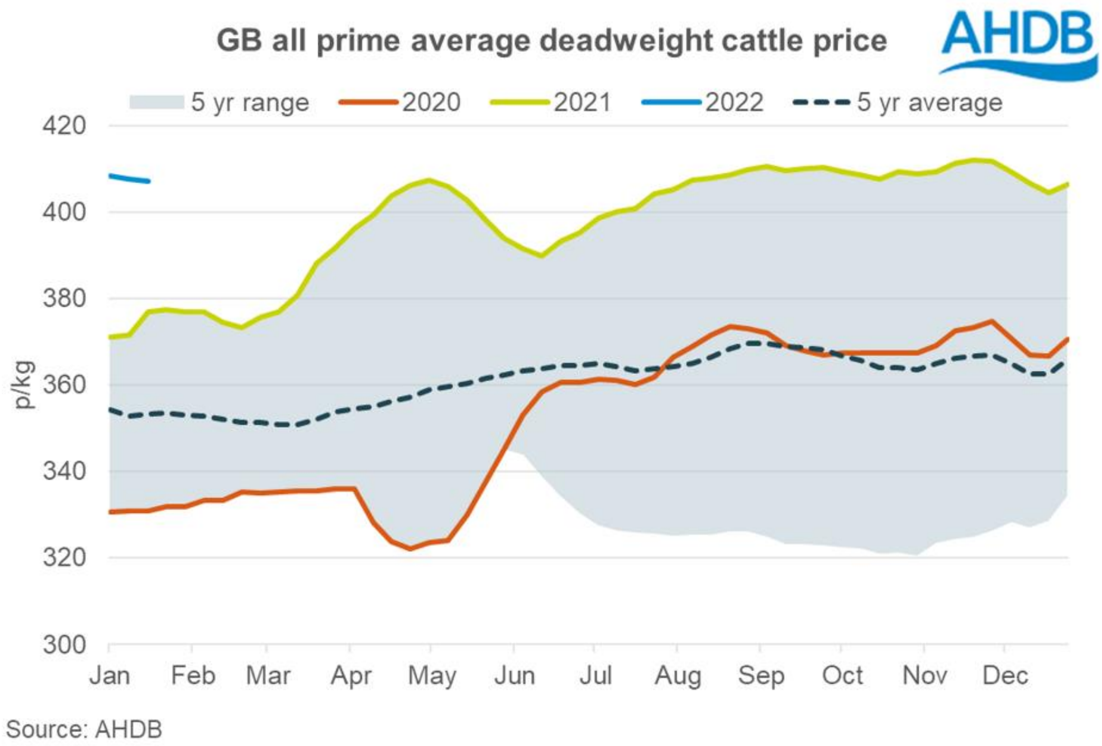

Figure 6. GB all prime average deadweight cattle prices for January 2020 to January 2022.

