Animal & Grassland Research and Innovation Centre
Moorepark

Moorepark Dairy Levy Research Update
Clonakilty Agricultural College
Moorepark Animal & Grassland Research and Innovation Centre

Tuesday 28th June, 2016

Series 31

Teagasc
Agriculture and Food Development Authority

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Principal's Welcome to Clonakilty Agriculture College

Majella Moloney

College Principal

Clonakilty Agricultural College locally known as Darrara College, has been involved in agricultural education since it was left to the local parish and later to the state for that purpose in 1905. Our aim is to train students for employment in the agricultural industry and to equip young entrants into farming with the knowledge and skills to become professional farmers. We are in partnership with Cork Institute of Technology and Institute of Technology Tralee to provide level 8 Agricultural Science degrees. Currently, we are providing training for 350 students between all of our courses. There is a balance of both school leavers and mature participants among the students. Students are trained in the theory and practice of Agriculture and business and get an opportunity to work in a practical way on farms as part of their training. Graduates of our courses not only return to farm the land but also contribute in many sectors of the Agricultural industry, including Co-Ops, trade suppliers, and Agricultural businesses.

The main purpose of the Open Day is to update dairy farmers of the research that has being carried out on the farm over the last three years. The overall aim of the research is to increase the efficiency of milk production from grazed pasture. You will see today significant progress being made over the last three years in achieving this goal. On behalf of Teagasc and Clonakilty Agricultural College, I welcome you here today and wish all involved a successful event.

Why white clover now?

Pat Dillon

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

Introduction

Ireland is in a very different milk production environment now compared with a number of years ago. Dairy farmers are no longer limited by the quantity of milk they produce; however, this is accompanied by volatile milk price. This is evident today with the very low milk price being paid to dairy farmers as a result of the downturn in global dairy markets. The most effective way to respond to the current crisis is to focus on the factors that are within your control. Ireland's competitive advantage in milk production hinges on maximising the contribution of grazed pasture – our cheapest feed resource. The current low milk price highlights the need to continue to focus on the basics of growing and utilising pasture efficiently. This means lowering production costs through a relentless focus on improved technical efficiency and in particular a re-emphasis on the role of pasture as the most cost-effective feed for dairy cows.

There are a number of factors that affect the quantity of pasture grown and utilised/ha on dairy farms. The quantity of pasture produced/ha will depend mainly on soil type, soil fertility, and the level of perennial ryegrass. The quantity of pasture utilised/ha will mainly depend on grazing infrastructure and grazing management, i.e. stocking rate, pre-grazing yields, grazing severity and rotation length. A major limitation to increased pasture production on many Irish dairy farms is due to insufficient use of lime, P and K. High levels of pasture production/ha will not be achieved without adequate levels of these key nutrients in the soil. High levels of pasture utilised/ha will not be achieved without the application of best grazing management practices. Teagasc has developed decision support tools to assist dairy farmers in achieving this; these include the spring rotational planner during the first grazing rotation; the feed wedge during the main grazing season and autumn feed budget in autumn/winter. PastureBase Ireland is now available as a web-based decision support tool that can help dairy farmers implement these best practices.

Why include white clover?

In 2010 Teagasc Moorepark initiated a research programme investigating the benefit of incorporating white clover into perennial ryegrass pastures for high stocking rate systems of milk production. These included a range of plot studies as well as two large farmlet studies - in Moorepark and Clonakilty. The Moorepark study is now in its fourth year comparing a grass-only system applying 250 kg N/ha to a grass-clover system applying 250 kg N/ha and a grass-clover system applying 150 kg N/ha, all stocked at 2.75 cows/ha. The Clonakilty study is now in its third year comparing diploid and tetraploid perennial ryegrass cultivars, with and without while clover stocked at 2.75 cows/ha. Previous research carried out at Solohead research farm had shown that a white clover ryegrass system stocked at 2.1 cows/ha with a nitrogen application rate of 90 kg/ha produced similar pasture DM production per hectare and milk yield per cow as a ryegrass only system at similar stocking rate with a nitrogen application rate of 250 kg/ha. The results from the current research can be summarised as following:

- Over three years a grass-clover system receiving 150 kg of N/ha produced similar grass DM production/ha as a ryegrass only system receiving 250 kg of N/ha (14.4 vs. 14.5 tonnes DM/ha respectively).
- A grass-clover system receiving 250 kg N/ha produced an extra 170 kg DM/ha in the Moorepark study and 1,850 kg DM/ha in the Clonakilty study compared to a grass-only system receiving similar N.
- The pasture production profile of a grass-clover system is significantly different to that of a ryegrass only system; similar pasture growth rates from February to May; higher pasture growth rates from May to October and lower pasture growth rates over the winter period compared to the grass-only systems.
- White clover content average 26% in the Moorepark study; 30% in the Clonakilty study; low levels in spring (<10%), increasing to a peak of 40-50% in late summer/early autumn.
- In the Clonakilty study perennial ryegrass ploidy had no significant effect on milk production, pasture DM production or clover content
- Animal performance has been consistently high in the grass-clover systems at similar stocking rates; +58 kg of MS/cow higher over two years in the Clonakilty study; +29 kg MS/cow over three years in the Moorepark study.
- Preliminary results to-date indicate that incorporating clover into a ryegrass pasture at similar or reduced nitrogen application rates had no effect on nitrate losses to ground water; research carried out at Solohead showed that replacing fertiliser N with white clover fixed nitrogen substantially lowered nitrous oxide emissions.
- The same grazing management practices developed for ryegrass pastures are equally applicable to grass-clover system. However, during the first grazing rotation in spring at similar high stocking rates there will be a requirement for an additional 150 kg of silage DM/cow for the grass-clover system.
- White clover can be incorporated in grassland either by direct reseeding or over-seeding using a recommended medium leaf size cultivar; it's important that established perennial weeds are controlled prior to establishment and post-establishment using a white clover friendly herbicide to control seedling weeds.
- The incidence of bloat was associated with pastures with clover content > 60%, low sward DM content and cows with an excessively high appetite when introduced to new pasture.

- In the future there will be a requirement to develop grazing strategies that avoid pastures with excessively high and low clover content.

The results of these studies indicate that incorporating white clover into ryegrass pastures has the potential to reduce costs (lower N input), increase animal performance (increase milk production per cow) and improve environmental sustainability (reduced nitrous oxide emissions). Further studies are planned to assure dairy farmers the benefit of incorporating white clover into their existing pastures, which includes on farm research.

The financial support for this research programme from Dairy Research Trust and state grants is gratefully acknowledged.

Clonakilty Update: The effect of tetraploid and diploid swards sown with and without white clover on the productivity of spring milk production systems

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[1]Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork; [1,2]Teagasc, Clonakilty Agricultural College, Darrara, Clonakilty

Summary

- White clover inclusion can increase milk (+ 784 and + 58 kg milk and milk solids per cow) and pasture dry matter (DM) production (+ 1.9 t DM/ha) in intensive pasture-based milk production systems.
- Perennial ryegrass ploidy had no affect milk or pasture dry matter production.

Introduction

The focus of this paper will be on the results of the first two years of the Clonakilty Agricultural College research experiment. The experiment was established in Clonakilty Agricultural College in 2012 and 2013. Seventy five percent of the experimental area was reseeded in 2012 and 25% reseeded in 2013. Four separate grazing treatments were sown on the experimental area, a tetraploid only sward (TO), a diploid only sward (DO), a tetraploid with clover sward (TC) and a diploid with clover sward (DC). Twenty blocks of paddocks (each block contained four paddocks) were created and to create the treatments, four diploid (Tyrella, AberChoice, Glenveagh and Drumbo) and four tetraploid (Astonenergy, Kintyre, Twymax and Dunluce) perennial ryegrass cultivars were sown as monocultures with and without white clover in five different blocks around the farm, thus creating a separate farmlet of 20 paddocks for each treatment. In the clover paddocks a 50:50 mix of chieftain and crusader white clover was sown at a rate of 5 kg/ha. There are 30 cows in each treatment group and treatments are stocked at 2.75 cows/ha, receive 250 kg of nitrogen (N) fertiliser per ha and target concentrate supplementation is 300 kg/cow for each treatment. Each farmlet is walked weekly to monitor average farm cover (AFC, using PastureBase Ireland) and when surpluses are identified they are removed in the form of baled silage. If a feed deficit occurs across all treatments, then all treatments are supplemented with concentrate. If a deficit occurs in an individual treatment then cows are supplemented with forage produced from within that treatment. As cows calved in 2014 and 2015 they were randomly assigned to their treatments and they remained on those treatments for the remainder of the grazing season within each year. The four treatments (swards) were rotationally grazed from mid-February until mid-November each year. The objective of the experiment is to compare milk and pasture production from tetraploid and diploid swards sown with and without clover. For the purpose of the paper the four individual treatments are referred to as TO, DO, TC and DC. When discussing the effect of grass-only (the mean effect of T and D; GO) versus grass-clover (the mean effect of TC and DC; GC) swards the terms GO and GC are used.

Pasture production

The effect of clover inclusion in the sward on daily pasture growth during the two years of the experiment is illustrated in Figure 1. Daily pasture growth rates for GO and GC swards were similar from January to May. However, from June to September GC swards had a 15 kg DM/ha per day greater daily pasture growth rate compared with GO swards. In October and November there was no difference in daily pasture growth rate between the GO and GC swards.

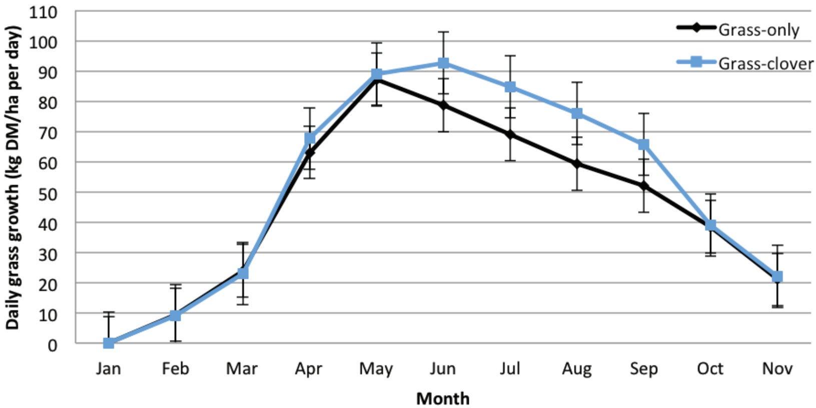

Figure 1: *The of effect sward type (grass-only and grass-clover) on daily pasture growth rates for each month over two years (2014 & 2015)*

The proportion of clover in the TC and DC swards is presented in Figure 2. There was no difference between TC and DC in terms of the proportion of clover in each sward and the profile of clover in both swards was consistent with the expected pattern of clover growth i.e. the proportion of clover in the sward is low in the spring and then increases to a peak in August and September. The average clover proportion was 28.3% and 30.7% for TC and DC swards, respectively during the two years of the experiment.

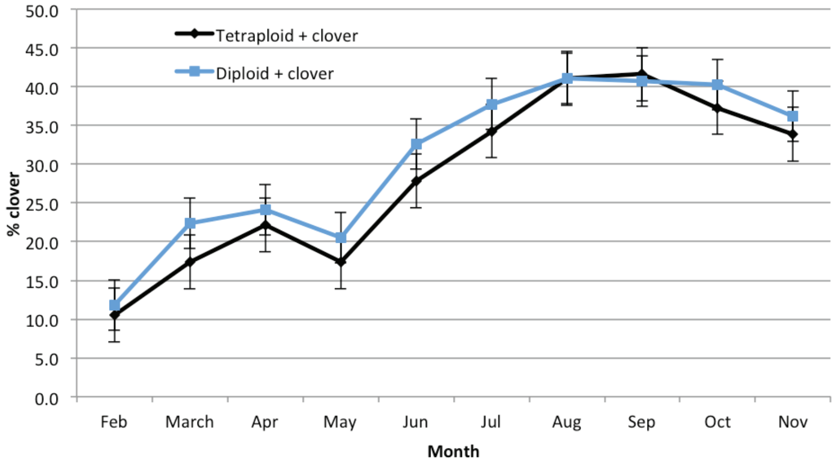

Figure 2: *Proportion of clover in the tetraploid + clover and diploid + clover swards for each month over two years (2014 & 2015)*

The effect of treatment on grazing characteristics and pasture DM production during the two years of the experiment is presented in Table 1. Ploidy had an effect on DM content, post-grazing height and pasture allowance as the diploid treatments (DO and DC) had greater DM content (18.5% vs. 17.6%), pre-gazing yield (1,789 vs. 1,696 kg DM/ha), post-grazing height (4.25 vs. 4.06 cm) and pasture allowance (17.1 vs. 16.0 kg DM/cow per day) than the tetraploid (TO and TC) treatments. Clover inclusion had a significant effect on sward DM content as the GC swards had a lower DM content than the GO swards (16.7% vs. 19.3%). Clover also had an effect on post-grazing height as the GO swards had a greater pre- and post-grazing height compared with GC swards (9.10 and 4.38 cm compared with 8.78 and 3.93 cm, respectively). Ploidy had no effect on pasture DM production, pasture utilisation or winter feed production, however, clover had a significant effect. Total pasture DM production was 1.9 t DM/ha greater on the GC swards compared with the GO swards over the two years. As a consequence, winter feed production (+ 0.23 t DM/cow) was greater on the GC swards in comparison with the GO swards.

