Breeding resilient cultivars for European grass based ruminant production systems

Gilliland, T. J.\textsuperscript{1}, Hennessy, D.\textsuperscript{2} and Ball, T.\textsuperscript{3}

\textsuperscript{1}Agri-Food and Biosciences Institute (AFBI), Hillsborough, BT26 6DR, Northern Ireland, UK
\textsuperscript{2}Teagasc, Animal & Grassland Research & Innovation Centre, Moorepark, Fermoy, Co. Cork, Ireland
\textsuperscript{3}DSV United Kingdom Ltd, Top Dawkins Barn, Wardington, Banbury, OX17 1FE, England, UK
Scope of the paper

Breeding resilient cultivars for European grass based ruminant production systems

• Not a comprehensive overview of contemporary grass agronomy & genetics
• Not a critique of grass breeding strategies
• Not about being robust - improving resistances - climate, disease or pests

Second line: remit to address the interface between herbage and ruminant

First line: key word is ‘Resilient’ and its meaning within this context
Resilience Concept

Resilience Theory, as defined by Greene et al., (2004) in human psychology and further contextualised by Malgorzata (2016) is defined as

• “....an individual's ability to successfully adapt to life tasks in the face of disadvantage or highly adverse conditions”

Southwick et al., (2014) redefined resilience as a multifactorial concept, which requires only minor adjustment of the human parameters to be applicable to grass breeding:

• “....the examination of variables in genetics, epigenetics, development, (demographics, cultural) regional practices and (economic and social) farm business factors”

This only lacks the environmental (climatic and edaphic) factor
Resilience Concept

‘Proficient & Sustained’ delivery of highly Utilisable, high yielding herbage

Although greatly simplified, implications are both complex & all encompassing

‘Proficient’ introduces multiple production factors
- efficient use of input resources (soil nutrients, light capture, water)
- adaptability to optimise under varying management practices
  (grazed, conserved, set stocked, rotational, zero grazed, intensive, extensive, etc)
- reduced leakage of inputs (lower environmental footprint, improved farm business margins)

‘Sustained’ reflects the need for greater predictability and reliability
- across a growing season and over years
- throughout a wide regional, climatic and edaphic range
- implicates climatic change with changing disease and pest pressures

‘Utilisable’ addresses greatest weakness in ruminant production from grass
- poor conversion of herbage mass (esp. protein components) to ruminant product
- better align to the intake and ‘grazability’ demands of livestock
‘Proficient & Sustained delivery of highly Utilisable, high yielding herbage’
Herbage Production:

- For over 50 years breeders have been achieving higher **DM yields**, in North-Western Europe in ryegrasses, at +0.4-0.6% yr⁻¹ (Wilkins & Humphreys, 2003; Sampoux et al., 2011)
- **Persistence** improvement achieved many years ago, now targeting ‘ware tolerance’
- **Disease resistance** has kept pace with disease pressures and protects productivity as climate change expands the territories at risk (Smit et al. 2005, Parsons et al. 2011)
- **BUT** these breeding objectives are the same as Cooper & Breeze reported in 1971
- Latterly **digestibility** testing added but rise is only modest at 0.5-1.0 g kg⁻¹ DM yr⁻¹

This is not a ‘multifactorial’ resilience breeding strategy as defined earlier.
Performance Consistency: Fodder Crises

Farmers placing greater dependency on grass need consistency of growth

- Breeders agribusinesses seek widely adapted cultivars to multiply fewer in larger quantities and lower production costs – so robust, durable, quick to recover types.

- In 2002 & 2013 bad NI weather so severely depressed grass yields that Government provided ‘weather aid’ and ‘fodder crisis’ support of over £6.5m (€7.4m).

