Practical grazing for ruminants

A nutritionists perspective

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Overview

- Background on pasture based dairy production systems
- Factors affecting the nutritional characteristics of swards
- Concentrate supplementation and substitution rate
- Management of early postpartum dairy cow at pasture
- Metabolic disorders of grazing dairy cows
- Environmental issues
- Summary and conclusions

Background

- Conversion of human-indigestible forage fractions, principally cellulose, to utilisable protein is the key contribution of ruminant production systems to global human food production
- In recent years, increased world demand for food and a continual increase in input prices has resulted in increased focus on grass-based systems of production.
- ‘Pasture-based’ production systems frequently includes farmers whose system is built around maximising milk from grazed grass, using fertiliser inputs; farmers who grazed but also used bought in feed to maximise milk yields; and extensive, low input grass-based farmers.
- In Ireland and other temperate regions, intensive grass-based milk production systems generally rely on inputs of nitrogen (N) in the form of chemical fertilizer to produce sufficient herbage (grazed grass or grass silage), and strategic concentrate supplementation during times of herbage deficit, to sustain milk output per hectare (ha) at economically viable levels.
- One of the main challenges is to balance stocking rate (SR), so that high levels of milk production per cow are achieved while maintaining high levels of pasture utilization per ha
- The optimum SR is that which gives the maximum sustainable profitability per ha. Consequently, to improve production per cow or per ha, better control of herbage growth, through improved grazing management, and prediction of herbage growth, are critical challenges for pasture-based dairy producers (Wilkinson et al., 2020).
- Farmer interviewees who built their system around grazed grass often receive their advice from outside the UK and felt they were marginalised in the UK dairy sector (James Hutton Institute)

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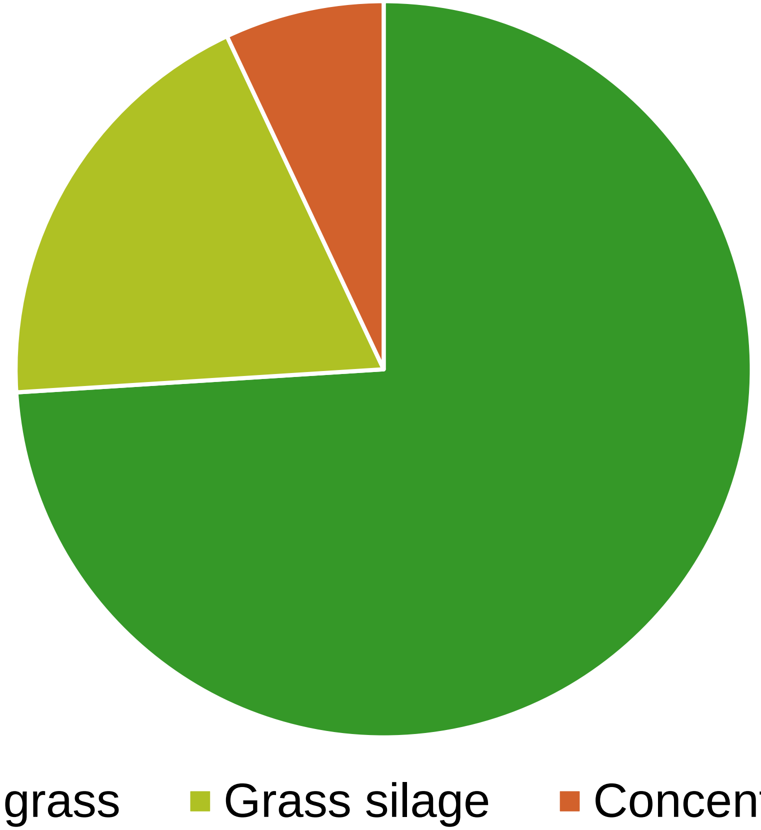
Annual feed budget for a spring calving cow

- 74% Grazed grass
- 19% Grass silage
- 7% Concentrates



Target production: 400-450 kg milk solids per cow per year

Source: Teagasc Dairy Manual (2016)

Variation to traditional grazing systems

- Many traditional pasture based regions within UK have, in recent years, adopted either fully housed systems (total confinement) or systems involving part-time housing during the summer (partial confinement)
- In addition, there is growing interest in 'zero grazing' systems in both Ireland and UK in which herbage is harvested daily throughout the summer period and offered to housed cows

- Partial confinement systems typically involve day-time grazing and night-time housing during summer months and are aimed at combining the benefits of confinement and pasture grazing systems.
- Across seven relevant studies, cow performance did not differ between partial and total confinement systems (Arnott et al., 2015)

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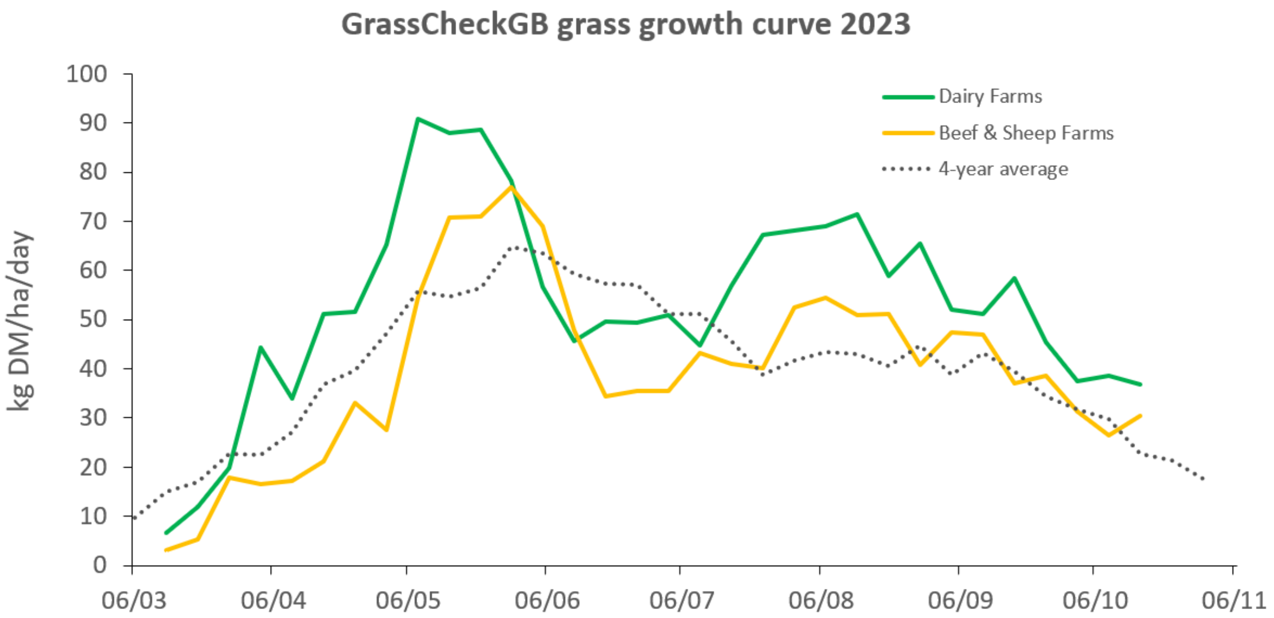
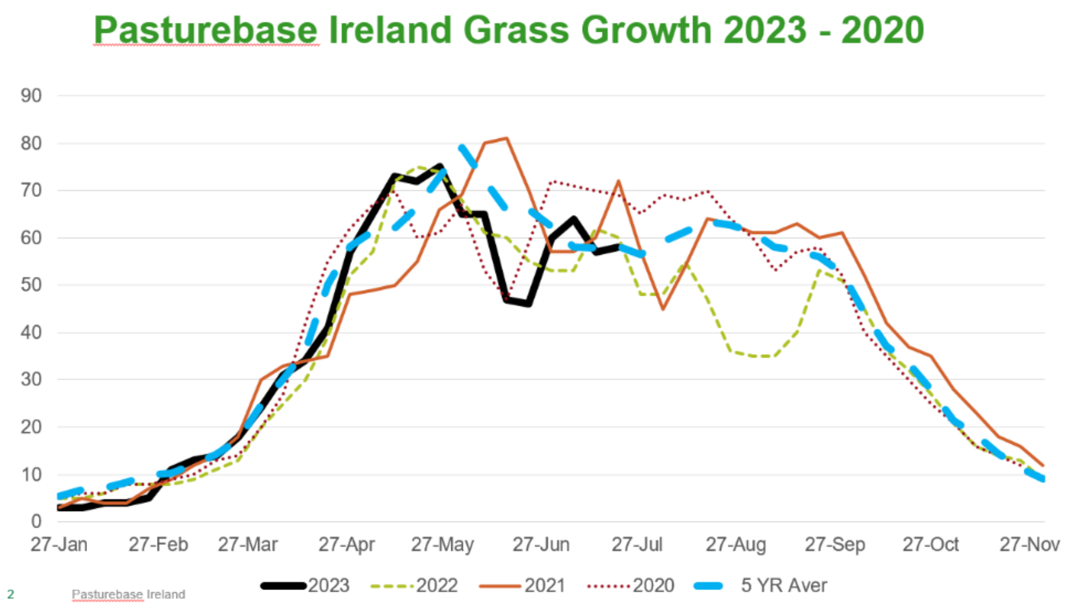
National Pasture Measurement Initiatives