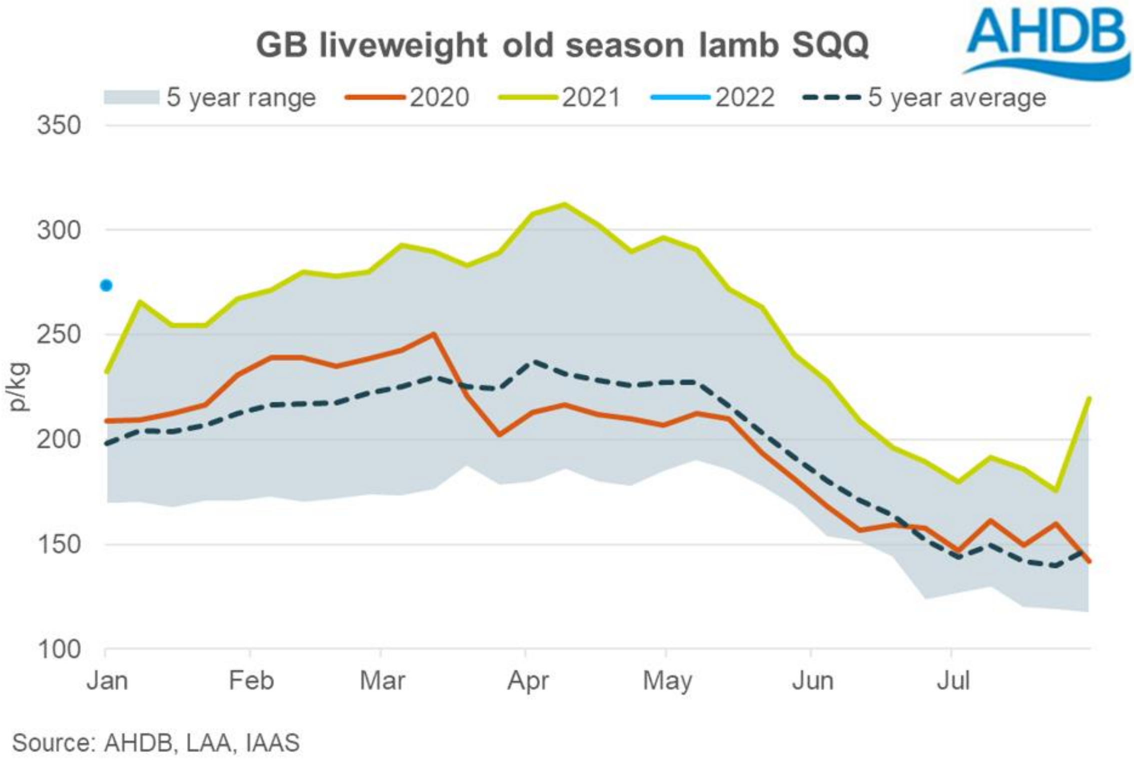

Figure 7. GB liveweight old season lamb SSQ for January 2020 to January 2022.

4.4 Increase Acreage of Conserved Forage Production

Increasing the acreage of conserved forage production (to compensate for lower N application and therefore yield) is unlikely to be justified, as it would reduce the availability of grazed grass, which is by far the cheapest feed produced on farm. Renting additional land area is highly unlikely to be economic unless optimum production is achieved.

Applying a lower rate of N on the area to be harvested for conserved forage would reduce the yield per hectare. To compensate for this the area allocated to cutting (silage production) would need to increase, to the detriment of available grazing, or alternative forage purchased. The forage cost calculations in Section 3 show that grazed grass is the cheapest available forage on the farm and unless alternative forage can be purchased for below £124/t DM (Appendix 1 - three cut silage cost/t DM) it is more cost effective to apply N, even at £650/t, particularly if quality is an unknown factor.

4.5 Impact of Reduced Nitrogen Application on Forage Quality

In high output systems, if manufactured N input on grassland is reduced for any reason there may be a small reduction in the grass quality of crude protein (CP) and/or neutral detergent fibre (NDF) content. However this may only occur in relatively few cases (2 or 3 sites in ten; Defra project IF01121).

A trial at North Wyke Research Station, Devon, found reductions in the CP content of fresh herbage cut from a perennial ryegrass dominant sward, averaged over 3 years, ranging from 15.1% CP at 400 kg N/ha annual input to 13.4% CP at Zero kg N/ha annual input (Sheldrick *et al*, 1990). At 200 kg N/ha annual input, 13.8% CP was measured. Little difference in digestibility (D-value) was measured between the three nitrogen inputs.

4.6 Can Variable Rate Nitrogen Application Help?

Any activity that leads to more precise consideration of N rates should be more worthwhile at high prices, including consideration of the least productive areas of the field, which may not warrant application of any manufactured N fertiliser.

Using variable rate N on a relative basis around a pre-set average rate shouldn't be affected by the price of fertiliser, assuming that the principles and factors for varying rates are sound (e.g. yield potential, previous nitrogen use, sward age, previous manure use and cutting history, i.e. factors that influence DM yield and soil nitrogen supply - SNS - on grassland). Early season grass growth can also be monitored using plate meters, vehicle mounted sensors, UAVs or satellite imagery, but a good understanding of how GGC (i.e. grass growth potential) varies within a field is also needed to interpret the data and adjust N application rates accordingly.

Any N fertiliser technologies that reduce losses of N to the environment will provide greater value when N fertiliser prices are high.

If using urea-based N fertiliser, which usually has a lower cost per kilogram or unit of N, consider using products that include a urease inhibitor. The N use efficiency of urea and urea ammonium nitrate (UAN) fertiliser products that include a urease inhibitor is likely to be greater than standard urea due to reductions in ammonia emission after application.

5 BEST PRACTICE WHEN APPLYING NITROGEN

5.1 Maximising Response from Nitrogen Applications

Well managed grass remains the lowest cost feed available for ruminant livestock. However, a wide variety of factors influence crop/grass growth including soil pH, availability of other nutrients, soil water, soil structure, solar radiation and the age/productivity of the sward. The high cost of manufactured nitrogen fertiliser makes it even more important to minimise the impact of other potentially limiting factors.