Table 1. The effect of treatment on grazing characteristics and pasture DM production over two grazing seasons (2014 & 2015)

	Treatment[1]			
	TO	DO	TC	DC
Dry Matter (*DM; %*)	18.7	20.0	16.4	17.0
Pre-grazing height (*cm*)	8.98	9.13	8.79	8.78
Pre-grazing yield[2] (*kg DM/ha*)	1,792	1,901	1,601	1,678
Post-grazing height (*cm*)	4.26	4.50	3.87	4.00
Pasture allowance[3] (*kg DM/cow/day*)	16.4	17.7	15.6	16.6
Pasture disappearance (*kg DM/cow/day*)	15.3	15.7	16.2	16.7
Pasture DM production				
Grazing pasture DM (*t DM/ha*)	11.3	11.1	12.3	12.1
Silage pasture DM (*t DM/ha*)	4.2	4.3	5.2	5.1
Total pasture DM (*t DM/ha*)	15.5	15.5	17.5	17.2
Winter feed produced (*t DM/cow*)	1.12	1.18	1.38	1.36

[1]TO = tetraploid only; DO = diploid only; TC = tetraploid + clover; DC = diploid + clover; [2]Measured above 4 cm

Milk production

Average concentrate supplementation across all treatments was 338 kg/cow during the two years of the experiment. Average silage fed during lactation to the GC was significantly greater (360 kg DM/cow) compared with the GO cows (314 kg DM/cow). The effect of treatment on milk production during the two years is presented in Table 2. Ploidy had no significant effect on any of the milk production variables. Clover had a significant effect on all milk production variables with the exception of days in milk, fat and protein content. Both milk and milk solids yield per cow and per ha were greater for cows on GC treatments compared with the GO treatments. Cows on GC treatments produced 784 kg and 58 kg more milk and milk solids than cows on the GO treatments which resulted in an extra 2,156 kg and 168 kg milk and milk solids yield per ha. Neither ploidy nor clover content had an effect on body weight or body condition score. Daily milk yield per cow for the GO (TO and DO) and the GC (TC and DC) treatments by week of lactation is presented in Figure 3. The GC treatments had greater daily milk yield per cow than the GO treatments from week 10 of lactation onwards.

Table 2. The effect of treatment on milk production variables over two years (2014 & 2015)				
	Treatment[1]			
	TO	DO	TC	DC
Days in milk (*days*)	276	277	277	277
Milk yield (*kg/cow*)	4,972	4,994	5,783	5,750
Fat (*g/kg*)	46.9	46.4	46.2	46.1
Protein (*g/kg*)	38.2	37.4	37.4	37.4
Lactose (*g/kg*)	47.7	47.7	48.2	48.4
Milk solids yield (*kg/cow*)	420	423	481	478
Milk yield (*kg/ha*)	13,673	13,732	15,904	15,814
Milk solids yield (*kg/ha*)	1,162	1,145	1,328	1,316
Bodyweight (*kg*)	505	494	505	513
Body condition score (*units*)	2.97	2.90	2.93	2.95

[1]*TO = tetraploid only; DO = diploid only; TC = tetraploid + clover; DC = diploid + clover*

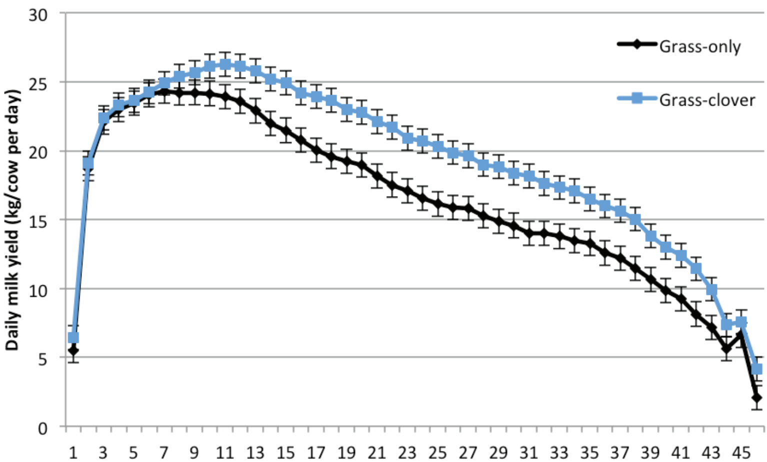

Figure 3: *Daily milk yield for the grass-only (tetraploid only and diploid only) treatments and grass-clover (tetraploid + clover and diploid + clover) treatments during the two years*

Conclusion

Perennial ryegrass ploidy did not affect milk or pasture DM production. However, white clover inclusion had a significant effect. Both milk (per cow and per ha) and pasture production were greater on the GC swards compared with the GO swards. The experiment demonstrates the potential of white clover to improve the productivity of pasture-based production systems in Ireland.

Crossbreeding to increase profit

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Summary

- High EBI crossbred dairy cattle outperform high EBI purebred contemporaries both within research studies and on commercial dairy farms
- Based on on-farm data, heterosis estimates for Holstein-Friesian Jersey F1 crossbred cows were + 25 kg milk solids (kg fat + protein), -7.5 days in calving interval and + 3.5% survival and was equivalent to between €100-150 additional profitability per cow per year.
- Dairy farmers should consider the significant added benefits of heterosis from cross breeding strategies in addition to the selection of high EBI dairy sires to maximise genetic progress within dairy herds.

The value of EBI

The EBI was introduced in 2001 by ICBF and Teagasc, against a back-drop of declining animal and herd fertility performance in the national dairy herd. Since then, the index has evolved to incorporate some 15 traits in total, the most important of which are female fertility, cow survival and milk solids production (kg fat and protein), with these traits having a combined weighting of about 70% of the overall index. Recent work presented at the Teagasc National Dairy conference compared the performance of 10,470 dairy herds that had herd EBI, female fertility and milk co-op performance data available. The results clearly demonstrated the value of EBI across the 10,470 dairy herds, with higher EBI herds consistently having much better fertility performance. Trends in milk performance delivered to the co-op, were also better for the higher EBI herds. It is important to note that this analysis was across all herds, regardless of breed. Therefore the clear message from this analysis was that dairy farmers should decide their breed preference, and then look to maximise the EBI within that breed.

Fundamentals of crossbreeding

The two primary reasons to crossbreed are: 1) to introduce favourable gene variants from another breed selected more intensively for traits of interest, and, 2) to capitalise on what is known as heterosis or hybrid vigour. The first point relates to additive genetic differences between breeds (e.g. breed differences in milk yield, milk composition, size, beef merit, fertility, mastitis resistance, intake capacity and feed efficiency). Heterosis refers to the phenomenon that occurs when divergent animal genotypes are mated, resulting in synergies that allow crossbred animals to perform better for certain traits than that expected based on the average of their parents.

Heterosis alone will not guarantee success in a crossbreeding programme. To avail of the full benefits of heterosis, a team of high EBI dairy sires of multiple breeds must be used to deliver hybrid vigour in addition to additive genetic progress.

Estimates of heterosis vary in magnitude depending on the trait being examined, and the genetic distance between the breeds being crossed. Heterosis for production traits such as milk yield or bodyweight/ growth rate is usually in the range 0 to 5%, whereas heterosis for traits related to fertility is usually in the range 5 to 25%. Milk composition is generally not influenced by heterosis, and therefore improvements in solids yield is due to the influence on milk volume. Heterosis will generally be higher in traits related to fitness and health i.e. traits that have lower heritability's. In New Zealand, crossbred cows (Jersey x Friesian) survive 227 days longer (almost one lactation more) compared with the average of the parent breeds. This equates to almost 20% hybrid vigour.

A big question form dairy farmers that have crossbred their cows is "where to after the first cross?" The three most common breeding strategies are:

- Two-way crossbreeding. This is where the first cross cow is mated to one of the initial parent breeds used. In the short term heterosis is reduced but after a number of generations it will settle at 66.6%.
- Three-way crossbreeding. In this scenario, a high EBI sire of a third breed is introduced into the breeding strategy. When the first cross cow is mated to a sire of a third breed heterosis is maintained at 100%. However, when sires from the same three breeds are used again in subsequent generations, heterosis levels out at 85.7%.
- Synthetic crossing. This involves the use of high EBI crossbred bulls. In the long term a new synthetic breed is created. Heterosis in this strategy is reduced to 50% initially and is reduced gradually with time.

Crossbreeding research in Moorepark

The earliest research into crossbreeding in Moorepark was conducted at Ballydague research farm during the period 2006 to 2010. This experiment compared both pure-bred Jersey and Holstein-Friesian cows in addition to crossbred (Jersey × Holstein-Friesian) cows. Clear benefits from crossbreeding were observed (Table 1). The proportion of cows pregnant to first service (+ 21%), in-calf rate after six weeks breeding (+ 19%) and in-calf rate after 13 weeks breeding (+ 8%) were considerably higher for the Jersey × Holstein-Friesian compared with the pure-bred Holstein-Friesian and Jersey cows. The economic analyses (incorporating differences in cull cow and male calf value) of this experiment showed that with a fixed land base the herd of Jersey × Holstein-Friesian cows was 48% more profitable than a herd of either of the parent breeds. On a per cow basis, the improved profit equated to over €180 per cow per lactation.

Table 1. Effect of breed group on milk production and reproductive performance in Ballydague between 2006 and 2010

	Breed group		
	Holstein-Friesian	Jersey	Jersey x Holstein Friesian
Milk yield (kg)	5,342	4,233	4,973
Fat %	4.06	5.26	4.72
Protein %	3.51	4.04	3.81
Milk solids[1] yield (kg)	407	392	424
Pregnancy rate to 1st service (%)	47	41	62
In-calf rate at six weeks (%)	56	51	70
In-calf rate at 13 weeks (%)	82	76	90

[1]*Milk solids = kg fat + kg protein*

Three more recent experiments have investigated further the effect of crossbreeding on performance at farm level and in controlled research experiments in Curtin's farm and Clonakilty Agricultural College. The first experiment compared milk production and fertility performance of Holstein, Friesian, and Jersey purebred cows, and their respective crosses in 40 Irish spring-calving commercial dairy herds from the years 2008 to 2012. Data on 24,279 lactations from 11,808 cows were available. This experiment represents the first evaluation of crossbred and straight bred cattle within commercial high EBI dairy herds, and again the results are consistently in line with the research findings from Teagasc research herds.

Milk yield was greatest for Holstein (5,217 kg), intermediate for Friesian (4,591 kg), and least for Jersey (4,230 kg), whereas milk constituents (i.e., fat and protein concentration) were greatest for Jersey (9.38%), intermediate for Friesian (7.91%), and least for Holstein (7.75%). Milk solids yield in crossbred cows exceeded their respective parental average performance: Jersey × Holstein-Friesian cows produced 25 kg milk solids per cow per year more than the mean of high EBI purebred Holstein-Friesian and Jersey cattle (6.5% heterosis). There was no consistent breed effect on the reproductive traits investigated. However, the crossbred cows achieved a 7.5 day shorter calving interval and had 3.5% higher survival rates compared to the purebred contemporaries within these herds. This corresponds to a considerable profit increase (economic heterosis) of between €100-150 /cow per lactation.

In the second experiment, in Curtin's farm, the objective was to investigate the effect of stocking rate and breed on milk production in spring calving pasture-based dairy systems. Four hundred and seventeen dairy cows (68 Holstein-Friesian and 71 Jersey x Holstein-Friesian crossbred cows in 2013, 2014 and 2015, respectively) were randomly assigned within breed to one of three stocking rates in order to achieve similar bodyweight per ha (BW/ha) across the two breeds. The three stocking rates were low (LSR; 1,200 kg BW/ha), medium (MSR; 1,400 kg BW/ha) and high (HSR; 1,600 kg BW/ha). Due to the lower bodyweight of the Jersey x Holstein crossbreds this effectively meant that the stocking rate in terms of cows/ha was higher for the crossbreds i.e. there was an extra 0.1 cows/ha for the Jersey x Holstein-Friesian herds compared to the Holstein-Friesian at each level of stocking rate. The results from the three years of the experiment to date are presented in Table 2. The LSR achieved the greatest milk and milk solids yield per cow, whereas HSR was least. At similar stocking rates (BW/ha), Holstein-Friesian cows had a greater milk yield per cow than Jersey x Holstein-Friesian crossbreds. In contrast, the Jersey x Holstein-Friesian crossbreds had a greater milk solids yield per cow and per ha at each SR. In summary, the Jersey x Holstein-Friesian crossbred cows are delivering an additional 92 kg milk solids per ha annually.