- In spring 2018 unseasonably wet and cold conditions retarded early spring growth.
Performance Consistency: Fodder Crises

- 2018 Spring following an early end of season in Ireland bad weather at turnout had swards at \( \sim 300 \text{kg DM/ha} \) below requirement.
- 6 Apr Minister of Agriculture allocates €1.5m for fodder import scheme
- Dairygold co-op imported 4,500 tonnes of fodder (haylage and hay) from UK for 500 farmers mostly in Munster

Challenges of this magnitude are beyond current breeding capability remedial measures are - local monitoring services; planning of fodder reserves; crises management.
Animal Nutrition & Intake:

- Average NI farm utilized grazing yields are $5.0\text{t DM ha}^{-1}\text{yr}^{-1}$
  
  \textit{(dairy 7.5t ; beef & sheep 4.1t McConnell, 2018 ; 7.8 t Irish dairy farms, Hanrahan et al., 2018)}

- Utilisation is around \textbf{50\%} (Bailey et al., 2017 ;).

- Top 1% ‘\textbf{GrassCheck}’ farms recording \textbf{14-16t} grown at $\sim\textbf{80\%}$ utilised.

- However, efficiency of ingested energy & protein only $\sim\textbf{30\%}$ of intake.

So key limit to livestock performance is herbage intake and metabolisation, not yield.

Key chemical impact traits typically include:

- crude protein concentration,
- neutral detergent fibre,
- water soluble carbohydrates
- organic matter digestibility

\textit{(Wilkins & Humphreys, 2003)}
Resilience Breeding Drivers

Animal Nutrition & Intake:

Key structural intake factors

- Sward Surface Height
- Bulk Density
- Proportion of Green Leaf
- Tiller Density
- Tiller Weight
- Sheath Length (Smit et al. 2005)
- Free Leaf Lamina (FLL) (Cashman et al., 2014; Wims et al., 2013)
- Length of Leaf Blade
- Non-extended tiller height
- Sward Leaf Content (Beecher et al., 2015; Flores-Lesama et al., 2006; Gowen et al., 2003)

Benefits:

- >FLL indicator of utilisation as >pseudo-stem and <true-stem (McDonagh et al. 2017) improves digestibility, lowers post-grazing sward heights (spaced plant flag-leaf length): estimated impact - **1.6 kg milk cow**⁻¹ day⁻¹ (Cashman et al. 2014, Wims et al. 2013)
- (Tubritt et al., 2018) Different cattle post-grazing/‘residual grazed’ heights of 3.7 to 4.8 cm negative association to cultivar yield but phenotypically unlinked: link to reduced 2nd heading & enhanced utilisation (O’Donovan & Delaby, 2005).
Environmental Impact:

Increasing regulatory pressure on grass farming to mitigate GHG, reduce nutrient loss to ground waters and sequester carbon into soil sinks (*ACRE, 2007*).

- Around **94%** of ammonia emissions in Europe stem from agriculture, mainly ruminants.
- Ruminant farming creates **59%** of total UK agricultural ammonia emissions (**24%**: beef, **31%** dairy, **4%** sheep; *Misselbrook et al. 2016*) and **9%** of total anthropogenic GHG emissions (*cH₄, N₂O; Gill et al., 2010*).
- In a less industrialised NI, ammonia rises to over **70%** of total emissions.
- Oct 2015, European Parliament agreed new 2030 reduction targets for NH₄ and N₂O emissions from agriculture ( reductions of **5-30%**)
- Similar controls exist on P₂O₅ loadings with land on many intensive cattle farms exceeding the target soil P index 2: 16-25 mg/l Olsen P
Environmental Impact: evidence of grass issues

In dairy cattle offered 35% concentrates and 65% fresh grass:

- 30% of gross energy intake lost in excretions, 6% as methane, 36% as heat, 23% retained in milk with 5% retained in the body (Hynes et al., 2016a).
- Of total protein fraction ingested (tracked as total N) only 27% and 2% retained in milk and body respectively, with 34% lost in faeces, 37% in urine (Hynes et al., 2016b).
- Only 33% of ingested phosphate transferred to milk with 3.5% retained and 63.5% excreted within faeces (Ferris et al., 2010).