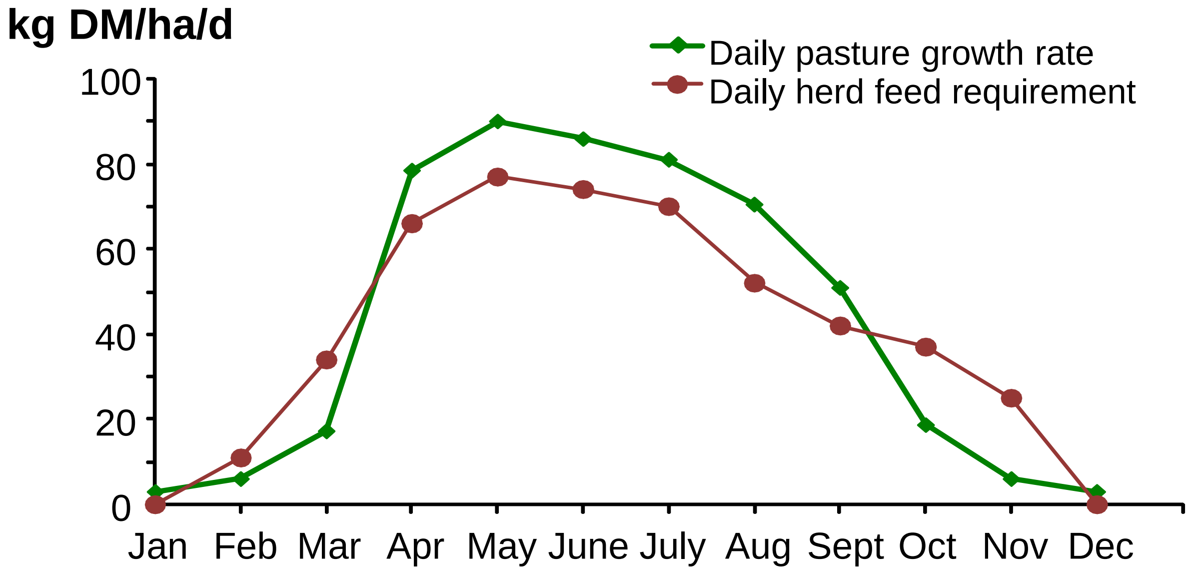




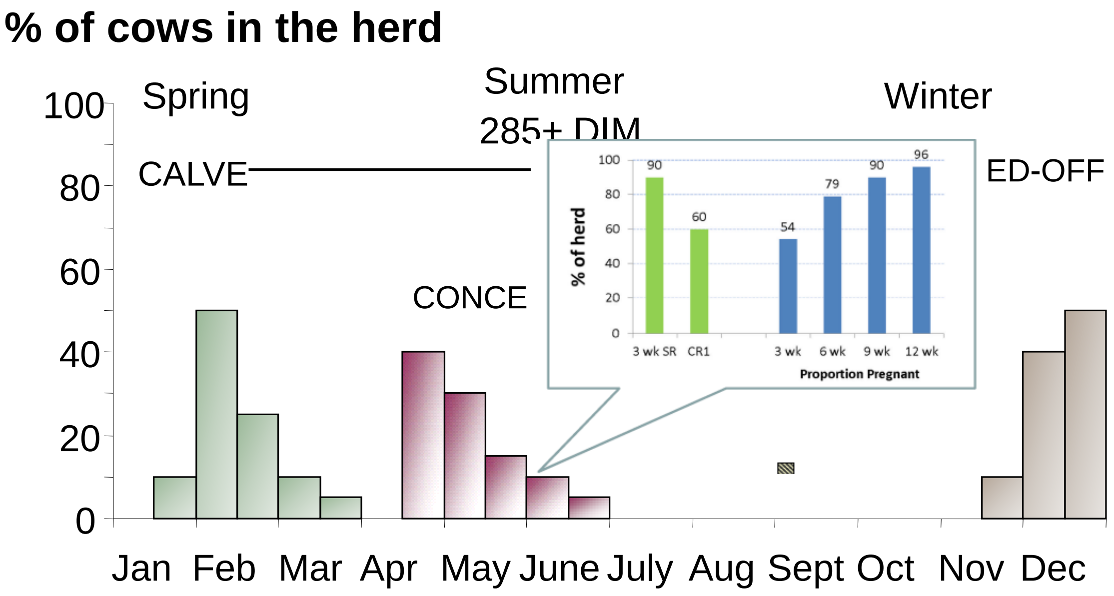
‘You can't manage what you can't measure’ – *Peter Drucker*

First principles of pasture-based dairy production systems

Alignment of Grass Supply & Animal Requirements



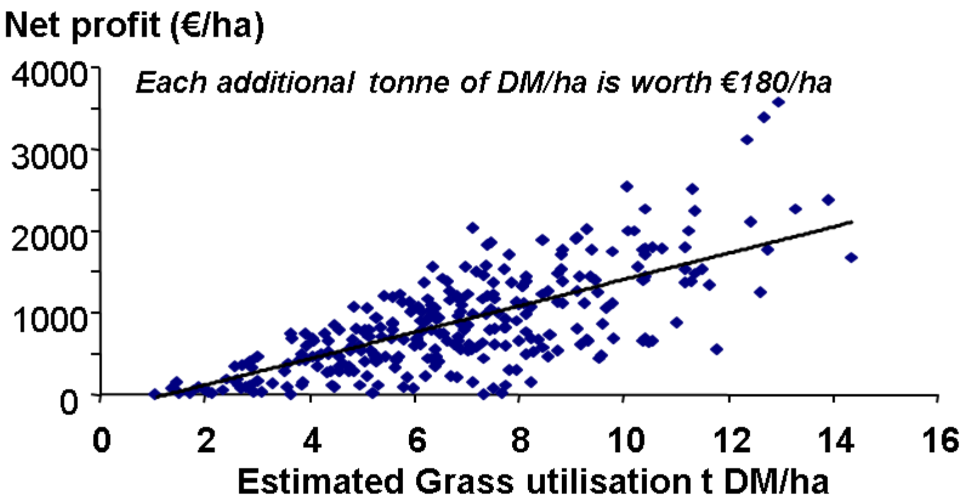
Compact calving, high fertility status dairy herd



“Simplicity is the ultimate sophistication” – Leonardo da Vinci.