- Field conditions - make sure field conditions are right for grass growth – soil water availability, soil organic matter, soil temperature and drainage.
- Soil Structure - check for soil compaction and rectify if present: see AHDB Healthy Grassland Soils. Poached, rutted or compacted soils will dry, aerate and warm less quickly in the spring, delaying growth.
- Soil acidity and nutrient content - analyse fields every 3-5 years to make sure nutrient content and soil pH are optimal. Ensure soil pH is at or above 6.0 for grassland fields (5.3 for peaty soils). Ensure soil phosphorus levels are at Index 2 (16-25 mg/litre) or above, and soil potassium levels are at Index 2- (121-180 mg/litre) or above – ideally at least mid-range to allow for in-field variation. If soil P & K levels are low, apply organic manure or apply fertiliser to raise them.
- Sulphur - apply sulphur with nitrogen where deficiency is likely, especially in later cuts, on light soils or where high N rates are used.
- Prioritise 1st cut as this is when the best response to N input is seen.
- Grass Growth Class (GGC) describes the ability of the site to respond to nitrogen depending on soil type and summer rainfall. The better the GGC, the greater the efficiency of N use and the greater the DM yield response - prioritise fields which are the most responsive/productive

See the “Checklist for decision making”, “Adjusting nitrogen use throughout the season” and “Assessing Grass Growth Class” in the AHDB Nutrient Management Guide (RB209): Section 3: Grass and forage crops

5.2 Making Better Use of Organic Manures

Organic materials are valuable sources of crop available nutrients which can reduce the need for manufactured fertiliser applications to grow the desired amount of grass on farm. Applications need to be carefully managed to maximise their fertiliser value and minimise nutrient losses to the environment.

Understanding the nutrient content of organic materials and quantifying application rates are crucial for making best use of manure nutrients. The nutrient content of organic materials will depend on several factors. For livestock manures, the main determining factors include livestock type, feeding regime, diet, the amount of rainwater dilution that occurs during storage and the amount of bedding used. For digestates and composts, the source of the feedstock material is the key factor.

Typical figures for the nutrient content of livestock manure are available in AHDB’s Nutrient Management Guide (2020/2021). However, laboratory analysis can give a more accurate assessment of the nutrient content of organic manures available on an individual farm, provided a representative sample is taken.

Nutrients in livestock manures are present in two forms: (i) readily plant available forms, which are immediately available to the crop and are most at risk of loss to the environment and (ii) organic forms, which will only become available to the plant over time, following the mineralisation of organic matter in the soil.

5.2.1 Nitrogen

For manures with a high proportion of total nitrogen in the readily available form (e.g. slurries, poultry manures and digestates) applying them at times when grass is actively growing will increase the nitrogen use efficiency and reduce the risk of nitrate leaching.

Spreading liquid manures containing high concentrations of readily available N with precision application techniques such as band spreaders, trailing shoe spreaders and shallow injectors instead of conventional surface broadcast applications will reduce the risk of ammonia emission (nitrogen loss to the atmosphere), odour nuisance and sward contamination. Precision application techniques can therefore improve nitrogen supply to the sward and also allow liquid manures to be spread evenly across known bout widths.

5.2.2 Phosphate and Potash

Applications of solid manure typically apply more phosphate (P_2O_5) and potash (K_2O) than is taken off by a crop in a single harvest year. For example, a 40 t/ha application of cattle FYM will supply around 130 kg/ha of P_2O_5 and 376 kg/ha of K_2O. In comparison, a grass silage crop yielding 23 t fresh weight/ha will typically remove 40 kg/ha of P_2O_5 and 138 kg/ha K_2O. Consequently, it is important to target solid manure applications to fields with low P and K status, particularly those which are harvested for conserved forage, to maximise their nutrient value and reduce the risk of excessive soil P levels, which increase the risk of P losses to water.

5.2.3 Application Rates

Accurately quantifying application rates is crucial for maximising the nutrient value of organic materials. There are three factors that control application rate: (i) the rate that material is pumped or discharged from the spreader; (ii) the spreading or bout width; and (iii) the forward speed of the application equipment. For broadcast slurry and solid manure applications, it is important to match bout widths from different applications to ensure even application across the field. In Nitrate Vulnerable Zones, the maximum quantity of organic material that can be spread to a field in any 12-month period is equivalent to 250 kg total N/ha. Under the Farming Rules for Water, which apply in England, applications must not exceed 'soil or crop need'.

5.2.4 Accounting for Manure Nutrients when Planning Manufactured Fertiliser Applications.

Crop available nutrient supply from contrasting manure application timings and methods can be calculated using the MANNER-NPK decision support tool or by reference to AHDB's Nutrient Management Guide (RB209). It is important that the nutrients supplied by the manures are accounted for when calculating manufactured fertiliser application rates to ensure that grass growth is not excessive and the risks of nutrient losses to the environment are not increased. Nitrogen fertiliser applications should be adjusted for the year and season when the manures are applied. Phosphate and potash applications should be adjusted over several years. Table 4 gives the nutrients supplied by typical applications of a range of organic materials based on manure nutrient contents published in AHDB's Nutrient Management Guide (RB209). Slurries and digestates can usually be considered good sources of crop available nitrogen and solid manures supply proportionally more phosphate and potash than nitrogen. At current fertiliser prices, the fertiliser replacement value of spring applied cattle slurry is estimated to be worth £5.70/m3; cattle FYM £13.70/t; pig slurry £7.60/m3; pig FYM

£16.00/t; poultry manure £55.80/t; whole digestate £9.60/m3; and biosolids £16.90/t. The values have increased by c. 120% compared with 2020.