Therefore these are critical grass industry & grass breeding challenges

- Increasing metabolisable energy improves conversion into animal product lowering N$_2$O emissions by reducing N excretion in the urine (Miller et al., 2001).
- Increasing WSC content drives reduced enteric CH$_4$ eructation (Martin et al., 2010; Shibata & Terada, 2010).
  improved CP metabolism; grazed grass (Miller et al., 2001); silage (Merry et al., 2006)
  Reduced N excretion (Yan 2018 pc)
- Maintaining livestock longer at grass (seasonality) reduces NH$_4$ emissions (Bailey 2018)
Breeder Priorities: What are/can breeders do to address the previous ‘drivers’?

In a ‘straw poll’ EU breeders asked to score their selection priorities for 33 traits, as follows:

- **A** (very important/essential)
- **B** (somewhat important/important)
- **C** (useful/irrelevant):

- **8 Productivity Traits:** Total herbage production; spring herbage production; summer herbage production; autumn herbage production; 1st cut silage yield; 2nd cut silage yield; 3rd cut silage yield; overwinter/low temperature growth.

- **9 Herbage Quality:** Spring grass quality; summer grass quality; autumn grass quality; digestibility; crude protein content; water soluble carbohydrate content; fibre content; fatty acid profile; tannin content

- **4 Structural Parameters:** Lamina length; leaf area index; erect/prostrate habit; density

- **7 Resistance Factors:** Rust resistance; mildew resistance; Drechslera resistance; other diseases, persistence/longevity; drought tolerance; cold tolerance/winter kill

- **5 Specialist Characters:** Nitrogen use efficiency; phosphorus use efficiency; utilisation under grazing; livestock output measure; lower methane emissions
Breeder Priorities: Poll: results summary:

- Productivity & resistance traits had highest priority
- Herbage quality and structure very much of secondary priority
- only 4 traits A-classed by all (total & spring production, spring quality and digestibility),
- 6 traits A-classed by majority (1st cut silage yield, sward density, rust & Drechslera resistance, utilisation under grazing and persistence/longevity).
- Additional characters proposed included: Fibre or Cell Wall Digestibility, Reheading, Tillering, Poaching/Wear Resistance and Seed Yield.

No clear consensus on priorities of traits:

- A-class - 1 breeder only total yield : 1 breeder listed 23 of the 33 traits
- Reflects the challenge of breeding for genetic gain without a singularity of end-use and depending on the inefficiency of the ruminant ‘end-user’.
- Indicates the challenge of achieving a multifactorial resilience by targeting progress across a wide diversity of traits.
Feed Value Evaluation in Grass – Poll - Eucarpia 2015 (J. Baert & H. Muylle)

6 Breeders / 6 evaluators / 4 nutritionists

• Is feeding value relevant in testing/breeding?
  Breeder/Evaluator: y/n, Nutritionist: only yes

• Which feeding value parameters?
  Breeder/Evaluator: digestibility, CP, WSC (if efficient methods)
  Nutritionists: 1º digestibility, NDF, WSC and reduced protein solubility,
  2º lipid content, DM%, vitamin/minerals

• What testing methods?
  Breeders: more efficient faster phenotyping needed,
  Evaluators: NIRS,
  Nutritionists: NIRS, SPAD chlorophyll meter

• Implementation for variety evaluation
  Breeders: weighted index (40% yld: 30% qual: 30% other);
  thresholds to protect from declines; only for information
  Evaluators: index set by variances, exclude high negative varieties
  Nutritionists: based on the predicted nutritive value of the trait gain
Cultivar Evaluation:

- A more multifactorial approach is now required to address ‘resilience’
- A number of evaluation schemes already use indices as performance indicators

- French small plot evaluation scheme, applies an index rating after cultivars are listed (Reglement technique d'examen des variétés de plantes fourragères et à gazon).

- Dutch Plantum index assigns weighting and scale factors (Protocol Beslissingen Opname en Afvoer Engels Raai Voeder 2017 Commissie Samenstelling Aanbevelende Rassenlijst)

- DairyNZ - Forage Value Index groups cultivars into star ratings annual values -$78 to +$29 (1 star) and +$351 to +$458 (5 star).