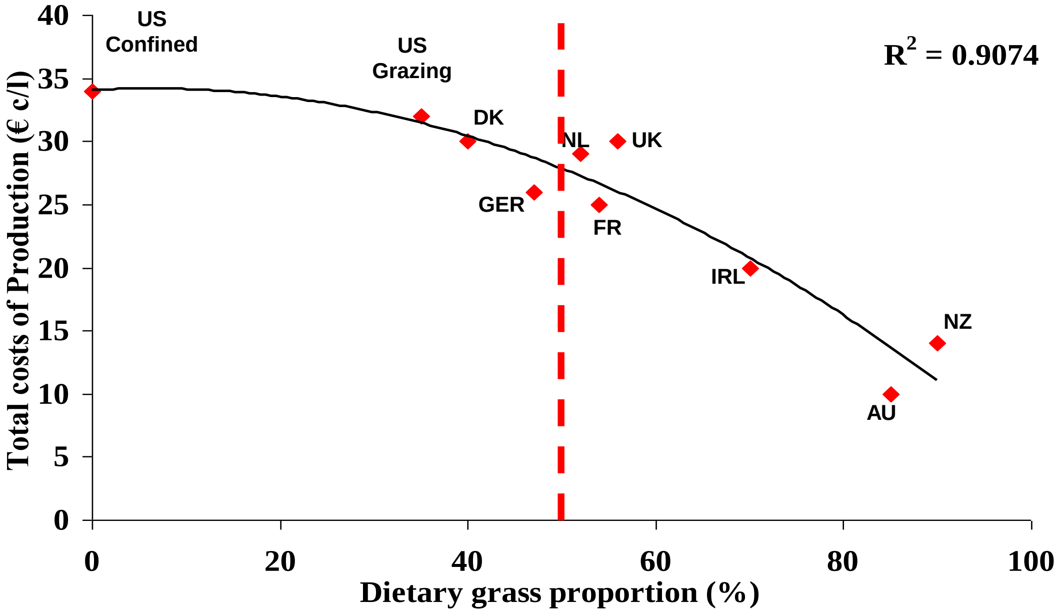
Economic imperatives for grassland systems

➢ **High profitability grazing systems are based on high levels of pasture utilisation**



➢ **Curvilinear relationship between grass proportion in the diet and milk production cost**

- Reduced feed related costs
- Low fixed costs



Dillon et al. (2008)

GROWING 14 TON GRASS DM/Ha

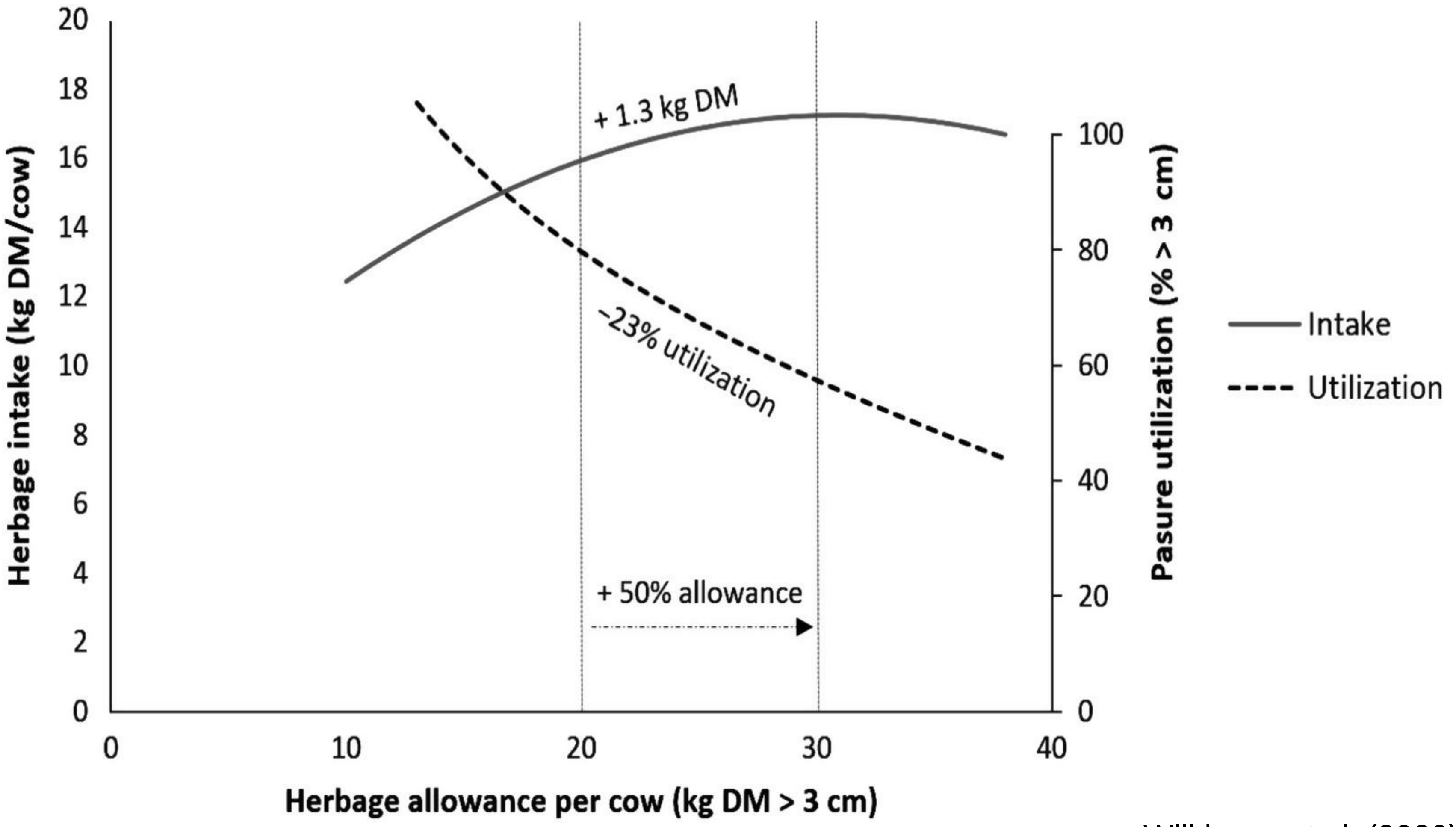
Growth Period	Grass Grown/Rotn (kg/ha)	Rotn. Length (days)	No. of Rotations	When Does Grass Grow?
Feb to Mid Apr	1000	65	1	10%
Mid Apr to Mid Aug	1400	20	2-7	60%
Mid Aug to Mid Sep	1600	30	8	30%
Mid Sep to Mid Oct	1900	35	9	
Mid Oct to Mid Nov	1100	35	10	
Total Grass production/ha	14000	285	10	100%

- To utilise 10 Ton Grass DM/Ha and Achieve 10 Grazings/Paddock/Year, the farm must grow about 14 Ton grass DM/Ha which is utilised at around 75%.
- 10% of the grass is grown in spring, 60% in summer and 30% in autumn
- Trends from PastureBase Ireland suggest much more variation in grass grown between farms than there is between paddocks on the same farm,
- Indicating that farmer's own grazing management decisions are having a greater affect on the grass grown rather than external factors like geographic location, soil type, climate, etc.

Pasture utilisation

- Pasture utilisation is a systems efficiency metric that encompasses annual pasture growth and feed demand patterns, supplementary feed and milk output, and is positively associated with profitability per unit area.
- Milk productivity per cow tends to increase profit only if derived from greater pasture utilisation.
- Indeed, Ramsbottom *et al.* (2015) concluded that production costs increase by approximately 1.5 times the rate of direct cost of supplementary feed purchase due to associated capital expenses.
- At the daily operational level, pasture utilisation for the optimal synthesis of milk requires consistent provision of high-digestibility, high leaf content swards, grazed at the optimal growth stage to the correct residual, by cows of a suitable genotype (Hennessy *et al.*, 2020).
- Hence, the role of feed supplementation within the system has become tactical in nature, being employed to address deficits in pasture supply and quality, or to deliver specific limiting nutrients.

Herbage allowance *v* intake and utilisation



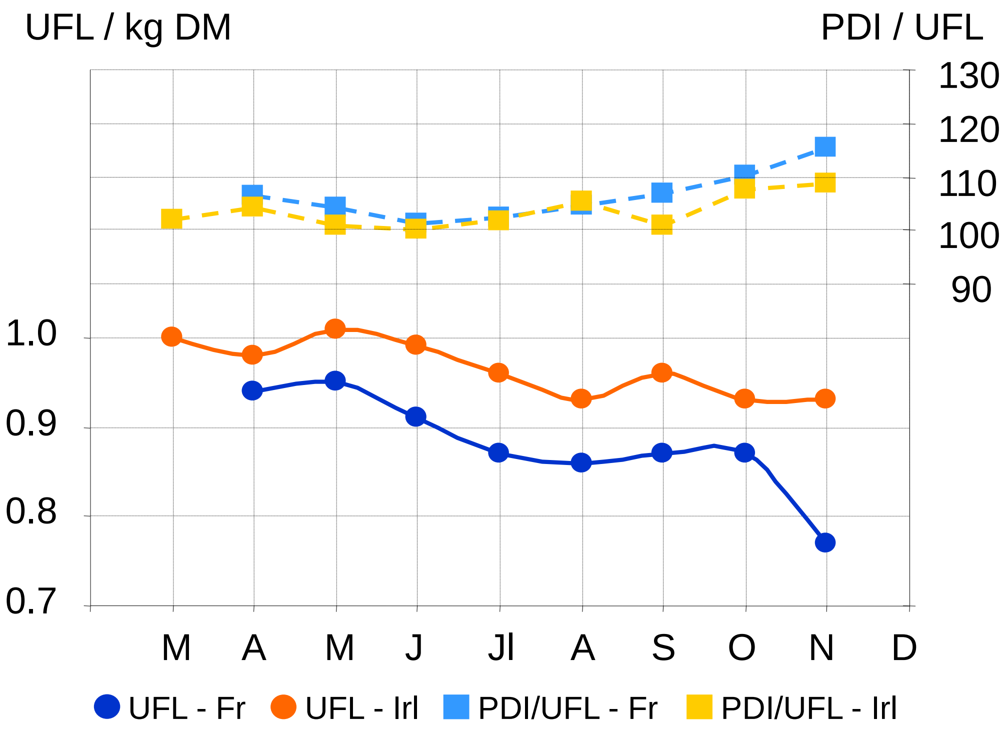
Wilkinson et al. (2020)