Table 4. Crop available nutrient supply and manufactured fertiliser replacement value from spring applied manures.

Manure type	Application rate t/ha	Crop available N* (kg/ha)	Total phosphate (kg/ha)	Total potash (kg/ha)	Value 2020 (£/ha)**	Value 2022 (£/ha)***
Cattle slurry	35	32	48	88	95	200
Cattle FYM	40	24	128	376	265	550
Pig slurry	35	69	53	77	112	270
Pig FYM	35	25	210	280	270	560
Poultry manure	8	67	136	168	205	450
Whole digestate	25	72	53	43	115	240
Biosolids	20	33	220	12	160	340

* Assumes spring application timing
** Assumes value of fertiliser N@ 65p/kg, P_2O_5@ 61p/kg and K_2O @45p/kg
*** Assumes value of fertiliser N@ £1.90/kg, P_2O_5 @ £1.20/kg and K_2O @ 93p/kg

6 LONG TERM STRATEGIES TO REDUCING NITROGEN USE

There is no clear indication at present regarding the future cost of manufactured fertilisers, and while output prices are high it currently makes economic sense to continue to purchase and apply manufactured N to optimise production. However, there are longer term strategies which can be implemented on livestock farms to reduce reliance on manufactured N. These could improve business resilience while also improving the sustainability of production and reducing a farm's carbon footprint.

6.1 Using Legumes in Grassland

Legumes, grown with grass or on their own, play an important role in providing highly nutritious forage and *free* nitrogen supply. All legumes share the ability to fix nitrogen from the air and make it available for plant growth. Legume-rich forage is therefore low cost as it requires little or no nitrogen fertiliser, although when grown with grass, a small, early-spring dose of N is recommended to stimulate grass growth before the legume begins to fix N. Legumes are also high in protein and because they are particularly relished by livestock for their high digestibility, improve animal performance. There are twelve legumes commonly used in UK grassland systems including the true clovers, the medics, sainfoin, bird's-foot trefoil and vetches. Bloat needs to be guarded against as it can lead to death, particularly when moved to grazing white clover but red clover also without a transition. Livestock should not be moved from bare pasture to a lush clover pasture and left to graze, particularly when it is damp and cold. Stock should be acclimatised slowly being introduced by day and removed over-night, with regular checks to pick up signs of bloat at an early stage. Some legumes, such as bird's-foot trefoil produce tannins, which are thought to reduce the incidence of bloat.

6.1.1 White Clover

White clover is the most popular forage legume. It differs from other clovers in having a stolon (or stem) that runs along the ground producing leaves and flower heads. Its stoloniferous nature makes it better suited for grazing than other legumes. It is long lasting and drought resistant and grows on nearly all soils. In common with most fodder legumes, it is best grown with grasses, which benefit from the N cycled, and increase total forage yield and produces a flexible sward that can be cut or grazed. Careful grazing management is required, particularly with sheep, which preferentially select clover and graze it out. For white clover-ryegrass swards there is likely to be some advantage in applying 50 kg N/ha for early grass growth.

The potential N supply from white clover is lower than for red clover and depends on the percentage clover leaf cover. Figure 8 (from AHDB Nutrient Management Guide) shows some examples of different white clover leaf cover levels and associated potential nitrogen supply.