Table 2. Effect of stocking rate (kg bodyweight/ha) and breed on milk production over three years in Curtin's (2013-2015)

SR	Low		Medium		High	
Breed	HF1	Jx[2]	HF	Jx	HF	Jx
Milk yield/cow (*kg*)	5,465	5,066	5,113	4,818	4,947	4,698
Milk yield/ha (*kg*)	13,025	12,684	14,945	14,710	16,353	16,108
Milk solids[3]/cow (*kg*)	454	460	420	434	403	418
Milk solids/ha (*kg*)	1,087	1,154	1,227	1,332	1,332	1,437

[1]HF = Holstein-Friesian, [2]Jx = Jersey x Holstein-Friesian crossbred, [3]Milk solids = kg fat + kg protein

The third experiment, at Clonakilty Agricultural College, has included a comparison between three breeds, pure-bred Holstein-Friesian, Jersey × Holstein-Friesian and Norwegian Red x Jersey × Holstein-Friesian (3way) crossbreds. This experiment has now run for three years at this point and the results are consistent with the previous two experiments in that the Jersey x Holstein-Friesian crossbred cows are delivering slightly more milk solids per cow per lactation (457 kg vs. 449 kg; Table 3) and have superior reproductive performance. The pregnancy rate to first service (+ 18%) and in-calf rate at six weeks (+ 11%) was greater for the Jersey x Holstein-Friesian cows compared with the other two breeds. The 3way cross cows have performed well with similar levels of milk solids production and reproductive performance to the Holstein-Friesian cows and they have improved consistently year on year in terms of their performance on the farm.

Table 3. Effect of breed group on milk production and reproductive performance in Clonakilty between 2013 and 2015

	Breed group		
	HF[1]	Jx[2]	3way[3]
Milk yield (kg)	5,583	5,365	5,176
Fat %	4.42	4.73	4.76
Protein %	3.66	3.79	3.83
Milk solids[4] yield (kg)	449	457	444
Pregnancy rate to 1st service (%)	56	74	60
In-calf rate at six weeks (%)	76	87	76
In-calf rate at 13 weeks (%)	92	94	96

[1]HF = Holstein-Friesian, [2]Jx = Jersey x Holstein-Friesian crossbred, [3]3way = Norwegian Red x Jersey x Holstein-Friesian crossbred, [4]Milk solids = kg fat + kg protein

Summary

Crossbreeding has the potential to make a significant contribution to the Irish dairy industry in the future. While crossbreeding is not for everyone, it is very clear from Teagasc research that crossbreeding in the dairy herd can very quickly improve traits such as fertility and productivity, and has a favourable effect on profit generating ability.

The influence of grass ploidy, autumn closing date, and spring turnout date on winter growth of ryegrass-white clover pastures

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Summary

- Clover inclusion in swards reduces pasture production over-winter
- Ploidy does not affect over-winter pasture dry matter (DM) yield and sward white clover content
- Closing date has an effect on pasture DM yield and clover content

Introduction

White clover (*Trifolium repens L.*; hereafter referred to as clover) is at a competitive disadvantage to perennial ryegrass (Lolium perenne L.) due to its limited cold tolerance and low growth rate at lower temperatures. The effect of both ploidy and autumn closing cover on clover morphology and growth over-winter, and its subsequent recovery in spring and the following growing season is little understood. Thus identifying the morphological characteristics that contribute to winter growth and survival is important. Such knowledge could indicate key plant and management factors that enhance spring growth potential. Two experiments were undertaken with the objective of understanding the key drivers in clover winter survival and its subsequent grazing seasons' productivity. The first experiment focused on the effect of ploidy and clover on over-winter growth (the Clonakilty experiment), while the second experiment focused on the effect of varying closing dates and opening dates on pasture DM yield and clover content (the Moorepark experiment).

The experiments

The Clonakilty experiment was undertaken at Clonakilty Agricultural College. This experiment consisted of four treatments (tetraploid-only; (T), diploid-only (D), tetraploid-clover (TC) and diploid-clover swards (DC)). Pasture DM yield, clover content, tiller density, tiller height, sheath height and leaf, stem and dead components of the sward were measured throughout the winter period of 2014-2015. When discussing the effect of grass-only (the mean effect of T and D; GO) versus grass-clover (the mean effect of TC and DC; GC) swards in this experiment, the terms GO and GC are used. As a result of the findings from the Clonakilty experiment, it was decided to undertake another over-winter study. So the Moorepark experiment was undertaken at Moorepark, Fermoy, and consisted of four closing dates (21st September; 12th October; 2nd November; 23rd November), and two opening dates (22nd February; 21st March). Pasture DM yield, clover content, tiller density and leaf, stem and dead components of the sward were measured throughout the winter period of 2015-2016.

Results

The Clonakilty experiment

There was no difference between D and T swards in terms of average over-winter pasture DM yield (Figure 1; T: 646 kg DM/ha, D: 678 kg DM/ha), or winter sward clover content (Figure 1; TC: 23.0%, DC: 23.0%). Pasture DM yield was significantly reduced by clover inclusion, with grass-only swards having greater pasture DM yield (789 kg DM/ha) compared with GC swards (534 kg DM/ha). Tiller density was also reduced by the inclusion of clover in the swards. Grass-only swards had approximately 1,953 more tillers per metre^2 (tillers/m^2) than GC treatments (GO: 4,789 tillers/m^2; GC: 2,837 tillers/m^2). Diploid swards had 773 additional tillers per m^2 than tetraploid swards (D: 4,195 tillers/m^2; T: 3,426 tillers/m^2).

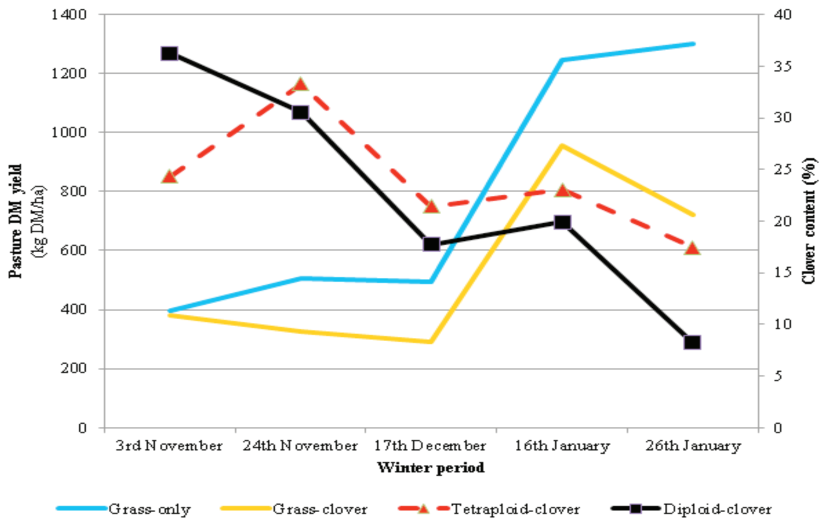

Figure 1: *Average pasture DM yield (kg DM/ha) across all measurement dates for grass-only (▬ tetraploid-only and diploid-only) and grass-clover (▬ tetraploid-clover and diploid-clover) swards, and the average clover content (%) across all measurement dates for each clover treatment (tetraploid-clover (▲); and diploid-clover (■)) in the Clonakilty experiment*

The Moorepark experiment

Closing date had a significant effect on pasture DM yield available on the 22nd February, but no differences between pasture DM yields were found on the 21st March. The sward clover content at both opening dates was affected by the closing date. Clover content was greatest for the plots closed later in the season, and for plots opened later during the following spring. Plots closed on the 12th October and opened on the 22nd February had the lowest clover content (0.81%), whereas those closed on the 23rd November and opened on the 21st March had the greatest clover content (3.85%). The clover contents presented are considerably lower than normal levels, possibly due to lower growth rates during the spring. However, on the 10th of May clover contents in the plots had recovered, and were on average 11%. On the 10th of May, plots closed later in the autumn had the greatest clover content (14.9%), whereas the plots closed earliest in autumn had lower clover content (10.2%). There was little difference in plots opened on the 22nd February, and 21st March in terms of clover content.

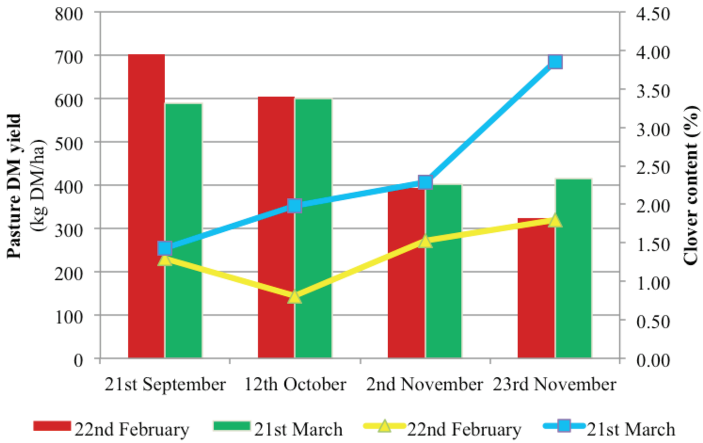

Figure 2: *Average pasture DM yield (kg DM/ha) at both opening dates (22nd February ■ 21st March ■), and their corresponding closing dates. Average sward clover content (%) estimated at each opening date (22nd February (■); 21st March (■)), and their corresponding closing dates in the Moorepark experiment*

Conclusion

In the Clonakilty experiment, perennial ryegrass ploidy had no effect on pasture DM yield, or sward clover content during the winter, despite differences in tiller density. However, clover caused a significant decrease in pasture DM yield and tiller density during this period. The implications of these differences on spring pasture production remains to be determined. Poor winter growth of the grass-clover swards may in turn indicate poor spring DM production. The preliminary results of the Moorepark experiment indicate that closing swards later in the growing season may enhance clover survival during the winter period. Along with this, swards opened later in the spring had increased clover content when compared with those opened a few weeks earlier. Later opening dates did not result in increased pasture availability for grazing, and as Figure 2 indicates there was little difference between the pasture available at the early and late opening date. Further studies should be undertaken to investigate the influence of poor winter growth on subsequent grazing season productivity in grass-clover swards.

Moorepark update: Pasture production and dairy cow milk production from a perennial ryegrass and mixed perennial ryegrass and white clover swards in a high stocking rate system

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Summary

- Annual milk solids (kg fat + protein: MS) production can be increased by up to 31 kg MS/cow when average annual sward clover content is 20%
- Annual pasture production was similar in a grass-clover sward receiving 150 kg N/ha to that in a grass-only sward receiving 250 kg N/ha
- Frequent tight grazing (4 cm above ground level) of grass-clover swards will encourage clover persistence in nitrogen (N) fertilised grazed swards

Introduction

Pasture-based milk production systems in Ireland rely on N fertiliser to ensure an adequate supply of high quality pasture to feed dairy cows for most of lactation. Nitrogen fertiliser use in Ireland is limited under the Nitrates Directive. Farms with high stocking rates (>2.5 LU/ha) have a high pasture demand, and therefore have a requirement for extra N for pasture growth. White clover (*Trifolium repens L.*; clover) has the ability to fix atmospheric N and make it available for pasture growth. Strategic use of N fertiliser on grass-clover swards can compensate for low clover growth rates in spring. Clover also has the potential to increase milk production. Previous research has shown that milk production is greater on grass-clover swards compared to grass-only in the second half of the year (June onwards).

Grazing experiment

A farm systems experiment was established at Teagasc, Animal and Grassland Research Innovation Centre, Moorepark, Fermoy, Co. Cork in 2013. This experiment is comparing pasture and milk production from a grass-only sward receiving 250 kg N/ha/year (Grass250) and grass-clover sward receiving 250 kg N/ha/year (Clover250) or 150 kg N/ha/year (Clover150). Each treatment is stocked at 2.74 cows/ha. All swards receive similar N fertiliser until May. From then onwards N fertiliser application is reduced on the Clover150 treatment. All three treatments have a similar rotation length, target pre-grazing pasture mass in mid-season is 1,300 to 1,500 kg DM/ha, and target post-grazing sward height is 4.0 cm.