Grass and Forage Science, Volume: 75, Issue: 1, Pages: 1-17, First published: 02 December 2019, DOI: (10.1111/gfs.12458)

Nutrition of early lactation dairy cows in grazing systems

- Supply of ME, and not metabolisable protein or specific AAs, is usually first-limiting for milk production in grazing systems (Kolver & Muller, 1998)
- Primarily a function of physical/behavioural limitations to feed intake on high quality pasture, rather than large differences in nutrient density or digestibility per unit of DM (Bargo et al., 2003)
- The early spring period in particular presents the challenge of synchrony between low postpartum intake potential at the animal level and potentially challenging grazing conditions (Kennedy et al., 2011; Patton et al., 2012)
- A key objective has been to develop strategies that strike a balance between high grass utilisation, support of high milk solids yield derived primarily from pasture intake and promotion of metabolic health of the cow (Dillon, 2006)

How to increase DMI of grazing cows?



Well managed, grazed grass
is a natural TMR

But grazed grass is characterised
by a low DMI
due to the form and nature
of the forage offered

Voluntary feed intake – sward characteristics

- Dry matter intake is higher for swards with higher proportion of leaf content and greater OMD (Peyraud & Delagarde, 2013)
- Cows grazing perennial ryegrass-white clover swards have been reported to obtain greater DMI than cows grazing grass only swards (Ribeiro Filho et al., 2003, Ribeiro Filho et al., 2005) resulting in greater milk and milk solids yield (Egan et al., 2018; McClearn et al., 2019)
- DMI of pasture is limited by the combined effects of bite rate, bite mass and number and duration of grazing bouts (Dillon, 2006)
- This is predicated on the provision of a requisite daily DM allowance such that grazing behaviour and animal intake capacity are first-limiting on herbage intake (Bargo et al., 2003)
- Examining the plant-animal interface is critical to identify plant traits with the potential to increase grazing efficiency.
- The sward characteristics that maximise intake may differ with grazing management regime, for example, optimal pregrazing sward height may be lower for continuous versus rotationally grazed swards (Dillon, 2006)
- Trade off - the objective of increasing daily pasture intake must also be balanced with a requirement to achieve a post-grazing residual that maintains sward quality for subsequent grazing

Voluntary feed intake - grazing impetus

- The length of time occurring between meals influences feeding motivation which in turn influences the ingestive tactics of the animal (Forbes and Gregorini, 2015).
- Fasted dairy cows grazed 85% of their total daily DM intake in 4 hours (Chilibroste et al., 2007)
    - greater bite rate
    - intake rate
    - stride length
    - walked faster
    - explored a smaller area while grazing
- More feed efficient cows (RFI) were more grazing efficient, walked less, masticated less, had a greater bite rate and expended less energy while grazing (Gregorini et al., 2015)
- Likely to be significant re-ranking of animals selected feed/grazing efficiency when measured under different feeding regimes (Kenny et al., 2018)
- Genetically superior dairy cows (Dairy NZ, 2020) and those with a higher fertility sub-index (Cummins et al., 2012) had higher forage DMI and improved energy balance
- Some evidence of self selection of various plant species based on palatability, nutritive value and fermentation efficiency

Pasture digestibility

- The nutritive value of pasture is closely related to its digestibility due to the effect of digestibility on net energy concentration and ingestibility (Peyraud & Delagarde, 2013)
- Digestibility affects the amount of ruminal fermentable carbohydrate that is available to support microbial protein synthesis and hence the supply of metabolisable amino acids (O'Mara et al., 1997)
- Pasture digestibility can be quite variable with a wide range being reported for the total-tract digestibility (TTD) in pasture-fed lactating dairy cows (72% to 84% organic matter TTD; Morgan & Stakelum, 1987; Rius et al., 2012; Garry, 2016)
- Many factors affect the digestibility of pasture such as pasture mass, nitrogen (N) fertiliser application, species and cultivar, morphological proportions, environmental conditions and physiological status/seasonal variation.
- Immature pasture is highly digestible with the majority of digestion occurring prior to the omasum/duodenum
    - extensive ruminal digestion of immature PRG N/AA occurs suggesting that cows consuming such diets exhibit a large dependence on microbial AA to support metabolisable AA supply;
    - measurement of the rumen pool size of cows fed highly digestible immature pasture indicates that rumen distension does not limit DMI;
    - consumption of immature pasture stimulates high ruminal liquid passage rate which may affect microbial metabolism and protein synthesis.

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Characterising pasture nutritive value

- Numerous lactating dairy cow studies have characterised the influence of digestibility on variables such as DMI, rumen pool size, rumination and milk production performance (Oba & Allen, 1999; Cotanch et al., 2014; Zontini et al., 2015).
- Beecher et al.(2018) demonstrated, in an investigation with sheep, that *in vivo* NDF digestibility of PRG was a better predictor of DMI than *in vivo* OMD.
- Dineen et al. (2021b) recently highlighted that when a more accurate characterisation of NDF digestibility is combined with the Cornell Net Carbohydrate and Protein System, a greater understanding of the nutrient supply and milk production performance of grazing dairy cows can be achieved.
- This increased understanding of pasture nutritive value, in regard to rumen turnover, metabolisable energy (ME) supply and post-ruminal AA flows, can aid in the development of future nutritional strategies to increase the efficiency and productivity of pasture-based systems.
- Such nutritional strategies could include development of improved pasture management practices (O'Donovan et al., 2002), optimisation of concentrate supplementation (Baudracco et al., 2010), selection of superior plant genetics (Lee et al., 2012) and the development of binary or multi-species pastures (McCarthy et al., 2020).

Pasture v TMR – Early lactation

- To examine the efficacy of pasture as the primary forage source in early lactation, Kennedy et al. (2005) evaluated performance of cows fed pasture plus concentrate (3–4 kg DM) relative to herd-mates offered a total mixed ration (TMR) containing 0.6 of DM as concentrate plus moderate-quality grass silage, and reported similar solids-corrected yield (25.9 vs. 26.6 kg) and bodyweight change
- No carryover effects were observed while milk protein content was improved through inclusion of pasture in the diet. Differences in concentrate feeding level were offset by superior intake and digestibility of grazed pasture relative to the forage silage component of the TMR
- In contrast, O'Neill et al. (2011) showed significantly increased milk volume and total solids yield for a maize/grass silage/concentrate-based TMR relative to pasture for early lactation cows
- This output difference resulted from greater daily DMI for the TMR (19.2 kg vs. 14.5 kg) at comparable levels of dietary energy density.
- Differences in the biological performance of pasture and indoor diets are determined by the DMI, nutrient densities and feed conversion efficiencies achieved within each system paradigm (Kolver, 2003)
- Such differences will ultimately determine the relative economic and environmental impacts for systems-level comparisons (Shalloo et al., 2004; O'Brien et al., 2012)

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Grazing v confined system at same concentrate allocation

	Full-Time Grazing	Total Confinement
Concentrate intake (kg/cow/day)	8.0	8.0
Milk yield (kg/cow/day)	26.8	27.1
Milk fat (%)	3.80	4.27
Milk protein (%)	3.47	3.49
Milk fat + protein yield (kg/cow/day)	1.94	2.11
Final body condition score	2.4	2.6

Arnott et al. (2015)

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Concentrate supplementation of grazing cows