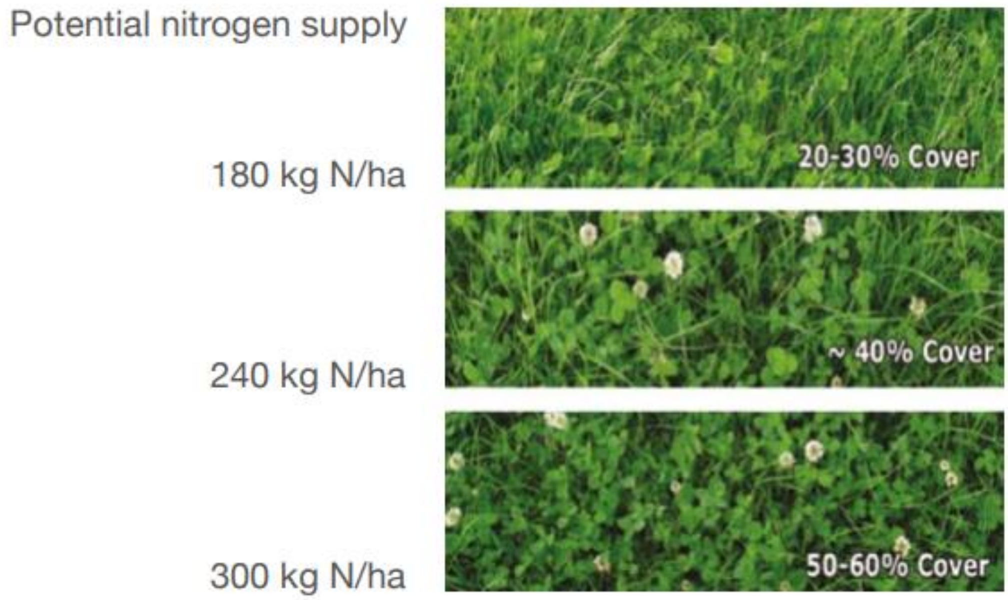

Figure 8 Percentage cover from clover

6.1.2 Red Clover

Red clover produces a third more yield than white clover but is less persistent, usually only lasting for between two and four years. It is normally used to produce high protein silage, although it can be grazed occasionally and finishes lambs well. It grows on nearly all soils including slightly acidic ones. A plant chemical compound, poly-phenol oxidase, in red clover is thought to provide animal performance benefits.

Red clover contains phyto-oestrogens that can cause concern to sheep farmers with regard to ewe fertility. Freshly grazed forage causes most concern, but the risk of a problem can be avoided by moving breeding animals off red clover around conception. An Innovative Farmers Field Lab is currently investigating whether modern varieties of clover grown in mixed swards have any negative effect on ewe fertility.

For red clover-ryegrass swards there is likely to be some advantage in applying 50 kg N/ha for early grass growth. Subsequently no N fertiliser should be required on red clover-ryegrass swards.

6.1.3 Lucerne

Lucerne is another high protein leguminous crop, which has no requirement for N fertiliser apart from that needed for establishment in low SNS soils. It produces up to 14 t DM/ha without N fertiliser and will persist for four years, if managed correctly, and is rich in vitamins and minerals, as are most legumes. If cut at the right stage it is low in fibre and high in energy, and in a dry summer it can outperform ryegrass or forage maize.

Lucerne can be quite slow to establish and is only suitable for free-draining land that is not acidic. It is not suitable for grazing cattle due to the incidence of bloat. It is often sown with a companion grass such as meadow fescue or timothy, which fill in the bottom of the crop and utilise cycled N in the soil. Lucerne is useful to dairy farmers wanting to produce a high protein silage that is complementary to maize. Chemical weed control options are now very limited, as they are for all legume crops.

6.1.4 Multi-species leys

These mixed leys are gaining in popularity in part due to their inclusion as option GS4 (Legume and Herb Rich Swards) in Countryside Stewardship Mid-Tier, which pays £358/ha per year for establishing a mixed sward that contains at least 5 species of grass, 3 species of legume (including bird's-foot trefoil) and 5 species of herb or wildflowers. The scheme prohibits the use of manufactured N fertiliser but not organic manures, such as slurry, and requires the sward to be shut up for 5 weeks in summer. Some farmers therefore prefer to manage multi-species swards outside a stewardship scheme as this gives them greater flexibility in the species they include and how they manage the sward.

As well as potentially providing additional income these mixed swards also have better drought resistance, promote biodiversity, create habitats, produce pollen and nectar and are also a top-quality forage. Bloat may become an issue if clovers become dominant.

The management challenges with these diverse swards include control of weeds (most of the legumes and herbs are not spray tolerant) and maintaining the sward diversity by avoiding over grazing or cutting too low when harvesting.

6.2 Rotational Grazing Systems

Implementing a rotational grazing system might be an alternative way to increase grass utilisation and therefore productivity without relying on manufactured fertiliser N. It may however require investment initially in improving farm infrastructure such as fencing and water provision. However, much depends upon the farm layout and the farmer's personal choice. Experiments at North Wyke and Wye College comparing rotational paddock grazing with continuous (not set stocking) grazing found no difference in animal performance as long as both systems were well managed. Rotational paddock grazing may be easier to manage, if a farm is suited to it, as it makes planning easier and it quickly becomes obvious when stock need to be moved.

For the three farms that completed the AHDB 'Grazing Beef Project' the overall stocking rate of the farms increased by an average of 64% over the three years of the project. This was achieved by splitting fields up and moving the cows every 2-3 weeks as opposed to set stocking. The farms both grew and utilised more grass. The AHDB booklet "Planning Grazing Strategies for Better Returns" also suggests the move from set stocking to rotational grazing will increase useable yield by 56%.

Effectively, many beef and sheep farmers would therefore find it more effective to move to rotational grazing rather than increase their spend on fertiliser. This may be different for the intensive dairy grazing farms as they may already be rotational grazing.