Results are available for the three year period 2013 to 2015. Pasture production was similar across the three treatments – 14,527 kg DM/ha per year (Table 1). Average sward clover content was 28% for the Clover150 treatment and 24% for the Clover250 treatment. The reduction in N fertiliser resulted in a 4% increase in sward clover content on the Clover150 treatment (Figure 1). The sward clover content on Clover250 treatment is higher than previously reported at that N fertiliser application rate, most likely due to the increased grazing intensity imposed in the current study. Intensive grazing ensures that pre-grazing pasture mass rarely exceeds 1,500 kg DM/ha and grazing to 4.0 cm allows light to penetrate to the base of the sward by reducing the shading of clover plants and therefore promoting clover stolon growth and persistence.

Milk solids production was greater on the clover treatments (508 kg MS/cow and 514 kg MS/cow on the Clover150 and Clover250 treatments, respectively) compared with the Grass250 treatment (482 kg MS/cow) (Figure 1). The difference in milk solids production was due to increased milk yield on the clover treatments compared to Grass250 as milk fat and milk protein contents were similar for all treatments. The clover treatments produced an additional 72 to 88 kg MS/ha compared with the Grass250 treatment (Table 1).

Table 1. Daily and cumulative milk production from and cumulative pasture production on grass-only swards receiving 250 kg N/ha (Grass250) and grass-clover swards receiving 150 kg N/ha and 250 kg N/ha (Clover150 and Clover250, respectively) and average sward clover content for the experimental period (2013 to 2015)

	Clover 150	Clover 250	Grass 250
Milk yield (*kg/cow/d*)	23.0	23.7	21.9
Milk solids (*kg/cow/d*)	1.84	1.87	1.75
Milk fat (%)	4.60	4.53	4.61
Milk protein (%)	3.60	3.57	3.64
Cumulative milk solids (*kg/cow*)	508	514	482
Cumulative milk solids (*kg/ha*)	1,392	1,408	1,320
Annual herbage production (*kg DM/ha*)	14,410	14,670	14,500
Clover content (%)	28.0	24.0	-

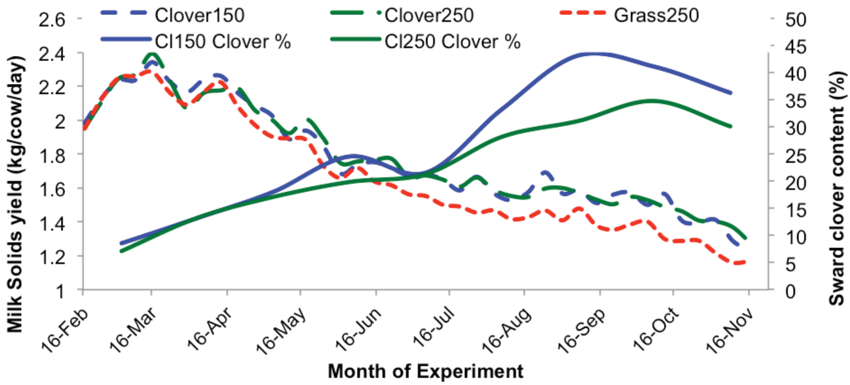

Figure 1: *Average (2013-2015) daily milk solids production (kg MS/cow) from a grass-only sward receiving 250 kg N/ha (Grass250), and grass-clover swards receiving 250 kg N/ha (Clover250) or 150 kg N/ha (Clover150) and sward clover content for Clover250 and Clover150*

Conclusions

Clover had a positive effect on milk production regardless of N fertiliser application rate. Clover inclusion into PRG swards had no effect the on total pasture production. However, reducing N fertiliser application in mid-summer on the Clover150 treatment resulted in an increase in sward clover content compared with Clover250. This offers a considerable potential saving to the farmer in terms of reduced N fertiliser application.

Acknowledgements

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Benefits of including white clover in N fertilised grass swards

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Summary

- Including white clover in grass swards receiving up to 250 kg N/ha can increase total annual pasture production by 2.9 t DM/ha
- Sward white clover content varies across the year; it is lowest in spring, increases to a peak in late summer, and then begins to decline during autumn
- Nitrogen fixation decreased as N fertiliser application increases and sward white clover content decreases
- Frequent tight grazing (4 – 4.5 cm above ground level) of grass-clover swards will encourage white clover persistence in grazed swards

Introduction

The Irish dairy industry relies on N fertilised perennial ryegrass swards to provide feed for dairy cows for most of lactation. White clover is not widely used on dairy farms. Currently there is increased interest in white clover as the cost of nitrogen fertiliser continues to increase, and application rates are limited under the Nitrate Directive. Clover fixes atmospheric N and makes it available for grass growth. Some of the previous research, and on-going Moorepark and Clonakilty research, in this area have shown that including clover in grass swards can increase milk production, particularly in the latter half of lactation. Clover growth is very seasonal, and therefore its contribution to sward pasture mass varies across the year. It is lowest in spring, peaking in late summer and declining during autumn.

Including white clover in fertilised grass swards

Poor clover persistence in N fertilised swards is one of the main reasons why clover is not widely used on dairy farms. However, good grazing management (18 to 21 day rotations mid-season; 4 – 4.5 cm post grazing sward height) is likely to benefit clover persistence. A four year grazing plot (8 m × 8 m) experiment was undertaken at Moorepark from 2010 to 2013. The experiment had two sward types (grass-only and grass-clover), and five N fertiliser application rates (0, 60, 120, 196 and 240 kg N/ha). Swards were grazed nine times in 2010 and 10 times in 2011 and 2012, and eight in 2013. Pre-grazing pasture mass and sward clover content were measured prior to each grazing. Nitrogen fixation was measured in 2011, 2012 and 2013 by subtracting the N yield of the grass-only from that of the grass-clover of the same N application rate.

Results

Across the four years of this experiment, regardless of N fertiliser application rate, the quantity of pasture removed by grazing animals from the swards increased by 2,900 kg DM/ha when clover was included in the sward (Table 1). The difference ranged from 4,230 kg DM/ha when zero N fertiliser was applied (9,080 kg DM/ha on grass-only and 13,310 kg DM/ha on grass-clover) to 1,790 kg DM/ha when 240 kg N/ha were applied (12,630 kg N/ha and 14,420 kg N/ha). As N fertiliser application rate increased, average annual sward clover content declined from 33.3% when 0 kg N/ha was applied to 19.6% when 240 kg N/ha was applied.

Nitrogen fertiliser application rate reduced the quantity of N fixed on the grass-clover swards in all years (2011-2013; Figure 1). The average quantity of N fixed across the three years was 220 kg N/ha when zero N fertiliser was applied, declining to 112 kg N/ha when 240 kg N/ha were applied. As sward clover content increased, N fixation also increased.

Table 1. Average annual pasture removed (kg DM/ha) and average sward clover content (%) from grass-only and grass-clover swards receiving 0, 60, 120, 196 and 240 kg N/ha per year between 2010 and 2013

Pasture removed (kg DM/ha per year)	N application rate (kg N/ha per year)				
	0	60	120	196	240
Grass-only	9,080	9,200	10,980	11,310	12,630
Grass clover	13,310	13,050	13,100	13,760	14,420
Sward clover content (% of DM)	33.3	30.6	27.0	21.7	19.6

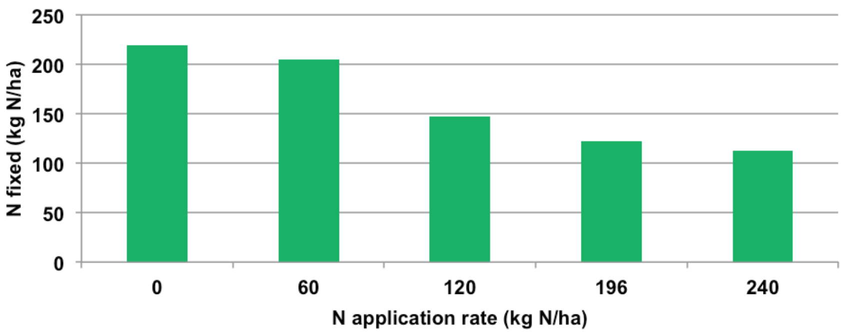

Figure 1: *The effect of N fertiliser application rate (kg N/ha) on the quantity of N fixed (kg N/ha; average of 2011-2013)*

Conclusions

Clover inclusion into perennial ryegrass swards resulted in an average increase of 2,900 kg DM/ha harvested pasture regardless of N fertiliser application rate. Sward clover content and N fixation decreased as N fertiliser application rate increased on grass-clover swards. The grazing management used in this experiment reduced the negative effect of N fertiliser application rate on sward clover content. The increased pasture production associated with incorporating clover in the sward offers potential for dairy farmers to reduce N fertiliser use, and therefore costs, as well as positive environmental impacts when compared to the commonly used N fertilised grass only swards.

Acknowledgements

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Establishing of white clover on grassland farms

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Summary

- White clover establishment requires high soil fertility; P and K index of ≥ 3 and soil pH ≥ 6.3
- Over-sowing can be a less expensive method of establishing white clover but requires excellent grazing management and suitable climatic conditions
- Pre-grazing covers should be kept < 1200 kg DM/ha and post-grazing sward height ≤ 4.0 cm in the establishment phase of a white clover/ ryegrass pasture

Introduction

The benefit of white clover in grassland in terms of savings in nitrogen fertiliser and increased animal performance has previously been shown in this booklet. With some farmers interested in incorporating clover into the grazing system, the question arises how you get clover into your swards. Direct reseeding is very successful method; however this will take a number of years to establish clover over the entire grazing area. A simple and low cost method of introducing white clover onto your farm is to over-sow the seed into existing grass swards.

Soil Fertility

Clover will establish and persist only on high fertility soils. Rhizobia bacteria that fix N in association with clover are more productive in soils with a pH of greater than 6.3. The phosphorus (P) content of the soil is also important when establishing a clover sward. White clover seeds are very small and clover seedlings tend to be relatively fragile. Seedling vigour is favoured by having plenty of P in the vicinity of the establishing seedling. It is usually recommended that clover seed is broadcast with a fertiliser that contains P fertiliser as this will favour establishment; generally 0-7-30 or 0-10-20 is recommended.

How to establish a clover sward on your farm

Clover can be established on your farm using two methods; 1) Direct reseeding, 2) Over-sowing.

Direct Reseeding

- Key steps involved in a full reseed:
- Take a representative sample of soil for P, K and pH analysis; if ploughing take sample subsequent to doing so
- Spray off the old pasture with a minimum of 5 L per ha of Glyphosate; allow 7 - 10 days after spraying before cultivating
- Avoid ploughing too deep (15 cm) as it can reduce soil fertility
- Prepare a fine, firm seedbed and apply lime, phosphate and potash as per soil test results
- Sow perennial ryegrass (27-34 kg/ha) and white-clover (1 to 3 kg/ha) seed mix
- Avoid sowing clover seed too deep as clover seed has a poor seed reserve – approx. 10 mm
- Ideally cover seeds and roll well to ensure good contact between the seed and the soil

Over-sowing

Over-sowing is a simple and low cost method of introducing white clover onto your farm. Success is very much dependent on weather conditions around sowing, therefore there is a certain amount of risk associated with this approach.

Key steps involved with over-sowing white clover;

- When over-sowing, the clover seed can be broadcast onto the sward or stitched in using a suitable machine (Einbock pneumatic seeder)
- Best practice to over-sow directly after grazing (≤ 4 cm post-grazing sward height) or after cutting the paddock for surplus bales – it is not recommended to over-sow clover into dedicated silage paddocks
- A slightly higher seeding rate (3.5 to 5 kg/ha) is recommended for over-sowing compared to a full reseed, to overcome the issues with slugs and a lower germination rate
- Sow with a fertiliser that contains P fertiliser as this will favour establishment particularly is soil fertility is poor
    - 1 bag of 0-7-30 or 0-10-20/acre
    - If possible reduce N fertiliser post over-sowing
- Soil contact post-sowing is one of the most crucial factors effecting germination
    - Roll paddocks post-sowing to ensure soil contact
    - Apply watery slurry (if available) – ideally around 2,000 gals/acre
- Ideally over-sow on well managed grassland – not suitable on old ‘butty’ swards with a low content of perennial ryegrass – if this is the case a full reseed is best practice

Table 1. Recommended white clover cultivars to include in grazing seed mixes

Clover Cultivar	Leaf Size	Clover Content	Grazing Enterprise
Aberace	Small	27%	Sheep/Cows
Chieftain	Medium	39%	Cows
Buddy	Medium	34%	Cows
Iona	Medium	36%	Cows
Crusader	Medium	34%	Cows
Aberherald	Medium	35%	Cows

Management of grass-clover swards after over-sowing

Poor establishment results have been obtained where the grass can get too strong after over-sowing. This is the single biggest reason for failure that lies within the farmer's control. Swards need to be grazed tight after over-sowing white clover. The single most important recommendation, is tight grazing for the first 3 grazings post sowing, both for direct reseeding and over-sowing, keeping pre-grazing pasture mass < 1,200 kg DM and grazing swards to < 4 cm. By doing this it allows light to penetrate to the base of the sward which is essential for clover establishment. Soil moisture conditions have a major influence on the success of over-sowing. In general, highest rates of rainfall are recorded during the winter and lowest rainfall during May, June and July. To improve the chances of success on drier soils it is recommended that over-sowing is carried out in late April or early May. Ideal circumstances would be paddocks where surplus grass is removed as baled silage.