- Concentrate feeding twice daily during milking is the predominant means of supplementation in pasture-based systems in Ireland, as it offers the advantages of simplicity of delivery, high energy and protein content and lower impact on pasture intake.
- It also provides a means of balancing macro and trace mineral deficiencies in pasture (Curran et al., 2016).
- Factors affecting variation in milk yield and body tissue accretion responses to concentrates are numerous and include pasture allowance and digestibility, stage of lactation and rate of supplementation (Bargo et al., 2003).
- Cow genotype can affect the marginal milk response to concentrate, which varied from approximately 0.5 to 1.1 kg solids-corrected milk between New Zealand and North American strains of Holstein Friesian, respectively (Horan et al., 2005)

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Supplement type and composition effects on dairy cow performance

- The ideal feed supplement for grazing cows will:
  - increase intake of a specific limiting nutrient
  - minimise pasture substitution to elicit an economic response
  - have low risk of rumen upset
  - facilitate ease of storage and feeding
- Principal issues include:
  - rate and timing of supplementation
  - supplement type
  - production and health responses
  - effects on nutrient balances
  - overall economic response

Substitution rate

- Milk responses to supplement feeding are governed to a large extent by substitution rate, defined as *the differential between unsupplemented pasture intake and supplemented pasture intake, divided by supplement feeding rate*
- While standard cereal-based concentrates may have net energy book values that are sufficient for up to 2 kg milk production per kg DM fed, the milk response rate is inevitably much lower (approximately 1:1) due to pasture substitution and the negative associative effect of concentrate on whole diet digestibility (Noziere et al., 2018)
- Developing more accurate real-time decision support on the likely responses to supplementation at pasture is an important objective (Ruelle et al., 2015)
- Inclusion of dietary forage with higher ingestibility gives reliable milk responses where it replaces a lower-quality feed, for example, where maize silage replaces moderate-quality grass silage (Burke et al., 2007), or indeed where high digestibility grass silage replaces lower-digestibility silage (Ferris et al., 2001)
- Maize may confer N-use efficiency (NUE) advantages compared to grass silage as a basal forage supplement (Burke et al., 2007)
- Milk responses to conserved silage supplements at grazing are usually limited by forage fill value and cow intake capacity however, particularly where pasture allowance and quality are not limiting

Table 4 Effect of supplement type [grass silage (GS), whole-crop wheat silage (WS), maize silage (MS), rapidly degradable concentrate (RC) and slowly degradable DM concentrate (SC)] and no supplement (NONE) on grass, supplement and total DM intake.

	Supplement type						s.e. of	Level of
	NONE	GS	MS	WS	RC	SC	difference	significance
Grass intake (kg DM per cow per day)	12·9[c]	11·2[bc]	8·9[a]	11·0[b]	11·8[bc]	12·2[c]	0·50	***
Supplement intake (kg DM per cow per day)	–	3·0[a]	6·3[c]	3·6[ab]	3·9[b]	3·9[b]	0·37	***
Total intake (kg DM per cow per day)	12·9[a]	14·2[b]	15·3[c]	14·7[bc]	15·7[c]	16·1[c]	0·50	***
Substitution rate (kg DM herbage kg^{-1} DM supplement)	–	0·56	0·63	0·53	0·28	0·18	–	–

***$P < 0·001$. Superscript letters that differ within a row indicate values that are statistically significant at $P < 0·05$.

Morrison & Patterson (2007)

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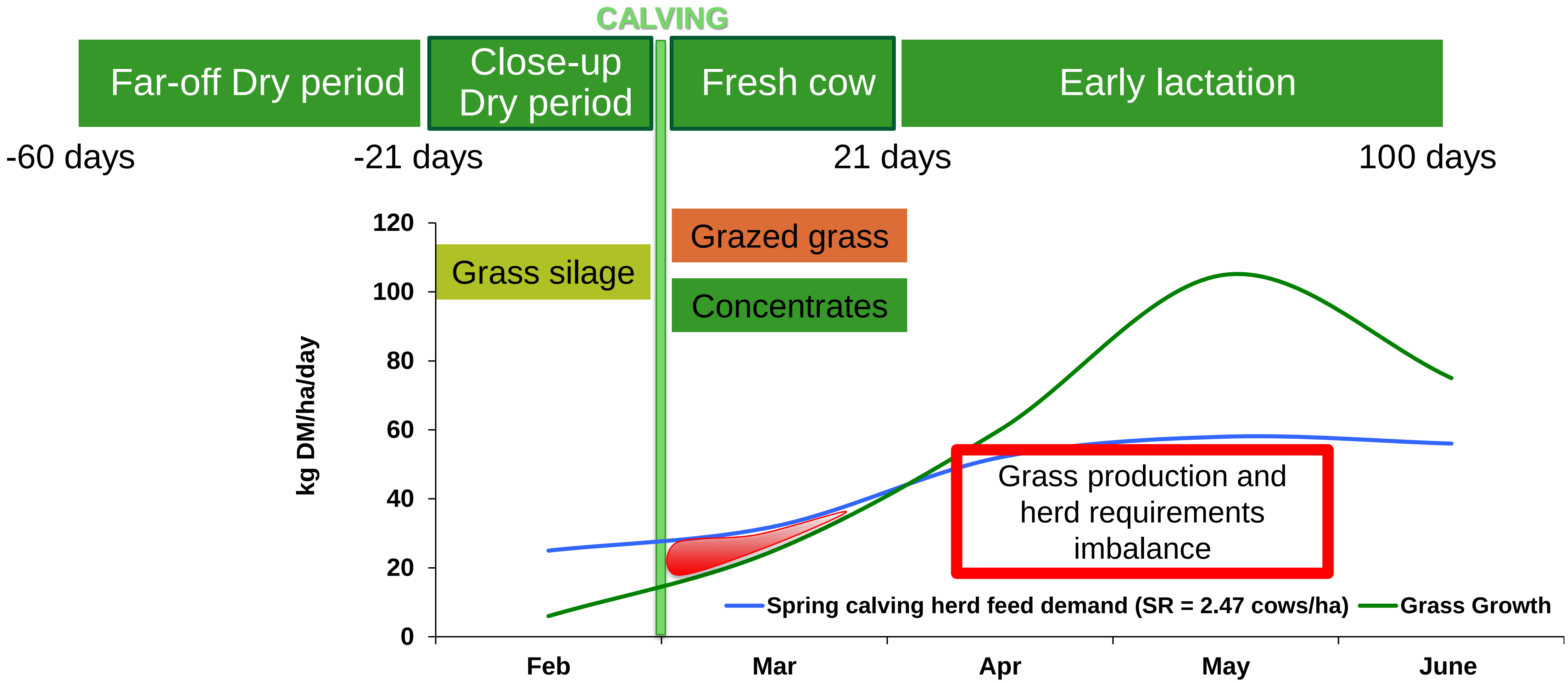
Transition period: Feeding management



Grass growth figure source: Elodie Ruelle

Challenges for the grazing transition cow

- Theoretically less because
  - Lower output (i.e., lower energy required for lactation)
- Reportedly similar
  - At 0 d postpartum:
    - » Clinical hypocalcemia (≤1.4 mmol/L): 6%
    - » Subclinical hypocalcemia (Ca ≤2.15 mmol/L): 60%
  - At 7 d postpartum:
    - » Hyperlipidemia (NEFA ≥1.0 mmol/L): 43%
    - » Hyperketonemia (BHB ≥1.2 mmol/L): 16%
- Potentially because limitations on DMI

Spaans et al. (2022) J. Dairy Sci. 105

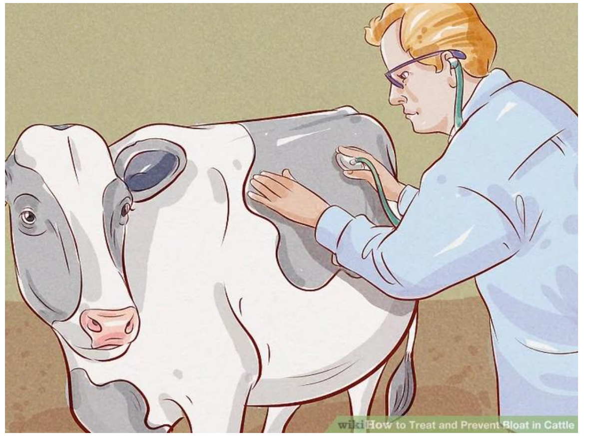
Some other metabolic disorders in grazing dairy cattle

