Grazing management to increase N use efficiency

Michael O'Donovan, Elodie Ruelle and Michael Egan

Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork

Summary

- Nitrogen use efficiency can be improved on all dairy farms
- More targeted use of nitrogen can help farmers make better grassland management decisions
- Spring slurry applications should be used to reduce the input of chemical nitrogen fertiliser
- Research has clearly shown the advantages of incorporating white clover in grassland swards to reduce nitrogen fertiliser requirement and to increase animal production and nitrogen use efficiency
- In swards with 20–25% white clover, nitrogen fertiliser can be reduced by 50–100 kg N/ha
- Avoid spreading excess nitrogen fertiliser on silage ground. Apply slurry, where available, using LESS and reduce chemical fertiliser N application according.

Introduction

Enhanced grazing management has the potential to yield further improvements in milk production efficiency and nitrogen (N) use efficiency (NUE). National statistics reveal clear evidence of increasing production efficiencies on dairy farms in recent years through a combination of farm management practices allied with accelerated genetic improvement within the national herd.

Ireland faces significant challenges in meeting national and international environmental targets with regard to greenhouse gas (GHG) emissions, air quality, biodiversity and water quality. The Teagasc Marginal Abatement Cost Curve (MACC) has set 26 actions that farmers can use to cut GHG emission levels by 10–15% by 2030 relative to 2017 levels. The European Green Deal, Farm to Fork Strategy identifies an urgent requirement to reduce dependency on pesticides and antimicrobials, reduce chemical fertiliser use, improve animal welfare and reverse biodiversity decline in food production systems. Over the next 10 years, the Ag Climatise roadmap has set a target of an absolute reduction in the overall level of N fertiliser used on Irish farms from a high of 408,000 tonnes in 2018 to 325,000 tonnes in 2030, with an interim target of 350,000 tonnes in 2025 (14% reduction from 2018–2025).

Grassland productivity is highly dependent on the supply of plant available N from the soil. The sources of this N includes chemical fertiliser, organic fertiliser (slurry, farmyard manure, dung and faeces deposition by grazing livestock), mineralisation of N in the soil organic matter and biological N fixation by legumes, including white clover.

The N loss pathways of primary concern to the dairy industry are nitrate leaching and emissions of nitrous oxide and ammonia (NH_3). The concentration of nitrate in water bodies in recent decades has been a cause of concern because of the perceived potential threat to human health, as well as the ecological and aesthetic consequences of eutrophication. The paper focuses on increasing the NUE of pasture-based dairy production systems to minimise the environmental impact without negatively affecting the economic viability.

What is nitrogen use efficiency?

There are a number of sources of N at farm level including:

- Organic N or slurry N produced by the cow (approximately 5,000 litres of slurry per cow per year), as well as dung and urine patches deposited directly on to the paddock by grazing livestock
- Chemical N fertiliser purchased on to the farm
- Concentrate or other feed purchased on to the farm
- Background soil N — this is the N mineralised from the organic matter in the soil. The rate supplied by the soil depends on soil type and weather conditions, and there is strong year-to-year variation in the quantities released from the soil
- Nitrogen fixed from the atmosphere by white clover and available for plant growth.

Farm gate NUE is the efficiency with which the N entering the farm (feed, fertiliser and replacement livestock) is utilised on the farm and converted into product sold from the farm (milk, cull cows, calves). National Farm Survey data shows that farm gate NUE is approximately 24% in Ireland. This can be improved considerably and the more efficient farms have an NUE of >35%. Recent research clearly shows significant increases in NUE under improved grazing management (up to 40%) and the inclusion of white clover in swards NUE can increase NUE to 55–60%.

Increasing N use efficiency on farm

Grazing management

Nitrogen use efficiency on grassland farms can be improved with greater use of grass measurement and better grassland management decisions. Informed decision making based on knowledge of current average farm cover and predicted grass growth rates can result in a more efficient use of N fertiliser. The average grass DM production on dairy farms using PastureBase Ireland over the past seven years (2013–2019) is 13 t DM/ha, with an average of 263 grazing days per year. National farm survey data indicates that the national average DM production on dairy farms is just over 10 t DM/ha. There are further gains to be made in increasing DM production on farms through better spring management, use of PastureBase Ireland to help with grassland management decision making, earlier turnout in spring and the incorporation of white clover into grassland swards. Over the last year, a Nitrogen Planner has been incorporated into PastureBase Ireland, to improve N use efficiency on grassland farms. At the beginning of the grazing season, a grassland farmer can plan his/her N application strategy over the coming grazing season. The Nirogen Planner can then be populated over the grazing season with actual N application. Therefore, an up-to-date comparison between actual N applied to that planned at the start of the season can be viewed during the grazing season.