7 CONCLUSIONS

Based on current fertiliser and feed costs (and average current meat and milk output prices), the N recommendations for grassland in the May 2017 update and subsequent versions of RB209 (AHDB's Nutrient Management Guide) are still valid.

Grazed grass is still the cheapest form of forage available to grazing livestock farmers.

At most sites, during the growing season, grassland response to applied manufactured N fertiliser is at least 20 kg grass dry matter (DM) per kg of N fertiliser applied, as long as the weather is not too cold (less than 5 to 6^{o}C) or dry (soil moisture deficits in excess of 5 cm, depending on the soil type). Only sites with a Very poor Grass Growth Class (GGC) or with high sward clover content will not respond in this way.

Even on Very poor/Poor GGC sites (which can usually provide 10-20 kg grass DM per kg N applied), farmers would still be economically justified in applying 50-100kg N/ha per cut of grass (according to forage need) as long as the ammonium nitrate fertiliser price is below £700/tonne.

It therefore makes economic sense to purchase and apply manufactured N fertiliser as normal. Nevertheless, the reality for many livestock farmers is that the cashflow implications of the increasing cost of fertiliser means they are having to reduce the amount they use. If output and overall business profitability is to be maintained these businesses may have to consider implementing longer-term strategies to reduce reliance on manufactured N fertiliser.

Any N fertiliser technologies and precision spreading techniques that reduce losses of N to the environment will be of greater value when N fertiliser prices are high.

When manufactured N fertiliser are high it is particularly important to:

- Consider which fields will provide the best response to applied manufactured N fertiliser. These will be the least droughty fields with target levels of phosphorus and potassium nutrients, good organic matter and at target soil pH.
- Consider the least productive areas of a farm or field where it may not make sense to apply N fertiliser.
- Minimise the impact of all potential limiting factors such as field conditions at the time of application, soil structure, soil pH, soil nutrient reserves and sulphur supply.
- Make best use of livestock and other manures available to the farm by knowing what nutrients are in the manure and how much you are applying. Get manures sampled and analysed and use the MANNER-NPK software tool to estimate manure nutrient supply based on how much is spread and when and how it is spread.
- Undertake nutrient management planning for each field. Once done it is likely to be a repeat exercise in following years. It is also a requirement of the Farming Rules for Water legislation.
- For grass silage, maximise the potential of first cut when grass growth is at its peak and soil water availability is usually good for most soil types.
- Estimate the likely quantity of first cut to enable a judgement to be made regarding further fertiliser purchase for subsequent cuts.
- Consider the local availability of other feedstuffs that could be fed to livestock with lower protein or energy demands (e.g. dry cows) while keeping your better-quality silage in reserve.
- Consider using clover or other legumes in the sward to reduce future reliance on manufactured N fertiliser.
- Consider using rotational grazing methods to improve grass utilisation.
- Consider adjusting stocking rates to match the *carrying capacity* of the land and any anticipated changes to the farming system.

8 REFERENCES

AHDB (2021) Nutrient Management Guide (RB209).

AHDB (2016) 'Planning Grazing Strategies for Better Returns' Beef and Sheep BRP Manual 8

AHDB website www.ahdb.org.uk

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APPENDIX 1 COST BENEFIT ANALYSIS

Analysis of cost benefit of applying 1kg N to produce grazed grass at a range of response rates and fertiliser prices.

Cost benefit over 1.0 means the relative feed value is greater than the cost of growing it (if reduced grass growth is replaced by concentrate equivalent)

Assumptions
Blend = £260/t @ 86% DM = £302.33/t DM equivalent
Grass = 11.3MJ ME/kg DM, 80% utilisation rate
Fertiliser spreading cost of £12/ha x 4 applications to apply 250kg/ha N = £0.19/kg

Response Rate of 30kg DM grass/kg N applied			
£/t 34.5% N	£/kg N	DM grass £	Cost benefit
250	0.9146	7.248	7.924
350	1.2045	7.248	6.017
450	1.4943	7.248	4.850
550	1.7842	7.248	4.062
650	2.0741	7.248	3.495
750	2.3639	7.248	3.066
850	2.6538	7.248	2.731

Response Rate of 20kg DM grass/kg N applied			
£/t 34.5% N	£/kg N	DM grass £	Cost benefit
250	0.9146	4.832	5.283
350	1.2045	4.832	4.012
450	1.4943	4.832	3.234
550	1.7842	4.832	2.708
650	2.0741	4.832	2.330
750	2.3639	4.832	2.044
850	2.6538	4.832	1.821