Subacute ruminal acidosis (SARA)

- Cows grazing highly fermentable pastures with high sugar contents can also have a low ruminal pH indicative of SARA. This is not accompanied by an inflammatory response but may affect milk production and gut microbiota. Grain-based SARA affects several aspects of gut health, but SARA resulting from grazing high-digestible pastures and insufficient coarse fiber less so (Plaizier et al., 2022)
- Irish study with cows receiving predominantly grazed pasture reported that 10% of cows had a ruminal pH of <5.5 and 53% of cows had a ruminal pH of <5.8 (O'Grady et al., 2008)
- Cows consuming ryegrass swards with clover typically have higher mean ruminal pH in the autumn compared with cows consuming ryegrass-only swards – Bloat a more pressing issue!
- Accurate rumen digesta sampling and pH measurement is a limitation to diagnosis

Summer scour syndrome (SSS)

- Recently identified pathological condition
- Weaned dairy calves at grass - a month post turnout
- No consistent pathogens identified
- Primary cause/s remain unclear
- Diagnosis of exclusion



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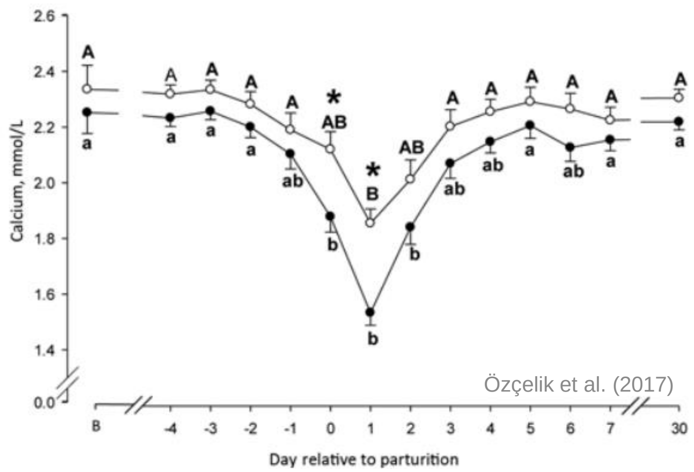
Mineral metabolism in pasture fed cows

High K intake

- **↑DCAD**
  Induces a metabolic alkalosis, which ↓tissue sensitivity to parathyroid hormone (PTH), and therefore also bone resorption and active Ca absorption
- **↓Mg absorption**
  ↓PTH secretion and action on its receptors

High P intake

- **Slurry/P fertilizer**
  ↓1,25(OH)2 Vit D and active Ca absorption

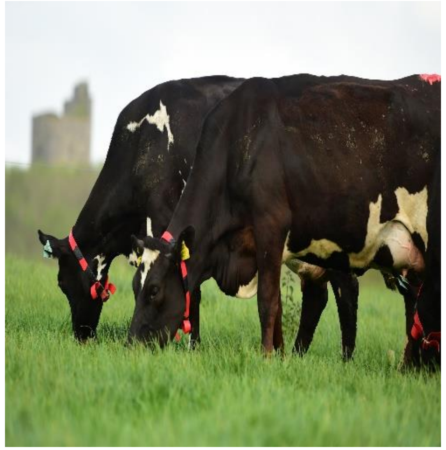


○Daylight (12 h in-/outdoor; n = 20)
●Control (fulltime indoor; n = 20)

Low UV light exposure

- **Indoor housing**
  Vitamin D_3 and derivative molecules synthesis, resulting on lower active Ca absorption

Effect of forage quality and composition on GHG emissions of dairy cattle



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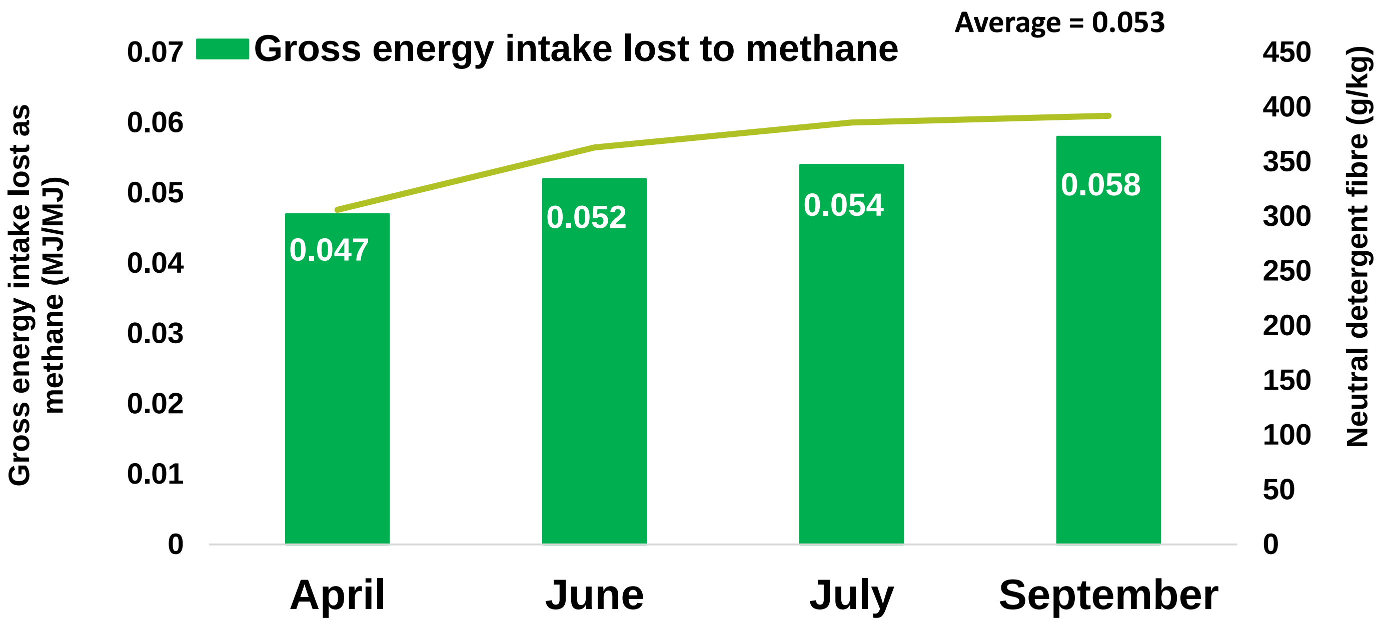
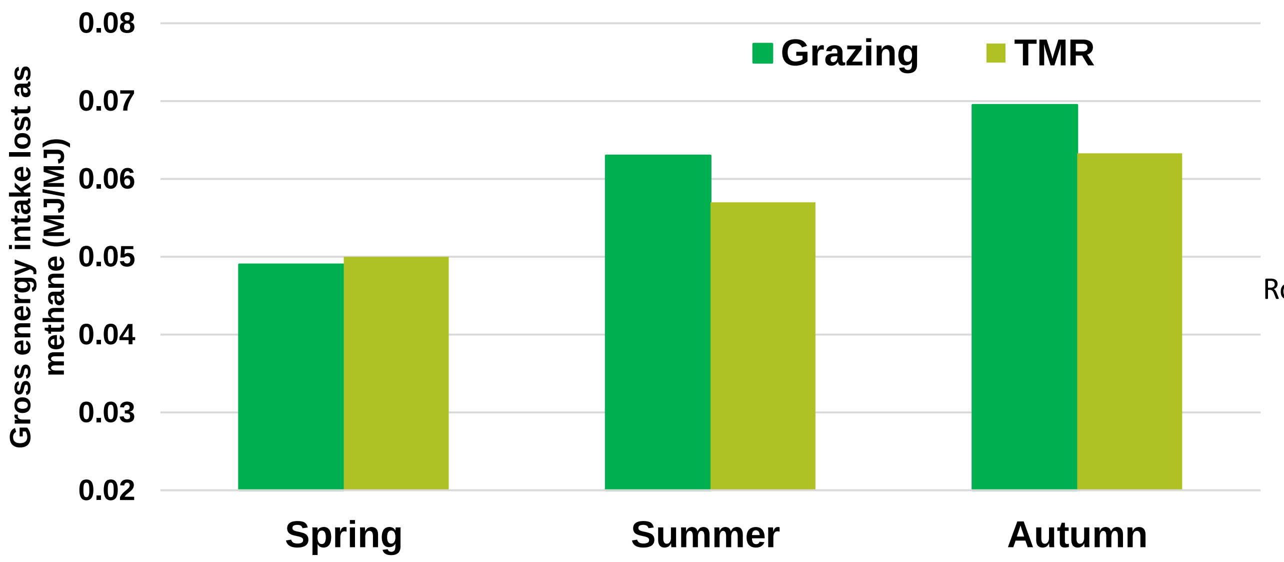
Seasonal methane profile for Irish dairy cows at pasture