Low emissions slurry spreading (LESS)

Slurry is an important source of nutrients (N, P and K) on grassland farms and application to grassland must be appropriately timed to maximise the efficiency of nutrient capture and utilisation, as well as replenishing soil fertility levels. The targeted application of slurry in spring, based on soil test results, will ensure the most efficient use of slurry nutrients for grass production and minimize potential ammonia losses. Slurry N losses in the form of ammonia emissions are potentially the largest loss of reactive N on Irish farms. There is a 50% increase in the availability of N for grass growth when it is applied by trailing shoe compared to splash plate (Table 1). Slurry N is also more available in spring compared to summer (Table 1). To achieve the best use of the slurry N available on farm, it should be spread in spring using LESS techniques (e.g. trailing shoe or dribble bar).

Table 1. Availability of N in 1,000 gallons of slurry applied using splash plate or trailing shoe in spring and summer				
	Splash plate		Trailing shoe	
	Spring	Summer	Spring	Summer
Available N (kg/ha)	6	3	9	6

Protected urea fertiliser

Recent studies have shown that protecting urea with a urease inhibitor reduces ammonia loss to the environment by 80%. Moorepark research has shown that there is no difference in herbage production between protected urea and CAN under repeated cow grazing studies. See elsewhere in this publication for more information on the effect of protected urea compared to CAN on herbage production. Protected urea can also help reduce N losses to water by holding N in the ammonium form, which is more stable in soil particularly during wet conditions.

Reducing concentrate crude protein content

The crude protein (CP) content of a feed depends on the N in that feed. On average, Irish dairy cows have a requirement for a diet with a CP content of 15–17%. High quality grazed pasture has a CP content of approximately 18% during the grazing season. Several studies have been completed during the last 10 years and have shown no benefit from feeding rations with high CP content (>16%) at pasture, as grazed grass alone can meet animal requirements for CP. Feeding high CP content concentrates during the grazing season results in excess N in the dairy cow diet. The cow has to expend energy to excrete this excess N, usually in urine resulting in high N content urine patches in grazed grassland. Reducing concentrate CP content will reduce both N surplus in the dairy cow diet and N loss to the environment. Using concentrates with a CP content of 12–14% is recommended when cows are grazing fulltime.

Increasing soil fertility

Increasing soil fertility (pH, P and K) increases NUE as it increases the availability of plant available N in the soil and increases the persistency and density of productive species (e.g. perennial ryegrass) in the sward. This will result in the production of greater quantities of grass at the same N application rate. More frequent soil fertility testing and greater use of nutrient management planning will increase NUE on grassland farms.

The role of white clover

White clover is included in perennial ryegrass mixtures to improve sward nutritive value for animal production and reduce N fertiliser use. Managing grassland with less chemical N fertiliser inputs and with greater reliance on biological N fixation by white clover can reduce costs (less chemical N fertiliser), reduce GHG emissions, and increase herbage quality and digestibility.

Results from recent research investigating the incorporation of white clover into perennial ryegrass swards at Teagasc, Moorepark and Teagasc, Clonakilty Agricultural College have shown the potential of perennial ryegrass-white clover swards to increase the productivity and profitability of Irish grazing systems. Pasture production was increased by 8% at Clonakilty when white clover was included in the sward (at a similar N fertiliser rate of 250 kg N/ha). At Moorepark the perennial ryegrass-white clover swards receiving 150 kg N/ha grew similar levels of herbage to the perennial ryegrass-only swards receiving 250 kg N/ha. Perennial ryegrass-white clover swards tend to be higher quality in mid-season compared to grass-only swards as sward white clover content increases from May onwards. Moorepark and Clonakilty research both show up to a 10% increase in milk and milk solids (kg fat + protein) production from perennial ryegrass-white clover swards compared to perennial ryegrass-only swards (Table 2).