Response Rate of 10kg DM grass/kg N applied			
£/t 34.5% N	£/kg N	DM grass £	Cost benefit
250	0.9146	2.416	2.641
350	1.2045	2.416	2.006
450	1.4943	2.416	1.617
550	1.7842	2.416	1.354
650	2.0741	2.416	1.165
750	2.3639	2.416	1.022
850	2.6538	2.416	0.910

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APPENDIX 2 FORAGE COST CALCULATOR (NO MANURES)

Forage cost calculator

Crop Type	Grazing (12-15kg DM)	1st Cut grass silage	1 cut silage/graze	3 cuts grass silage	*Maize silage*	*Wholecrop*	Perm Pasture (6-8kg DM)
Crop Life (years)	10	5	7	5	1	1	
Establishment	**£ / Ha**	**£ / Ha**	**£ / Ha**	**£ / Ha**	***£ / Ha***	***£ / Ha***	**£ / Ha**
Seed	168	144	144	144	190	68	
Fertilisers	106.5	106.5	106.5	106.5	323.75	575.8	
Lime	72	72	72	72	72	72	72
Sprays	26	26	26	26	45	170	
Labour & Machinery:							
Cultivations	140	140	140	140	140	140	
Sowing	34	34	34	34	51	50	
Fertilising	12	12	12	12	24	24	
Spraying	13	13	13	13	26	52	
Total Establishment Cost	572	548	548	548	872	1,152	72
Establishment cost per year	57	110	78	110	872	1,152	7
Production	**£ / Ha**	**£ / Ha**		**£ / Ha**	***£ / Ha***	***£ / Ha***	**£ / Ha**
Fertilisers	537	387.2	658.2	831.4			176
Sprays	10	10	10	10			5
Labour & Machinery:							
Fertilising	60	12	60	60			24
Spraying	12	0	12	12			6
Harvesting	0	167	167	471	187	182	0
Total Production Cost	619	576	907	1,384	187	182	211
Rent	250	125	250	250	321	321	200
Total forage cost per year	**926**	**811**	**1235**	**1744**	**1380**	**1655**	**418**
Tonnes FW produced per Ha	70	23	45	50	40	30	40
Dry Matter %	18%	30%	25%	25%	30%	45%	18%
Tonnes DM produced per Ha	**12.6**	**6.9**	**11.25**	**12.5**	**12**	**13.5**	**7.2**
Cost per tonne DM	**£ 74**	**£ 117**	**£ 110**	**£ 140**	**£ 115**	**£ 123**	**£ 58**
Cost per tonne fresh	**£ 13**	**£ 35**	**£ 27**	**£ 35**	**£ 34**	**£ 55**	**£ 10**

Assumptions

Value	Assumption	
Establishment		
Seed	37kg/ha rate, 1-2yr ley £108/ha, 3-5yr ley £144/ha, 5+ yr ley £168/ha	
Fertilisers	Fertiliser rates: Grass: 50kg P, 50kg K/ha; Maize: 50kg N, 55kg P, 175kg K/ha; Wholecrop: 190kg N, 55kg P, 160g K/ha;	N=190p/kg, P=120p/kg, K=93p/kg.
Lime	2.4t/ha (1t/acre)	£30/tonne delivered and spread
Sprays		
Labour & Machinery:		
Cultivations	Contractor cost; Ploughing (£65/ha), Spring tine harrowing (£40/ha), pressing (£35/ha)	
Sowing	Contractor cost; Grass seeding with harrow (£34/ha)	
Fertilising	Contractor cost (£12/ha) - 2 applications for maize/w'crop	
Spraying	Contractor cost; 200l/ha and 24m boom (£13/ha)	
Production		
Fertilisers	Grazing (12-15t DM/ha): 270kg N, 20kg P/ha	N=190p/kg, P=120p/kg, K=93p/kg.
	One cut silage (12-15kg DM/ha high SNS): 110kg/ha N, 40kg P, 140kg K/ha;	
	One cut silage/graze (12-15kg DM/ha high SNS): 240kg N, 60kg P, 140kg K/ha	
	Three cuts grass silage (12-15kg DM/ha high SNS): 250kg N, 80kg P, 280kg K	
	Permanent Pasture Grazing (6-8kg DM/ha): 80kg N, 20kg P	
Sprays	MCPA	
Labour & Machinery:		
Fertilising	£12/application x four	
Spraying	Contractor cost; 200l/ha and 24m boom (£13/ha)	
Harvesting	£167/ha first cut gras silage, remaining cuts £152/ha - pit	
Rent	£100/ac grass, £130/ac arable, £81/ac PP	

Sources

Defra Fertiliser Manual (RB209)
Nix farm management pocketbook, 52nd edition, 2022

Disclaimer

These values are averages used to illustrate the costs of different forage types, they are not to be used as guidance for conducting the specified tasks and will vary considerably.