Weed control is an essential element in both direct reseeding and over-sowing. Weeds in new reseeds are best controlled when grass is at the 2-3 leaf stage. Docks and chickweed are two of the most critical weeds to control in new reseeds; it is important to control these at the seedling stage, by applying the herbicide before first grazing. When clover is included in the swards, it is important to use a clover safe herbicide (Table 2). When over-sowing clover into existing grass swards, it may be better to control more established weeds before over-sowing the clover into the sward. If you are considering this it is important to consider the residue time from application of the spray to over-sowing the clover, as it can vary from one month to four months. It is important to contact your merchant if doing this. All pesticides users should comply with the regulations as outlined in the Sustainable Use Directive (SUD).

By ensuring the above steps are carried out successfully, clover content in the sward can equate to >15% of the sward make up the following year. The grazing management in subsequent years is also of critical importance to ensure the persistence of clover in the sward.

Table 2. List of clover safe herbicides in established swards and new leys

Product	Clovermax	Eagle	Prospect	Triad	Legumex DB
Established Grass	Yes	Yes	Yes	Yes	Yes
New Leys	Yes	Yes	Yes	Yes	Yes
Clover Safe	Yes	Yes	Yes	Yes	Yes
Rate per ha	7 l/ha	40-60 g/ha	22.5 g/ha	10 g/ha	7 l/ha
Approx. Cost €/ha excl. VAT	€45	€30	€34	€22	€56
Key Weeds					
Bracken	R	R	R	R	R
Buttercup, Creeping	S	R	R	R	S
Chickweed	R	R	R	S	R
Daisy, Common	-	R	R	R	-
Dandelion	-	R	R	R	R
Dock, Broadleaved	MR	S	S	R	S
Dock, Curled	MS	S	R	R	S
Fat Hen	MS	R	R	R	-
Nettle, Common	MS	R	R	R	-
Plantain spp	S	R	R	R	S
Ragworth	R	R	R	R	R
Redshank	MS	R	R	R	-
Rush, Soft	-	R	R	R	-
Thistle, Creeping	MS	R	R	R	S
Thistle, Sow	MS	R	R	R	S
Thistle, Spear	MS	R	R	R	MS
Willow Herd	-	R	R	R	-
Yarrow	-	R	R	R	-

S = Susceptible, MS = Moderately Susceptible, MR = Moderately Resistant, R = Resistant

Effect of white clover seed inclusion rates and ploidy on white clover establishment

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Summary

- Perennial ryegrass ploidy had no significant effect on white clover establishment
- A white clover seeding rate of 2.5 kg/ha was sufficient to achieve good sward clover content in well managed grazing swards
- Including white clover in a grass seed mix increased annual pasture production by an average of 800 kg DM/ha

Introduction

There is renewed interest in the inclusion of white clover (*Trifolium repens L.*; hereafter referred to as clover) into grazing systems in recent years as a result of positive results in terms of pasture and milk production observed in a number of Moorepark studies. There are challenges with establishing and maintaining clover content in newly established swards. Poor clover establishment can result in low clover content in subsequent years. The successful establishment of productive grass-clover swards requires both high levels of germination and the establishment of an adequate number of clover plants. Currently in Ireland there is no specific recommended clover seed inclusion rate for grass-clover swards. Commercial seed companies include clover seed as standard in 80% of grass seed mixtures, at a rate of 1.2 – 2.5 kg/ha. Despite the inclusion of clover in 80% of seed mixtures, the clover content of Irish swards is generally low (< 10%).

Clover seeding rate study

An experiment was established at Teagasc, Animal and Grassland Research Innovation Centre, Moorepark, Fermoy, Co. Cork in 2013 to investigate the effect of clover seeding rate and the ploidy of the companion ryegrass on sward clover content and pasture production. The clover seeding rates used were 0.0 (grass-only), 2.5, 5.0, 7.5 and 10.0 kg/ha. The clover cultivar was Iona, a medium leaf clover cultivar. All clover seeding rates were sown with a tetraploid (Kintyre) and a diploid (AberChoice) perennial ryegrass. The grass seeding rate was 27.5 kg/ha for all treatments. All plots were grazed eight weeks post-sowing at a pre-grazing pasture mass of 1,000 kg DM/ha to a residual of 4 cm. For the remainder of the establishment year (2013) plots were grazed at or below a pre-grazing pasture mass of 1,100 kg DM/ha. Clover plant emergence 11 weeks post-sowing was measured by counting the number of clover plants/m^2 in each plot. Plots were grazed by dairy cows on eight occasions in 2014 and nine occasions in 2015 (18-21 day grazing interval), maintaining pre-grazing pasture mass at or below 1,500 kg DM/ha, and grazing to a post-grazing sward height of 4 cm. All plots received 150 kg N/ha/year. Pasture production and sward clover content were recorded at each grazing.

Clover seeding rate had an effect on sward clover content in the first 11 weeks post-sowing (Figure 1). After the establishment year, there was no difference in sward clover content between any of the clover seeding rates (Figure 1). Similarly perennial ryegrass type did not have an effect on sward clover content, with the tetraploid and diploid swards having similar average sward clover content (19.8%). In this experiment, regardless of clover seeding rate, annual pasture production increased by 800 kg DM/ha once clover was included in the sward (Figure 2).

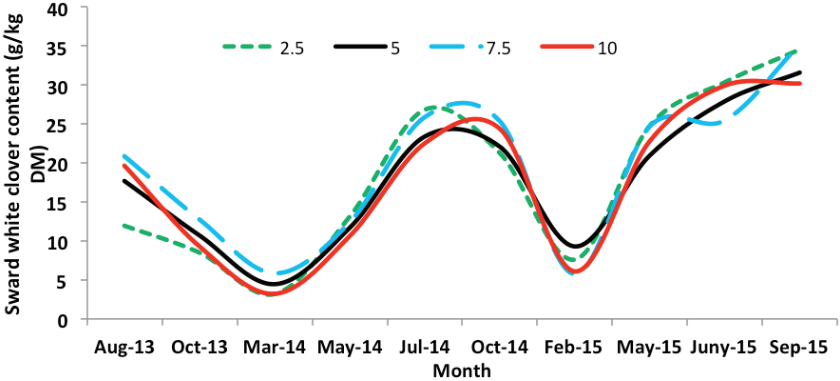

Figure 1: *Average sward clover content (>4 cm) on the diploid and tetraploid perennial ryegrass swards on each clover sampling date during the experimental period (2013 to 2015) for each clover seeding rate (2.5, 5.0, 7.5 and 10.0 kg clover seed/ha).*

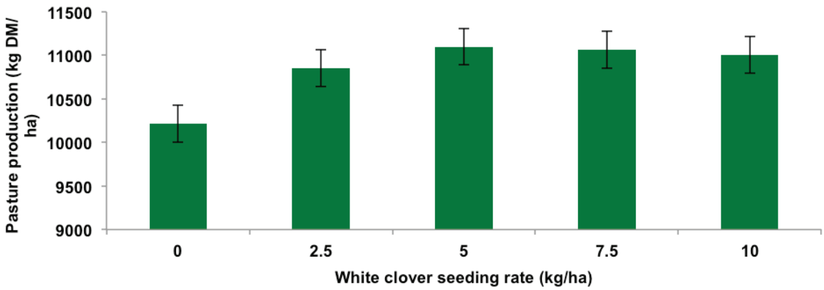

Figure 2: *Average cumulative pasture production (2014 & 2015; kg DM/ha (>4 cm)) on the diploid and tetraploid swards for the different clover seeding rates (0, 2.5, 5.0, 7.5 and 10.0 kg clover seed/ha)*

Conclusions

Including clover in the seed mixture increased annual pasture production by 800 kg DM/ha. Increasing clover seeding rate increased sward clover content in the establishment year, however, there was no difference in subsequent years. All clover seeding rates had similar sward clover content in 2014 and 2015. At a clover seed inclusion rate of 2.5 kg/ha, sward clover content can be maintained >20%, with the grazing management practices imposed in this current study. Additionally, perennial ryegrass ploidy had no significant effect on sward clover content.

Managing white clover pastures – lessons learned so far

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Summary

- The same grazing management practices developed for ryegrass pastures are equally applicable to white clover ryegrass pastures. Spring pasture supply on highly stocked white clover ryegrass pastures will be less than in ryegrass only pastures due to lower winter grass-clover growth rates
- The incidence of bloat was associated with pastures with clover content > 60%, low sward DM content and cows with an excessive high appetite when introduced to new pasture
- Development of grazing strategies that avoid pastures with excessively high and low clover content will be major focus of future research

Introduction

As has been described previously in this booklet, white clover has the potential to increase the productivity of spring calving pasture-based milk production systems. While undertaking the grass-clover experiments at both Moorepark and Clonakilty, a number of challenges associated with grass-clover swards have been identified to date. The four main challenges identified are 1) lower winter grass/clover growth resulting in reduced spring pasture supply, 2) spring/autumn grazing management 3) bloat and 4) large variation between paddocks in clover content. The aim of this paper is to describe the lessons learned on how to deal with these challenges at farm level and future studies to address these issues.

Lower winter grass-clover growth rates resulting in reduced spring pasture supply

Over winter pasture growth in grass-clover swards can be lower than that of grass-only swards due to the lower growth rate of clover at temperatures of below 10°C. From the research undertaken over the last few years, we know that farms/paddocks with high levels of clover (> 25%) at closing in autumn have reduced pasture growth during the winter (up to 70% reduction in overwinter growth compared with grass-only swards) and can even lose pasture mass over the winter period. This results in reduced pasture availability (i.e. reduced average farm cover (AFC)) in the spring which can be a major issue for compact spring calving herds, as a reduction in pasture supply means that extra supplement (silage or concentrate) will be required and cows may have to be housed for longer, both of which result in extra costs. Data from Clonakilty shows that overwinter pasture production and spring opening AFC was significantly different between grass-clover and grass-only swards (Figure 1). Even though closing AFC was similar on the grass-only and grass-clover swards at the end of November, on average pasture growth rates over the winter were lower on the grass-clover swards (1.2 kg DM/ha per day) compared with the grass-only swards (4.7 kg DM/ha per day). This resulted in a large difference in opening AFC between the grass-clover (781 kg DM/ha) and the grass-only (1,048 kg DM/ha) swards over the two years. When we looked into why we had such a poor growth rate on the grass-clover swards over the winters in 2014 and 2015, we found that a number of grass-clover paddocks that had a very high clover content (> 50%) lost pasture mass over the winter and effectively cancelled out any positive growth that occurred on the other grass-clover paddocks.

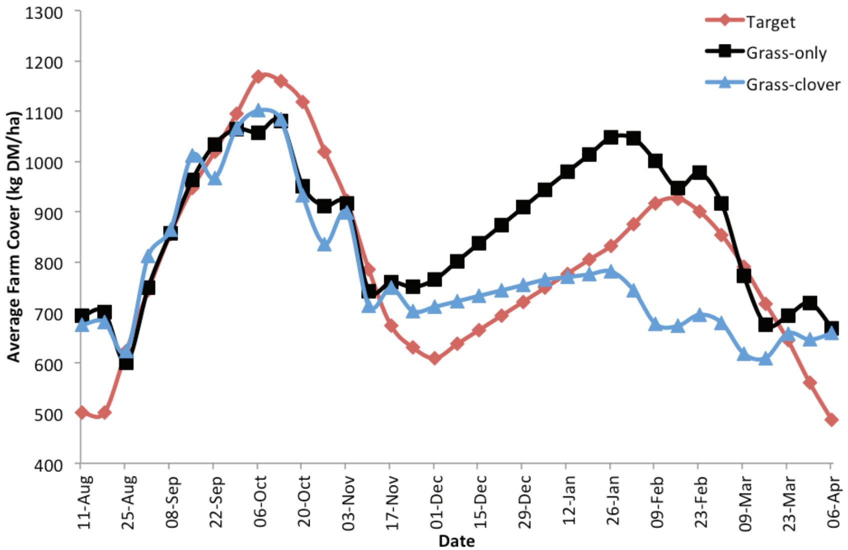

Figure 1: *Average autumn/spring average farm cover (kg DM/ha) target and actual values achieved at Clonakilty in 2014/2015 and 2015/2016 for the grass only and grass clover treatments*

Spring/autumn grazing management

The grass-only treatments had a high opening AFC, and as cows calved, they were able to go straight out to pasture day and night on a pasture and concentrate diet for the most part in both years. On-off grazing was practiced when weather and ground conditions were less than ideal and cows had to stay in on a number of occasions due to high rainfall, especially in spring 2016. In contrast, on average over both years, the grass-clover treatments had an opening AFC well below target and as a result cows had to be supplemented with baled silage and housed by night. The decision to house cows by night was made to ensure that the spring rotation planner targets were maintained and that AFC was maintained at desired levels. The quantities of concentrate and silage fed to the grass-only and grass-clover treatments in spring 2015 and spring 2016 are presented in Table 1. Concentrate fed was similar (174 kg/cow) for all treatments but cows on the grass-clover treatments were fed 145 kg silage DM more than cows on the grass-only treatments. Similar result were obtained at Moorepark over the last number of years in terms of overwinter pasture growth, opening AFC and spring growth (Figure 2). However, the higher pasture growth rates in the grass-clover system in the June to September period should be more than capable of producing this extra silage DM. Additionally, the quality of the silage produced from the grass-clover systems should be superior to the silage produced from the grass-only system.