Table 2. Effect of white clover inclusion on pasture production, milk and milk solids yield in Teagasc Moorepark (2013–2016) and Teagasc Clonakilty (2014–2017) grazing experiments			
Teagasc Moorepark experiment	Grass-only 250 kg N/ha	Grass-clover 250 kg N/ha	Grass-clover 150 kg N/ha
Pasture production (t DM/ha)	13.7	14.0	13.7
White clover content (%)	-	23	27
Milk yield (kg/cow)	6,108	6,498	6,466
Milk solid yield (kg/cow)	460	496	493
Teagasc Clonakilty experiment	Grass-only 250 kg N/ha	Grass-clover 250 kg N/ha	
Pasture production (t DM/ha)	15.6	16.8	
White clover content (%)	-	23	
Milk yield (kg/cow)	5,222	5,818	
Milk solid yield (kg/cow)	437	485	

The existence of white clover is not widespread on grassland farms in Ireland, and its persistence may be problematic on heavier soils. Establishing white clover, in sufficient quantities, i.e. an annual sward white clover content of 20–25%, on dairy farms remains a big challenge. Improved methods of sowing and management at and after sowing are required for establishment. Excellent grazing management is required to maintain high levels of white clover in pastures. While this is taken for granted, grazing management is generally one of the main reasons for poor persistence of white clover on farms. Further work is required to increase the persistency of white clover at farm level and encourage greater adoption.

What can farmers do to increase nitrogen use efficiency on their farms?

The following are the key strategies all farms can use to increase NUE on their dairy farm:

- Apply slurry in spring using LESS
- Limit and control concentrate use by increasing grass quality and supply through improved grassland management. Use a lower CP concentrate
- Measure grass weekly and plan N fertiliser applications based on current farm cover and predicted grass growth
- Plan N applications on a paddock by paddock basis (use the Nitrogen Planner in PastureBase Ireland)
- Incorporate white clover into the swards. Target 20–25% annual white clover content across the farm
- Optimise the use of soiled water on paddocks and reduce chemical N fertiliser accordingly
- Manage N better on silage ground to avoid over use. Apply slurry, where available, using LESS and reduce chemical fertiliser N application accordingly
- Quantify the nutrient composition of the slurry on your farm annually.

Grazing management to improve nitrogen use efficiency

Spring management

There is always an element of debate around the right approach for spring N fertiliser application. This usually hinges around the knowledge that N applied in early spring is normally utilised less efficiently in terms of kg of grass DM grown per kg of N applied (average response of 10–12 kg DM/kg N applied in spring compared to 21 kg DM/hg N applied in summer). The high value associated with grass availability in early spring means that even relatively small additional quantities of grass can make a big contribution to the overall feed budget.

Applying N in spring in a way that maximises the response is important both to ensure a good return on investment, and to minimise potential losses of N to water or as gaseous emissions. Improving the efficiency of N use during this period provides a major opportunity to improve the environmental credentials associated with N use.

Early spring growth is influenced by the genetic capacity within the sward to respond the N fertiliser applied. Newer swards with high perennial ryegrass content are more likely to respond to N fertiliser application than older swards. Soil factors driven by soil texture in combination with weather also influence the response to N fertiliser application. Colder soils are slower to respond to fertiliser N application. The general guidance is to apply the first N fertiliser when soil temperatures are 5–6°C and rising. Avoid applying N fertiliser immediately before heavy rainfall. Likewise, soil drainage plays a big role as land that is more prone to waterlogging and poor trafficability for extended periods in spring is less likely to respond to early N fertiliser. Drier soils are more likely to respond to N, but are also more at risk of N leaching.

The response to N fertiliser in spring and the risk of N leaching are highly variable depending on year due to different weather patterns. Modelling work conducted at Moorepark shows that, depending on the year, the N response to early N fertiliser application varies from 7.4 kg DM per kg N applied in a year like 2014 to 17.4 kg DM per kg N applied in a year like 2012. The corresponding N leached (at 1 m depth) due to an early N application of 30 kg of N/ha was 12 kg N/ha and 4.5 kg N/ha, in 2014 and 2012, respectively. This highlights the need to move to more informed and precise N fertiliser application based on current weather conditions, weather forecast and predicted grass growth.

Key guidelines for spring N fertiliser usage

- Target fields/paddocks that are most likely to respond to early N application — high perennial ryegrass content/recently reseeded, drier, free draining paddocks
- Paddocks with a grass cover of >400 kg DM/ha
- Paddocks with optimum soil fertility, i.e. Index 3 for P and K, pH > 6.3
- Replace chemical N fertiliser on approximately 60% of the farm with slurry. Target slurry applications to fields with low P and K levels and low grass covers. 25 m³/ha (2,500 gals/ac) applied using LESS will supply ~25 kg/ha (20 units/ac) of available N
- Use protected urea
- Apply up to 29 kg N/ha (23 units N/ac) in the first split in late January or early February to area that has not received slurry
- Link early N application strategy with spring feed budget for the farm
- Only apply N if soil temperature are higher than 5°C and rising and no/low rainfall is forecasted for the coming days
- On wetter/heavier soils, the application dates should be delayed 3–4 weeks.