Lahart et al. 2022



Robertson and Waghorn ,2002

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Effect of pasture quality on methane emissions

Table 2. Effect of sward DM digestibility on mean intakes, methane production, and apparent whole-tract digestibility of heifers

	Sward DM digestibility			
Item	Low, n = 6	High, n = 6	SEM	*P*-value
Feed intake, kg/d				
Fresh weight	31.0	37.6	1.1	0.003
DM	5.38	7.66	0.26	0.006
OM	4.93	7.14	0.27	<0.001
Digestible DM	4.30	6.73	0.23	<0.001
Methane production				
CH_4, g/d	138	193	9.7	0.003
CH_4, g/kg of DMI	25.6	25.7	1.5	0.95
CH_4, g/kg of digestible DMI	32.1	29.3	1.6	0.24
CH_4, MJ/MJ of GE intake	0.098	0.099	0.0056	0.92
Apparent whole-tract digestibility, g/kg				
OM	715	830	12	<0.001
CP	569	748	19	<0.001
NDF	682	810	15	<0.001
ADF	667	781	18	0.001

Hart et al. (2009)

Table 3. Effect of herbage mass on animal performance, grass intake, and methane production during measurement 1 and measurement 2 for low (1,000 kg of DM/ha) and high (2,200 kg of DM/ha) herbage mass treatments

	Measurement 1[1]				Measurement 2			
Item	1,000	2,200	SED[2]	Significance	1,000	2,200	SED	Significance
Animal performance								
Milk yield (kg/d)	22.2	21.5	0.90	NS	18.0	17.0	0.77	NS
Milk fat (g/kg)	36.1	38.4	0.12	*	413	4.20	0.11	NS
Milk protein (g/kg)	33.3	33.2	0.05	NS	33.2	32.8	0.06	NS
Milk lactose (g/kg)	45.1	45.9	0.05	NS	45.6	45.4	0.06	NS
Milk solids (kg/d)	1.52	1.53	0.06	NS	1.33	1.26	0.05	NS
BW	495	507	6.5	†	500	494	7.78	NS
BCS	2.77	2.89	0.152	NS	3.02	2.95	0.035	*
Grass DMI (kg/cow per d)	16.9	15.4	0.41	*	14.6	14.6	0.45	NS
Methane production								
g of CH_4/cow per d	286	286	16.18	NS	278	320	12.71	**
g of CH_4/kg of milk yield	13.0	13.6	0.90	NS	16.4	19.9	1.21	**
g of CH_4/kg of milk solids	187	192	10.6	NS	219	266	15.9	**
g of CH_4/kg of grass DMI	17.0	18.7	0.06	NS	19.2	22.3	0.06	*
GE[3] intake lost as CH_4 (%)	5.4	6.3	0.24	*	6.4	7.4	0.32	*

[1]Measurement 1 = June 21–26; measurement 2 = July12–17.
[2]SE of the difference.
[3]Gross energy.
** $P < 0.01$; * $P < 0.05$; † $P < 0.1$.

Wims et al. (2010)

- **Improved pasture quality = higher DMI and lower methane emissions per unit of digestible DM, gain/milk output**

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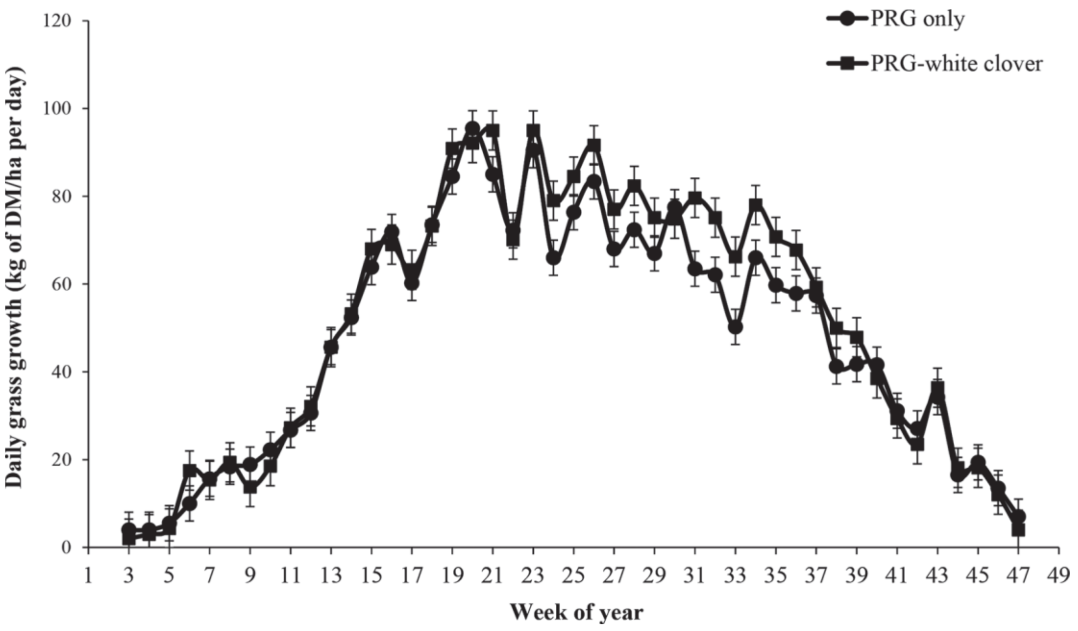
Effect WC presence on pasture growth and cow milk solids yield



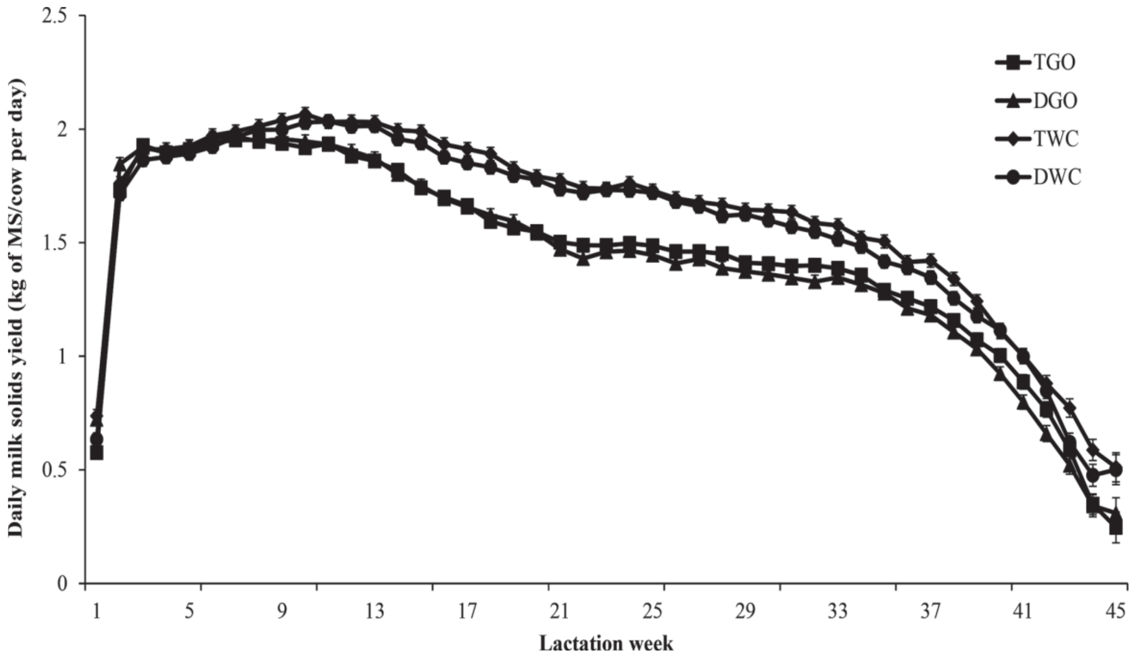


Figure 1. Comparison of perennial ryegrass (PRG)-only (tetraploid and diploid mean) and PRG-white clover (tetraploid and diploid mean) swards for daily grass growth (mean 2014–2017). Error bars represent SE of daily grass growth.