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APPENDIX 3 FORAGE COST CALCULATOR (MANURES APPLIED)

Forage cost calculator

Crop Type	Grazing (12-15kg DM)	1st Cut grass silage	1 cut silage/graze	3 cuts grass silage	*Maize silage*	*Wholecrop*	Perm Pasture (6-8kg DM)
Crop Life (years)	10	5	7	5	1	1	-
Establishment	**£ / Ha**	**£ / Ha**	**£ / Ha**	**£ / Ha**	***£ / Ha***	***£ / Ha***	**£ / Ha**
Seed	168	144	144	144	190	68	
Fertilisers	21.6	21.6	21.6	21.6	88.1	332.5	
Lime	72	72	72	72	72	72	72
Sprays	26	26	26	26	45	170	
Labour & Machinery:							
Cultivations	140	140	140	140	140	140	
Sowing	34	34	34	34	51	50	
Fertilising	42	42	42	42	48	99	
Spraying	13	13	13	13	26	52	
Total Establishment Cost	517	493	493	493	660	984	72
Establishment cost per year	52	99	70	99	660	984	7
Production	**£ / Ha**	**£ / Ha**		**£ / Ha**	***£ / Ha***	***£ / Ha***	**£ / Ha**
Fertilisers	537	215.35	486.35	502.9			176
Sprays	10	10	10	10			5
Labour & Machinery:							
Fertilising	60	88.5	136.5	213			24
Spraying	12	0	12	12			6
Harvesting	0	167	167	471	187	182	0
Total Production Cost	619	481	812	1,209	187	182	211
Rent	250	125	250	250	321	321	200
Total forage cost per year	**921**	**704**	**1132**	**1557**	**1168**	**1487**	**418**
Tonnes FW produced per Ha	70	23	45	50	40	30	40
Dry Matter %	18%	30%	25%	25%	30%	45%	18%
Tonnes DM produced per Ha	**12.6**	**6.9**	**11.25**	**12.5**	**12**	**13.5**	**7.2**
Cost per tonne DM	**£ 73**	**£ 102**	**£ 101**	**£ 125**	**£ 97**	**£ 110**	**£ 58**
Cost per tonne fresh	**£ 13**	**£ 31**	**£ 25**	**£ 31**	**£ 29**	**£ 50**	**£ 10**

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Assumptions

Value	Assumption	
Establishment		
Seed	37kg/ha rate, 1-2yr ley £108/ha, 3-5yr ley £144/ha, 5+ yr ley £168/ha	
Fertilisers	Manure applied; Grass 10t/ha cattle FYM, Maize 12t/ha & W'crop 25t/ha cattle FYM	N=190p/kg, P=120p/kg, K=93p/kg.
	Fertiliser rates: Grass: 18kg P/ha; Maize: 35kg N/ha & 18kg/ha P; Wholecrop: 175kg N/ha	
Lime	2.4t/ha (1t/acre)	£30/tonne delivered and spread
Sprays		
Labour & Machinery:		
Cultivations	Contractor cost; Ploughing (£65/ha), Spring tine harrowing (£40/ha), pressing (£35/ha)	
Sowing	Contractor cost; Grass seeding with harrow (£34/ha)	
Fertilising	Contractor cost (£12/ha) plus £3/t for FYM spreading	
Spraying	Contractor cost; 200l/ha and 24m boom (£13/ha)	
Production		
Fertilisers	Grazing (12-15t DM/ha): 270kg N, 20kg P/ha (no manures)	N=190p/kg, P=120p/kg, K=93p/kg.
	One cut silage (12-15kg DM/ha high SNS): 79kg/ha N, 4kg P/ha, 65kg K/ha (30m3/ha 6%DM slurry band spread in March)	
	One cut silage/graze (12-15kg DM/ha high SNS): 209kg N, 24kg P, 65kg K/ha (30m3/ha 6%DM slurry band spread in March)	
	Three cuts grass silage (12-15kg DM/ha high SNS): 196kg N, 8kg P, 130kg K (30m3/ha 6%DM slurry band spread in March & June)	
	Permanent Pasture Grazing (6-8kg DM/ha): 80kg N, 20kg P (no manures applied)	
Sprays	MCPA	
Labour & Machinery:		
Fertilising	£12/application x four plus slurry @ £2.55/m3 (£76.50 per application)	
Spraying	Contractor cost; 200l/ha and 24m boom (£13/ha)	
Harvesting	£167/ha first cut gras silage, remaining cuts £152/ha - pit	
Rent	£100/ac grass, £130/ac arable, £81/ac PP	

Sources

Defra Fertiliser Manual (RB209) - tables used to calculate nutrients from manures

Nix farm management pocketbook, 52nd edition, 2022

Disclaimer

These values are averages used to illustrate the costs of different forage types, they are not to be used as guidance for conducting the specified tasks and will vary considerably.