Mid-season management

The primary objective during the main grazing season is to maintain high animal performance from a high quality all-grass diet. In general, from late April onwards, grass supply exceeds demand, and pre-grazing herbage mass should be maintained at 1,300–1,600 kg DM/ha, with a grazing residual of 50 kg DM/ha (4 cm post-grazing height). Excellent pasture quality is required to maximize the potential animal performance from pasture in summer. From mid-April to mid-August, farm cover should be maintained between 150–180 kg DM/cow with a rotation length of 18–21 days. The aim in that period is to achieve six grazing rotations and utilise 8,000 kg DM/ha. Paddocks with surplus grass should be removed as baled silage as soon as possible to maintain grass quality.

In mid-season, when grass growth exceeds herd demand, careful consideration of N fertiliser application strategies is important. In planning N fertiliser in mid-season it is important to know what grass you have on the farm and how much grass you need. Key to this is utilising all available information including:

- How much grass do you need (herd demand)?
- How much grass is currently on the farm (average farm cover)?
- What grass growth is predicted (MoSt Grass Growth Model)?
- Is there slurry available? If there is apply using LESS
- What is/are the weather forecast/growing conditions — consider soil N mineralisation. Mineralisation increases with increasing soil temperature once there is adequate soil moisture (rainfall)
- Is N available from N fixation (is white clover present on the farm)?
- Are you making bales in every rotation, particularly in July and August? If you are there is too much grass on the farm and there is a great opportunity to reduce N fertiliser application.

Mid-season N fertiliser applications generally result in a high grass growth response (≈ 20–35 kg DM/kg N applied on average), provided conditions are optimum. In periods of high soil moisture deficits (low/no rainfall or drought) the response to N fertiliser is much reduced; there is little point to applying N when grass growth is <30 kg DM/ha/day. Applying N fertiliser could lead to excessive N loss when rainfall occurs. Post drought (high soil temperatures and increasing soil moisture content), there is a large release of soil N which negates the requirement to restart N fertiliser application until grass supply returns to excess on the farm.

Autumn management

Autumn closing date is the main management factor influencing grass supply in early spring. To ensure that adequate quantities of grass are available at the start of calving on highly stocked farms, an average farm cover of 650–750 kg DM/ha is required on 1st December (at closing). Farmers must calculate their own spring grass demand, and implement an autumn closing strategy to facilitate the required opening spring farm cover. The final decisions regarding closing strategy also require some consideration of the expected grass growth over the winter period (i.e. average of previous five years). Typically, the grazing rotation length is extended from mid-August (+2 days/week) to allow for large quantities of herbage to be accumulated prior to the decline in grass growth to facilitate the extension of the grazing season for the final rotation. Any surplus paddocks should be removed in early August. Removing paddocks from the rotation for bales after the first week of September should be avoided, if possible, as harvesting this late in the year results in slow regrowth's. By achieving the right average farm cover at the right time, grazing decisions are easier to make. Average farm cover must be increased from mid-August with peak cover achieved in late September (≈1,100 kg DM/ha). Achieving this will reduce supplementation requirement for the remainder of the grazing season and ensure that

average farm cover is not reduced below 650–700 kg DM/ha at closing. Disappointingly, many farms do not build up enough grass in the autumn, resulting in high levels of supplementation in September and October and a shorter grazing season period, both of which have a negative impact on NUE.

As grass growth reduces from September onwards, the capacity of the sward to utilise N reduces steadily. Any N not used by grass in autumn is susceptible to leaching over autumn, winter and even spring, particularly in free draining soils. Ensuring that good N fertiliser management is practiced in late summer/early autumn is of critical importance to ensure adequate grass available on farm for the extension of the grazing season while minimising N losses.

Conclusion

Significant changes to how grass is managed inside the farm gate are required to maintain the current levels of DM production in a scenario where N fertiliser allowances are reduced. Developing N fertiliser management plans, more grassland measurement and better grassland management, making better use of slurry, and incorporating white clover on farm can all contribute to reduce N fertiliser use, maintenance of herbage production, improved herbage quality and an increase in farm NUE.