- Teagasc - Pasture Profit Index (PPI) - predicted economic values 2018 range €61-€225 ha\(^{-1}\) yr\(^{-1}\) (for cultivars recommended by Government DAFM),

- Teagasc - PastureBase Ireland (PBI) - 2017 network of 66 farms with 11 RL cultivars, under intensive grazing, a farmer decision support tool and database. (Byrne et al., & Hanrahan et al., 2017).

All use small plot trials & only 1\(^{st}\) traits but gain very strong engagement of farmers
Where Now for Resilience Breeding?

Penalties for failing to improve on a multifactorial ‘resilience’ strategy - substantial:

• Retain current weaknesses:
  - Grass protein use inefficiency: 20%
  - Energy inefficiency: 22%
    “not a product that is easy to sell and certainly not at a premium price”

• Resilient breeding business model?
  - Farm Gate Seeds Costs 1980 2018 RPI
    Perennial Ryegrass/WC £25 (€) £50 (€57) £102 (€116)

  - grass breeding - lowest earning seed business in Europe/globally (3% royalty)
  - Surveyed breeder/evaluator cited prohibitive cost of selecting/testing novel traits
  - moderate genomics - €300k training population, €100k/yr verify pheno/genotype
Where Now for Resilience Breeding?

Can we deliver improved multifactorial resilience?

Improving grass structural characteristics:
Considerable evidence of +ve livestock responses to specific characters, as detailed. Two easy measure examples:

- Leaf size: FLL - **3.6-6.1 cm** in length and **1.2-2.2 cm** in width, area of **1.7-3.3 cm²**. Shown to be: (McDonagh et al. 2017)
  - a good indicator of cattle grazing intake
  - differences correlated closely to spaced plant leaf length both when reproductive \( R^2 = 0.88 \) and vegetative \( R^2 = 0.99 \)
  - freely available and amenable to selection in breeders’ plant nurseries.

- Grazing efficiency:
  Tubritt et al EGF (2018) showed cultivars differed significantly in cattle grazing utilisation, with ‘residual grazed heights’ of **3.7** to **4.8cm**
  - simple mob grazing & rising plate use could provide a new measure of intake potential
Where Now for Resilience Breeding?

Can we deliver improved multifactorial resilience?

Improving grass chemical composition:
Again considerable published evidence of

- positive livestock responses to specific nutrient and energy balanced forages, as already detailed. Further examples:
- many studies report cultivar differences in, water soluble carbohydrate, crude protein, fatty acids, fibre digestibility, DM digestibility, (*Miller et al., 2001; Merry et al., 2006, Wilkins et al., 2000, Gilliland et al., 2002, Tas et al., 2005 Downing & French, 2009*)
- varying evidence/magnitudes of improved intake and animal outputs.

Opportunity for breeding intervention possibly by new NIRS & UAV scanning technologies on elite late generation material?
When? Now!

Potentially with a new **premium value** breeding business model?:

- **Changing farmer attitudes**: Unexpected implication of indices/on-farm trials (PBI) farmers sowing single cultivars not mixtures: experience of using single cultivar identified winners under grazing lead grassland farmers have expertise to manage loss in flexibility would create a more challenging seed market but cost-benefit driven

- **Premium Brands**: The ‘milchindex’ trademark has been successfully used by DSV to market cultivars of high digestibility and quality in Germany as a premium brand in an otherwise price sensitive market. However ‘mark-up’ is modest

- **Changing consumer attitudes**: ‘TRULY GRASS FED’ ([www.trulygrassfed.com](http://www.trulygrassfed.com)) A brand promoting “clean, wholesome dairy produce”, “**happy**, healthy cows”, **95% grass fed**

These typify the benefits breeders might gain if grass cultivars were specifically defined for animal performance potential and/or financial value

In the two surveys, breeders highlighted that

“Selection for quality is expensive and a return on investment is essential”

Leading farmers are already moving on – the time for breeders/evaluators is now!