Figure 3. Daily milk solids (MS) yield per cow by lactation week for tetraploid perennial ryegrass (PRG)-only (TGO), diploid PRG-only (DGO), tetraploid PRG-white clover (TWC), and diploid PRG-white clover (DWC; mean of 2014–2017). Error bars represent SE of daily milk solids yield.

McClearn et al. (2019)

Perennial ryegrass and white clover swards

J. Dairy Sci. 97:1400–1412
http://dx.doi.org/10.3168/jds.2013-7034

Milk production and enteric methane emissions by dairy cows grazing fertilized perennial ryegrass pasture with or without inclusion of white clover

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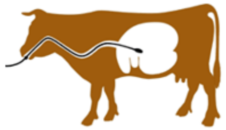
40 spring calving dairy cows
(HF, NR and HF x NR)

Perennial ryegrass only
(PRG; n=20)

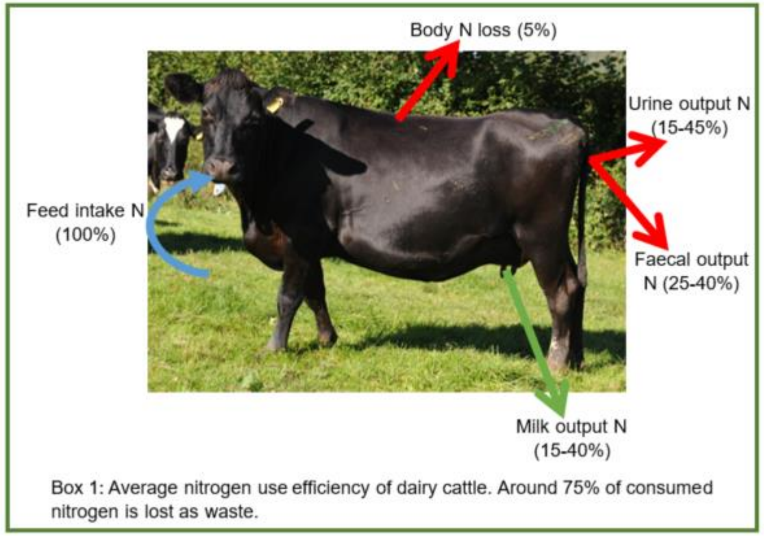
Perennial ryegrass and white clover
(WCPRG; n=20)



Rumen digesta samples collected at the end of 6 day methane emissions estimation period

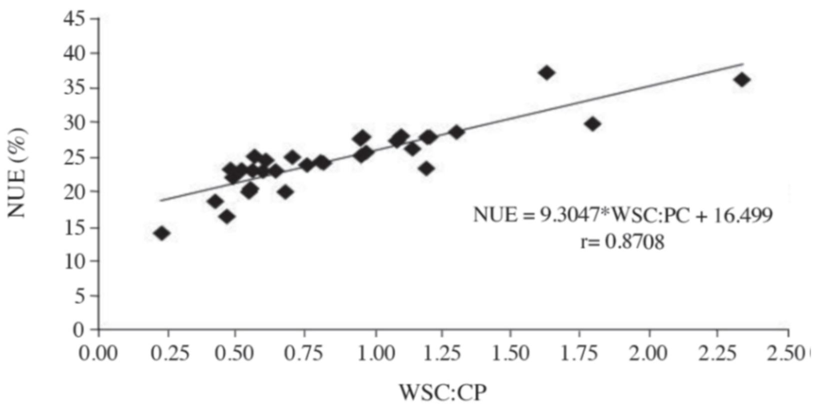
- Sward NDF content 7.4% lower in WCPRG ($P < 0.01$)
- No difference in milk yield
- WCPRG tended to have a higher DMI ($P = 0.07$)
- No difference in daily methane emissions (DME; g/ day)
- WCPRG had a 11.9% ($P < 0.05$) reduction methane yield (MY; CH_4 g/ kg of DMI)

Nitrogen use efficiency

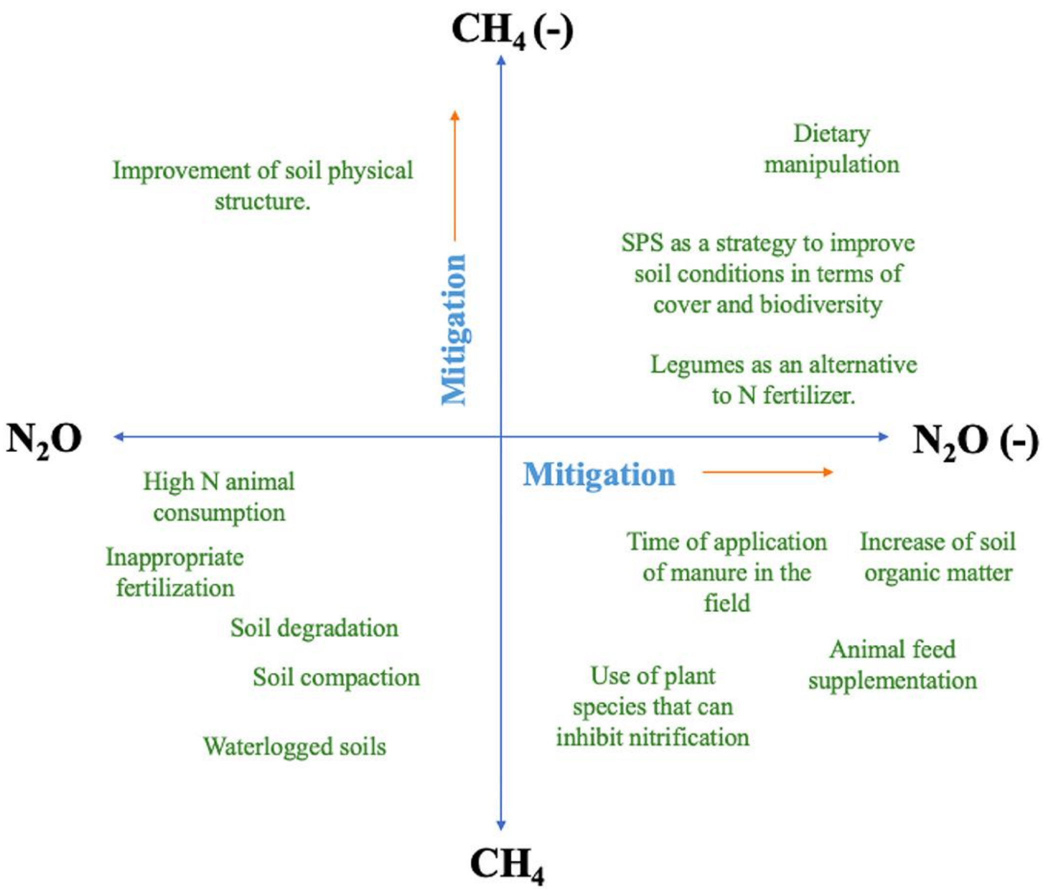


Box 1: Average nitrogen use efficiency of dairy cattle. Around 75% of consumed nitrogen is lost as waste.

Ruth Wonfor, IBERS



Keim and Anrique (2011)



Summary and conclusions

- Management practice that supports the quantification of pasture supply, and underpins maintenance of pasture quality throughout the grazing paramount to successful grazing based dairy systems
- The ability of cows to both milk and maintain sufficient body condition for reproduction is fundamental to pasture based seasonal production systems
- Strategic dietary supplementation during periods of restricted pasture availability/quality is required but the chemical composition, intake and substitution rate characteristics of supplement are important
- There is clear evidence of genotype x environment interaction in the adaptive potential of dairy cow breeds and genotypes to pasture based production systems
- The efficacy of nutrition of the cow prior to and during the transition period is key to regulation of voluntary feed intake postpartum which is the key driver of metabolic health in pasture fed cows
- Greater understanding of the intrinsic biochemical control of the interaction between metabolic status pre- and postpartum, sward chemical composition, rumen microbiome and metagenome, together with genomically based selection programs (both plant and animal) will facilitate more optimum swards, animals, measurement approaches and nutritional regimens for health and welfare friendly, economically and environmentally sustainable and pasture based production systems

Thank you!

Agriculture and Food Development Authority