Table 1. Feed allocation and feed costs associated with grass-only and grass-clover swards in Clonakilty spring 2015 and 2016

Spring[1] (average 2015 and 2016)	Grass-only	Grass-clover
Average feed allocation		
Pasture (*kg DM/cow/day*)	11.2	7.9
Concentrate (*kg DM/cow/day*)	2.7	2.7
Silage (*kg DM/cow/day*)	0.7	4.0
Total concentrate fed (*kg DM/cow*)	175	173
Total silage fed (*kg DM/cow*)	222	367

[1]Spring = 15th January to the 7th April

As with perennial ryegrass swards, excellent grazing management is required on grass-clover swards in order to maintain sward quality. Tight grazing in spring to a post-grazing sward height of 3.5 cm allows light down to the base of the sward to reach the dormant clover plant to stimulate growth and promote stolon production. It is important that poaching on grass-clover swards is minimised as it can result in a loss of stolons and reduced pasture production. This can be difficult as grass-clover swards can be more open and have a lower grass tiller density than grass-only swards, making them more susceptible to poaching, especially in the spring and autumn when ground conditions are often poor. Achieving grazing targets in spring and autumn (area grazed, post-grazing sward heights) on grass-clover swards can be difficult and requires a high level of management, i.e. accurate area and silage allocations, on/off grazing. In our spring management of the swards we follow best practice grazing management guidelines across all treatments, i.e. 25 units of N spread in late January/early February, 40 units in early March and slurry spread on as much of the grazing platform (60%) as possible. The spring rotation planner is used to graze an increasing proportion of each farmlet each week. The combination of early N and early grazing helped to break the dormancy of the clover plant in the grass-clover swards, resulting in similar growth on both experiments (Clonakilty and Moorepark) for the grass-only and grass-clover swards in spring (Figure 2; 32 and 31 kg DM/ha per day, respectively). Our autumn management also follows best practice grazing management guidelines i.e. closing paddocks from early October, using the 60:40 planner and following autumn budget targets. On/off grazing is again a very important grazing management practice that is used to get paddocks grazed without damaging the sward.

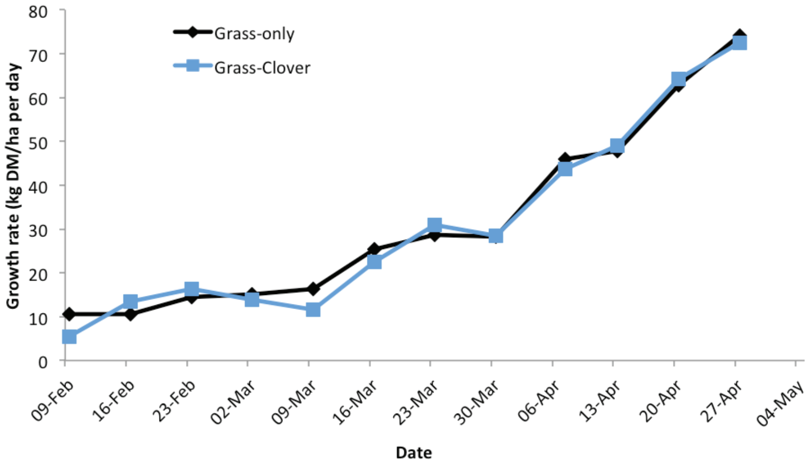

Figure 2: *Growth rate (kg DM/ha per day) on grass-only and grass-clover system at Moorepark (2014-2016) and Clonakilty (2015-2016) in spring*

Bloat

Bloat can be a challenge in grass-clover swards. Bloat can occur at any time of the year but particular risk times are April/May (due to lush, low DM swards) and from August onwards when sward clover content is highest. Management practices can help to reduce the risk of bloat, however constant vigilance and a high level of management is required to minimise bloat incidences. There are certain indicators that bloat may occur including:

- sward clover content - typically > 60% and repeat incidences of bloat can occur in paddocks that continuously have very high sward clover content (> 60%)
- weather conditions - high rainfall over a prolonged period leading to lower DM swards or mornings where there is a heavy dew
- changing from grass-only to grass-clover swards
- hungry cows going into a paddock with high levels of clover

Grazing management of grass-clover swards should be adapted according to these factors. A routine preventative measure is to add bloat oil to drinking water. Bloat oil can be added either directly to water troughs or dispensed through the water system, usually from June to September, at a dose rate of 25 ml per cow per day (at a cost of approximately €0.20 per cow per day). This generally works well during good grazing conditions where cows are drinking enough water to achieve an adequate intake of bloat oil. However, issues may arise during periods of very wet weather when a cow's consumption of water can be reduced. In a scenario like this, the first grass allocation in a paddock should be reduced from a 36 hour allocation to a 12 hour or even a 3 hour allocation in extreme cases. This reduces the area available for the cows and forces cows to graze lower into the horizon. This prevents the cows selecting and gorging on clover and ensures they consume grass stem/pseudostem (fibre).

Avoiding large variation in white clover content between paddocks

Based on previous research and the recent research at Moorepark and Clonakilty, the optimum average annual level of clover in the sward is 20-25%. However, achieving and maintaining these levels of clover is not easy as there can be large variation in clover content between paddocks. Optimising the level of clover in swards requires excellent grazing management skills in terms of achieving correct pre-grazing yields (ideally 1,300 – 1,600 kg DM/ha) and post-grazing sward height (4 cm in the main grazing season and 3.5 cm in the first and last rotation) to ensure light reaches the base of the sward for clover stolon production. The clover content of a sward increases after harvesting a heavy crop of grass silage (> 5,000 kg DM/ha). Directly after cutting silage, competition with the grass plant for light is reduced, enabling to clover to prosper and sometimes become dominant in the sward. Therefore, careful use of silage conservation may be a useful method to manipulate sward clover content. If clover content is too high in a paddock the use of a non-clover safe herbicide spray to check the level of clover in the paddock may be used.

Summary

Managing grass-clover swards can be challenging. Excellent grazing management skills are required but the basic principles of good grazing management are the same for grass-only and grass-clover swards. Using some of the management practices outlined in this paper should help you manage grass-clover swards more efficiently.

White Clover Research at Solohead Research Farm

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Summary

- Under conditions at Solohead herbage and milk solids production from a grass-clover system receiving 100 kg/ha of fertiliser nitrogen (N) was 92% of a system using the maximum fertiliser N input allowed under the Nitrates Directive Regulations
- The clover persisted well in swards (at around 23% of herbage dry matter) over a 12 year period in the grass-clover system receiving 100 kg/ha of fertiliser N
- The lower costs associated with the clover-based system was not sufficient to compensate for the higher output and profitability of the higher input system
- White clover offers potential to lower greenhouse gas emissions from Irish grassland

Background

Between 2000 and 2012 a series of experiments on the productivity of clover-based grassland for milk production was conducted at Solohead Research Farm. In the early days the research was in the context of milk quota limiting output from farms, direct payments decoupled from stocking rates, substantial REPS payments for farming at less than 2 LU/ha, and rising fertiliser N costs. Average stocking rates on dairy farms at that time was 1.8 LU per ha. The capacity of clover to convert atmospheric N into a plant-available form in the soil made it a useful source of N for grassland on higher-stocked REPS farms where fertiliser N use was restricted. Maintaining the persistency of the clover in swards by over-sowing and grassland management was a long-term objective of this research.

Pasture and milk solids production

The objective of research between 2000 and 2003 was to compare a clover-based system receiving 80 kg/ha of fertiliser N and stocked at between 1.8 and 2 LU/ha with a grass-based system receiving between 170 and 210 kg/ha of fertiliser N. The clover system compared favourably with the grass-based system. Between 2004 and 2006 a clover-based system receiving 95 kg/ha of fertiliser N was compared with a grass-based system receiving 225 kg/ha of fertiliser N. Both systems were stocked at 2.2 LU/ha. There was little difference in pasture and milk solids production between these systems during these years.

Between 2007 and 2009 we ran experiments examining the impact of post-grazing height (PGH), rotation length during the autumn and pasture covers during the winter on the productivity of clover swards. Grazing to a PGH of 4 cm increased the clover content of swards, pasture production and persistency of clover compared to a PGH of 6 cm. The lower PGH had no effect on milk yield per cow or milk composition. A rotation length of 42 days during the autumn gave the best response in terms of pasture yield and the persistency of clover compared with shorter and longer grazing intervals. Grazing over the winter was very favourable to the persistency of clover over winter and during the following grazing season.

Between 2010 and 2012 we compared a clover-based system receiving 110 kg/ha of fertiliser N and stocked at 2.42 LU/ha with a clover-based system receiving 280 kg/ha of fertiliser N and stocked at 2.66 LU/ha. On the low input system pasture production was 92% and milk solids output was 91% of the high input system. This is in agreement with earlier studies at Solohead and elsewhere. The clover content of swards declined during this experiment, partly attributable to the difficult grazing conditions experienced during 2012.

Between 2013 and 2015 the number of cows on Solohead Research Farm was increased from 100 to 126 or to a stocking rate of 2.5 LU/ha. Fertiliser N input was increased to 280 kg/ha across the entire farm. Replacement heifers were contract reared off-farm in 2015. Whereas prior to the beginning of 2010 the entire farm was under grass-clover swards with a clover content of 24%, by 2015 clover content of swards had fallen to < 5% and made only a minor contribution to sward productivity. The main reason for the decline in the clover content was attributed to the three-fold increase in fertiliser N use on the farm from 90 kg/ha in 2009 to 280 kg/ha in 2013. The clover content of swards persisted quite well for the first two years under high fertiliser N but went into decline subsequently.

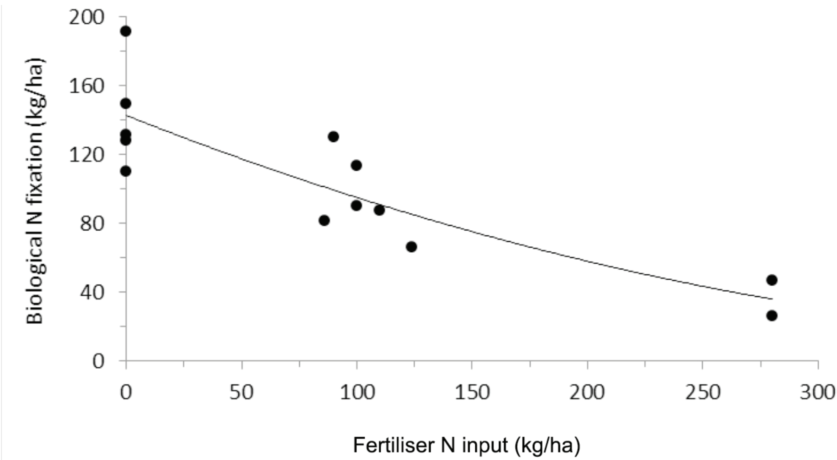

Figure 1: *The impact of fertiliser N input on biological N fixation in swards with previously high clover contents (24% annual average) at Solohead Research Farm*

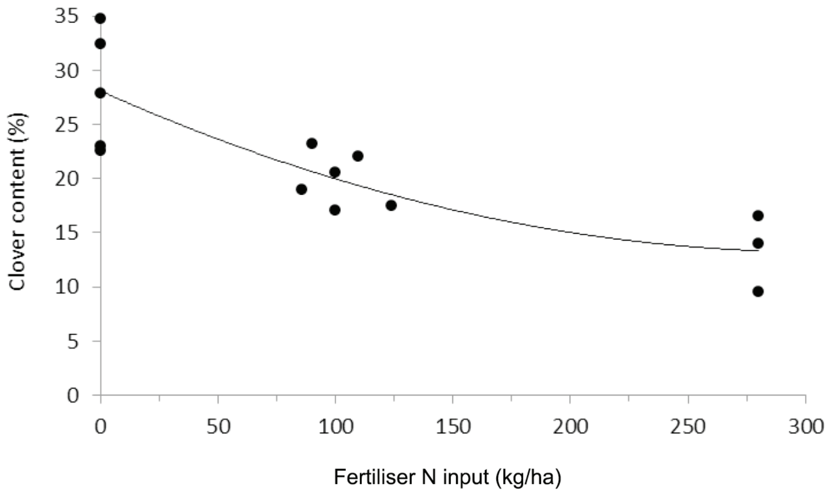

Figure 2: *The impact of fertiliser N input on the clover content of swards with previously high clover contents (24% annual average) at Solohead Research Farm*

Fertiliser N is known to impact on white clover in two ways: (1) increasing fertiliser N input directly lowers nitrogen fixation by the clover (Figure 1) and (2) increasing fertiliser N input increases grass growth which increases competition between the grass and clover which eventually drives the less competitive clover out of the sward (Figure 2). Under fertiliser N input of 280 kg/ha, the clover content of swards declined from 22% in 2011 to 14% in 2012, 9% in 2013 and < 5% in 2014.

Environmental impact of grass-clover based dairy production

In conjunction with the dairy production experiments described above, a series of experiments were conducted to examine the environmental impact of clover in swards in terms of (1) nitrogen losses to water and (2) nitrous oxide emissions to the atmosphere. Nitrous oxide is a very potent greenhouse gas with 300 times the global warming potential of carbon dioxide. Nitrous oxide accounts for between 35% and 40% of the greenhouse gas emissions from dairy systems in Ireland. Fertiliser N, other N inputs, and N recycled in slurry, dung and urine are the major sources of nitrous oxide from dairy systems. Our results showed that replacing fertiliser N with biological N fixed (BNF) by white clover had no impact on nitrate losses; nitrate losses to water were proportional to the amount of N cycling in the dairy production system regardless of the source, whether fertiliser N or clover/BNF. Nitrate losses recorded at Solohead were very low in these various studies; rarely exceeding 3 mg/L of nitrate N. Replacing fertiliser N with white clover/BNF substantially lowered nitrous oxide emissions with a 33% reduction in nitrous oxide emissions for the same level of milk solids output.

Economics

An economic evaluation comparing the performance of the low input grass-clover system with the higher input grass-only systems at Solohead was conducted based on the data collected over 12 years. In the absence of REPS payments and milk quota the clover system was only occasionally more profitable than the high input system, such as in years when a high price for fertiliser N combined with a low milk price; 2009 for example. Currently fertiliser N costs approximately €1 per kg. At this price our analysis shows that with a milk price greater than €0.30/L a fertiliser N-based system is more profitable. With a milk price of less than €0.30/L the grass-clover system becomes more profitable. This relationship changes as fertiliser N becomes more expensive and would favour clover-based systems if fertiliser N were to become substantially more expensive in the future. Nevertheless, in recent years the milk price/fertiliser N price relationship has been at a level that makes the higher input fertiliser N-based system more profitable. Similar to 2009, 2016 is exceptional in this regard.

Conclusions

The results presented in this paper are specific to conditions at Solohead Research Farm, which has a highly fertile heavy-textured soil with impeded drainage and a shallow water table. High background soil fertility and wet soil conditions, which are prone to poaching damage, are not as conducive to getting maximum benefit from clover as might be possible on lighter textured, drier soils. Nevertheless our results show that clover can persist very well in swards under conditions at Solohead at around 23% of herbage dry matter over a 12 year period under moderate inputs of fertiliser N i.e., around 100 kg/ha. Productivity was around 92% of that achieved with a system using the maximum rate of fertiliser N allowed under Nitrates Directive Regulations. At milk and fertiliser N prices experienced in recent years, the lower input costs of the clover-based system at Solohead was not sufficient to compensate for the higher milk solids output and profitability achieved with high fertiliser N input.

On-farm variety evaluation

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Summary

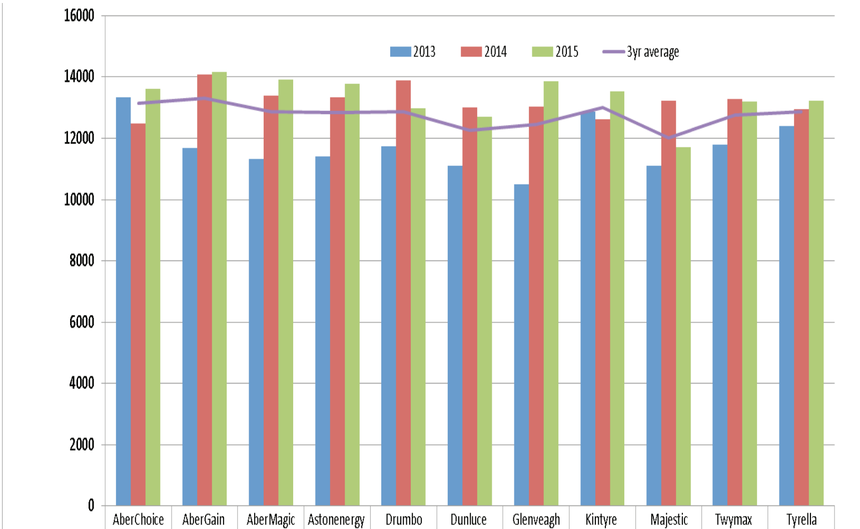
- The difference in DM performance between varieties on commercial farms was 1.3t DM/ha (2013-2015)
- In the Clonakilty study the DM production difference was 1.7t DM/ha between varieties, with AberChoice (16.6 t DM/ha) the highest yielding variety and Tryella (14.9t DM/ha) the lowest.
- The Pasture Profit Index (PPI) can be used along with the DAFM recommended list to select varieties suitable for reseeding
- Grassland farmers should differentiate between varieties that are suitable silage or grazing when deciding on a seed mixture

Introduction

The future competitiveness of Ireland's low cost seasonal grass-based ruminant livestock production system will be underpinned by the selection of grass varieties that are highly productive and of high nutritive value. Different grass variety evaluation protocols are employed throughout Europe, and testing is generally conducted under cutting management practices. The protocols employed can generally be segregated into simulated grazing or conservation based cutting regimes, with some integrating both conservation and simulated grazing. Simulated grazing protocols entails more frequent harvesting and mirrors or 'simulates' typical animal grazing rotations with eight to ten harvests per year. Grass evaluation protocols based on conservation cutting regimes have less frequent harvesting with two to three conservation harvests and five to six harvests in total. All these protocols do not involve actual animal grazing and are only evaluated over a short time period-two to three years. The objective of this research was to evaluate the performance of grass varieties under actual grazing conditions on commercial farms and over a much longer time period.

Variety evaluation on commercial grassland farms

Since 2012, Teagasc Moorepark has been investigating the performance of grass varieties on commercial farms. One of the main objectives is to establish if location/environment by variety differences are present within the performance of varieties (i.e. are varieties performing better if sown in wet or dry land types) and to finally establish the long term DM yield persistence of varieties over five to 10 years. At present the number of farms on the project is approximately 80 and this will increase as more farms across the country are added. Counties represented (numbers of farms per county are in brackets) are Cork (27), Limerick (9), Galway (9), Tipperary (9), Kerry (5), Kilkenny (5), Kildare (4), Westmeath (3), Wexford (3), Roscommon (2), Donegal (2) and Sligo (1). It is planned to get a wider representation of farms across other counties to ensure the island of Ireland is properly represented. Tyrella has been used as the control grass variety across all farms in the first four years; this will change to using AberGain as the control variety from 2016. One of the reasons for changing the control is that Tyrella is now beginning to fall in economic value in the PPI, while AberGain retains a very high position. A realistic target for this project to have 80% of PPI listed varieties evaluated on farms by 2018. It is envisaged that all new varieties introduced to the Recommended List and PPI list will be sown on commercial farms and evaluated from 2016 onwards. Total and seasonal pasture DM production will be captured through PastureBase Ireland. Pasture quality will be measured on a subset of the 80 farms (approximately 30) from April to September. Sward ground score will be measured annually on all paddocks at the end of the growing season. The initial three years pasture DM production data has established year by variety differences across the farms and this is shown in Figure 1. There was a 1.3 t DM/ha difference between varieties across the farms. There was also a trend in pasture quality differences between varieties, however more data will be have to be assembled to fully quantify these differences.



	AberChoice	AberGain	AberMagic	Astonenergy	Drumbo	Dunluce	Glenveagh	Kintyre	Majestic	Twymax	Tyrella
2013	13338	11696	11321	11420	11738	11098	10501	12868	11112	11800	12391
2014	12494	14084	13403	13329	13900	13004	13042	12632	13234	13278	12965
2015	13613	14177	13915	13792	12971	12699	13856	13540	11713	13211	13226
3yr average	13148	13319	12880	12847	12870	12267	12466	13013	12020	12763	12861

Figure 1: *Pasture DM production of varieties sown on commercial farms 2013-2015*

Variety evaluation on the Clonakilty farm

For the purpose of this study all the pastures were established in Clonakilty Agricultural College in 2012 and 2013. Seventy five percent of the area was reseeded in 2012 and 25% reseeded in 2013. The varieties evaluated included four diploid (Tyrella, AberChoice, Glenveagh and Drumbo) and four tetraploid (Astonenergy, Kintyre, Twymax and Dunluce) perennial ryegrass varieties. They were sown as monocultures with and without white clover in five different blocks around the farm. In the clover paddocks a 50:50 mix of chieftain and crusader white clover was sown at a rate of 5 kg/ha. There was a significant variety effect on DM production and the range in DM production from 2013-2015 was AberChoice (16.6 t DM/ha), Twymax (16.4 t DM/ha), Drumbo (16.1 t DM/ha), Astonenergy (15.9 t DM/ha), Glenveagh (15.7 t DM/ha), Dunluce (15.4 t DM/ha) Kintyre (15.3 t DM/ha) and Tyrella (14.9 t DM/ha) (Figure 2). The variety with the highest (AberChoice) and (Tyrella) lowest DM production in this study also ranked highest and lowest in the DAFM grass evaluation trials (simulated grazing). On average the silage DM contribution varied from 27-32%, with all varieties producing sufficient silage from their individual paddocks. Within the farm there is some variation in how some varieties have performed in combination with clover, as the diploid variety Glenveagh has lost some vigour (tiller density) in a number of clover paddocks. The true extent of this reduction in tiller density will be seen by how this variety can maintain its DM production across future years.

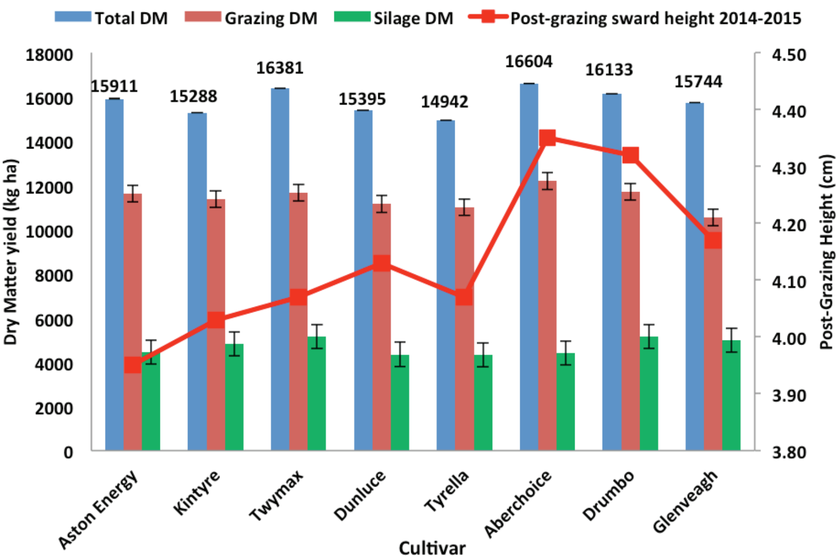


Figure 2: *Variety DM production (2013-2015) on the Clonaklity farm*

Pasture Profit Index 2016 new evaluations

Table 1 shows the Pasture Profit Index (PPI) for grass varieties available in 2016. The performance values included in the PPI are based on data collected from the DAFM grass evaluation trials. Varieties are evaluated over a minimum of two separate sowings, with each sowing harvested over two consecutive years after the sowing year. The two harvested years include a six cut system involving one spring grazing cut, followed by two silage cuts and then three grazing cuts; as well as an 8 – 10 cut system corresponding to normal commercial rotational grazing practice. The PPI index values ranges from €210 to €61/ha per year for the 30 varieties where the data were assigned to. The sub-indices present the opportunity to select varieties for specific purposes. For example, if selecting a variety for intensive grazing, the focus is placed on seasonal DM yield, quality and persistence with less importance placed on the silage performance. If selecting a variety specifically for silage production, then greater emphasis would be placed on the performance of that variety within the silage sub-index and persistence. It is likely, similar to all indexes, that new traits will be developed and incorporated into the index.

Summary

On-farm grass variety evaluation is now beginning to highlight the differences between varieties in commercial farm environments. This project is just at an early stage but is now delivering key information on individual variety performance. This information will ensure the grassland industry focuses on the selection of varieties with the most economically important traits for the grassland industry.

Table 1. Teagasc Pasture Profit Index (PPI) 2016

Variety Details			Pasture Profit Index Sub-indices (€ per ha per year)						Total €/ha/year
			Dry Matter Production			Quality	Silage	Persistency	
Variety	Ploidy	Heading date	Spring	Summer	Autumn				
AberMagic	D	May 31	47	50	63	36	14	0	210
AberGain	T	June 5	38	44	32	65	25	-5	199
Nifty	D	May 27	77	50	49	-6	20	0	190
AberPlentiful	T	June 9	44	51	38	30	14	0	177
Solas*	T	June 10	34	45	51	31	14	0	175
Dunluce	T	May 30	32	42	43	39	23	-5	174
AberChoice	D	June 9	23	47	36	64	8	-5	173
Rosetta	D	May 24	92	25	33	2	16	0	168
Seagoe	T	May 28	33	41	29	20	37	0	160
Kintyre	T	June 7	28	35	47	33	13	0	156
Astonenergy	T	June 2	7	37	31	61	11	0	147
Xenon	T	June 11	22	39	26	46	14	0	147
Magician	T	May 22	53	30	26	7	26	-5	137
Alfonso	T	June 4	13	38	27	51	4	0	133
Aspect	T	June 6	25	41	17	37	9	0	129
Carraig	T	May 24	46	37	23	-11	30	0	125
Navan	T	June 6	10	39	40	26	9	0	124
Solomon	D	May 21	69	29	22	-23	21	0	118
Kerry	D	June 1	34	40	32	0	7	0	113
Delphin	T	June 2	17	40	19	16	20	0	112
Glenroyal	D	June 5	29	40	31	2	7	0	109
Drumbo	D	June 7	26	30	24	44	-5	-11	108
Boyne	D	May 22	54	29	24	-39	39	0	107
Clanrye*	D	June 6	34	42	10	-10	15	0	91
Twymax	T	June 7	-13	44	7	35	16	0	89
Majestic	D	June 2	39	32	33	-16	-1	0	87
Glenveagh	D	June 2	27	35	20	-10	8	0	80
Stefani	D	June 2	21	27	16	-2	8	0	70
Tyrella	D	June 4	40	18	8	3	-1	-5	63
Piccadilly	D	June 3	26	31	12	-23	15	0	61

Ploidy – T – Tetraploid; D - Diploid

Breeding improved varieties of white clover

Patrick Conaghan

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Summary

- Teagasc has over 50 years' experience breeding white clover varieties for Irish farm systems
- Our goal is to breed new improved varieties of white clover that offer higher yields and greater persistency over a long grazing season
- Latest Teagasc white clover varieties include Galway, Coolfin, Iona, Buddy and Dublin
- Teagasc has entered into a new partnership with Goldcrop Ltd. to support the programme and commercialise all new varieties that emerge from the programme. Goldcrop are an Irish seed and inputs company with headquarters in Carrigtwohill, Co. Cork

Introduction

Teagasc has been breeding white clover (*Trifolium repens L.*) for over 50 years at Oak Park, Carlow. Chieftain, Avoca, Susi, Aran and Tara are some of the successful and well-know Teagasc-bred varieties. Changing climate, pests, diseases and farming practices (as dictated by economic and national policy shifts, and new knowledge) mean new varieties are continually required in order to optimise the performance of our grassland. Breeding new varieties offers a low-cost means of improving the profitability of animal production from grassland. There is usually little difference in the price of seed of new and older varieties. Sowing a new, improved variety offers a permanent increase in performance over the lifetime of the variety. In contrast, a management scheme designed to improve crop performance must be continually re-applied each year, at a recurring cost.

Breeding goals

Our goal is to increase the profitability and sustainability of animal production from grassland in Ireland by breeding improved varieties of white clover for Irish farm systems. Teagasc varieties are bred and tested in Ireland under real-world conditions using a combination of cutting and animal grazing over multiple years and locations. The main traits for genetic improvement are: (i) total and seasonal yield of white clover, (ii) combined yield of clover and companion grass, (iii) persistency, (iv) stolon density and (v) disease resistance. The programme breeds small, medium and large leaf size varieties.

Variety improvement

The release of a new white clover variety is the culmination of a 15 to 20 year process consisting of three main stages: (i) forage breeding (product development), (ii) independent variety evaluation (product testing) and (iii) commercial seed production (product release).

The breeding process consists of a multistep and cyclic process where the best genotypes (plants) are evaluated, selected and intercrossed to produce a new variety. The process is known as recurrent selection. The generalized method consists of three parts: (i) development of a source population from which to begin selection, (ii) evaluation of individual plants from the source population and (iii) selection and intercrossing of superior plants to form a new population. Most important forage traits are quantitative and controlled by the joint action of many genes. Recurrent selection increases the frequency of favourable genes and superior genotypes in the population by repeated cycles of selection and can achieve in successive cycles of selection what would almost certainly never be achieved by non-recurrent selection.

The source population from which to begin selection consists of varieties, elite families and introductions from gene banks. Selection is based on phenotypic and genotypic recurrent selection. Phenotypic recurrent selection is selection based on visual observation or physical measurement of the trait and is most useful for traits with high heritability. Genotypic recurrent selection is selection based on progeny performance. In our white clover breeding programme, we mainly use full-sib progeny test selection.

The superior genotypes identified through one cycle of recurrent selection may become the starting point for the next cycle of recurrent selection or may be used to construct new synthetic varieties. A synthetic variety is defined as a population produced by crossing in all possible combinations a number of selected genotypes and which is thereafter maintained by random mating in isolation. The new variety is submitted to the Department of Agriculture, Food and Marine for independent testing under cutting and grazing. The variety is added to the Irish Recommended List if it is found to offer improved agronomic performance and its botanical characteristics are distinct from other varieties, uniform and stable (DUS). Commercial seed of Teagasc bred varieties are produced and sold under license by Goldcrop Ltd. or DLF-Trifolium.

Varieties

Buddy, Avoca and Chieftain, all bred by Teagasc, are the top three yielding medium leaf size white clover varieties on the Ireland Recommended List. Buddy was newly released in 2015. Although a medium leaf size variety, Buddy offers exceptional persistency and ground cover under tight grazing comparable to a small leaf size variety. Coolfin and Galway are scheduled for release in 2017. Coolfin is a small leaf size variety that bucks the trend in producing higher yields than any medium leaf white clover variety on the Ireland Recommended List. Galway is a very small leaf size variety that is especially suited for tight grazing. In 2018, Dublin will be released. Dublin is a large leaf variety offering further improvements in yield and persistency, and greater choice for farmers looking for a variety suitable for grazing and silage production.

Conclusions

The Teagasc forage breeding programme continues to develop new, improved varieties of white clover for Irish farmers. Farmers may currently choose among four white clover varieties bred by Teagasc for reseeding, including the top three yielding medium leaf size varieties. A further two small leaf varieties and one large leaf variety are currently undergoing seed increase for future release.

Funding

The Teagasc grass and clover breeding programme is funded by Goldcrop Ltd., Carrigtwohill, Co. Cork.

Coping with milk price volatility

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Summary

- Milk price volatility is a key feature of international dairy markets since 2007
- Long term volatility management strategies
  - Optimising farm profit
  - Cash flow budgeting
  - Increase milk solids concentrations
  - Fixing milk price
  - Cash management
- Short term volatility management strategies
  - Reduce costs
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  - Evaluate options to sell livestock
  - Reduce/eliminate capital development
  - Liaise with your bank
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Introduction

Milk price volatility is a key feature of dairy farming today and this is likely to continue as the world market responds to changes in product supply and demand. In the past various levels of protection, operating mainly at EU level, provided market support at times when there was an in-balance in the Global supply/demand dynamic. However, this protection has not operated at the market level to a large extent since 2007 (except in exceptional circumstances), which has meant that the milk price received by farmers is much more volatile now than experienced in the past (See Figure 1). Currently, milk price is in a significant trough, which is causing many problems for virtually all dairy industries around the world. Ireland's milk production represents approximately 0.8% of global production and irrespective of our scale or how much we expand; in general we are price takers. Therefore, the focus at farm level must be based on putting the farm in the best possible position to deal with a volatile price while availing of tools and mechanisms to stabilise price. It must also be recognised that most dairy farmers in Ireland this year will experience a cash deficit when they combine the cash generated from the dairy farm with their drawings and tax from the business. The rest of this paper will focus on long and short term volatility management strategies on Irish dairy farms.

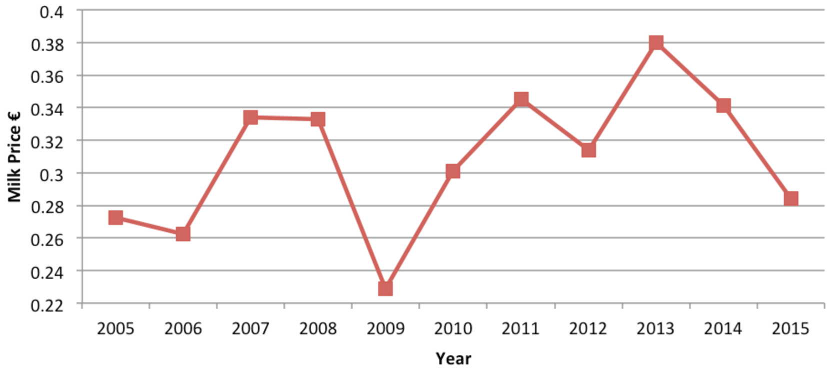

Figure 1: *Base milk price received by Irish farmers between 2005 and 2015*

Long term volatility management strategies

Optimising farm profitability

The first and key step in ensuring the resilience of any business during periods of low milk prices centres on having the right system in place. The overall system operated on farm will be a key determinant of business resilience. A focus on a high EBI/crossbred cow within a system that maximises grass growth, matching grass growth and demand while minimising capital investment will result in a business that has a low overall cost base and will be best placed to deal with price volatility. Based on the analysis of National Farm Survey data, maximising grazed grass utilisation and minimising purchased supplementary feed use will maximise farm profit per hectare and per kg MS produced. Nationally, there is huge scope to increase grass utilisation and reduce the levels of bought in feed across the national dairy herd. Having the right type of robust cow capable of converting grass to milk in an efficient manner, producing high milk solids, with minimal supplementation and capable of withstanding short term fluctuations in feed supply, with a low replacement rate and associated with a reduced labour requirement are essential parts of a resilient business.

Cash flow budgeting

The expansion process at farm level has put a significant strain on scarce cash resources and is confounded by the current drop in milk prices. Expansion usually results in increased debt servicing costs, reduced immediate farm productivity, growing stock numbers and increased on-going farm development costs. In many cases the on-farm investment is completed from cash generated from within the business instead of from borrowings which places unnecessary additional strain on the business. The creation of cash flow budgets that can be used to identify particular cash deficits within and between years, and can allow a plan to be developed around financing expansion and managing cash is a must for the business. For many farmers, this process will identify potential pit-falls during the expansion process and will provide opportunities to seek solutions. For example, seeking a moratorium on capital repayments of bank debt for the initial period of the expansion could make the process viable and reduce the exposure to liquidity issues. Another solution would be to secure short-term finance (within year) to overcome periods of cash deficit as occurred on many farms in the spring of 2013. Cash flow budgets should be set up at the start of the year. On at least a quarterly basis, these budgets should be compared with actual cash flow from the bank statements. Ideally this process should be undertaken with the bank to build a strong relationship and understanding between the bank and the business. After each review process, projections should be completed for the remainder of the year to determine the new overall picture for the farm and steps should be taken if a cash deficit issue is apparent.

Increase milk solids concentrations

Most milk payment systems across the country are now based on the A+B-C system to reward farmers for higher milk solids concentrations. There has been significant progress made at farm level over the past 10 years based on investment in breeding and grassland management. Figure 2 shows the change in fat and protein concentration over the past 15 years on Irish dairy farms. It is evident that the annual increase in milk solids concentrations is higher now than it was in the past. At a base milk price of 29c/l and based on the 2015 milk volume output, the increase in solids concentrations between 2000 and 2015 is worth €161 million annually at farm level or 2.5 c/l. While the benefits from increasing milk solids concentrations decline with lower milk prices the relative benefit becomes more important at lower milk prices. A key strategy at farm level around volatility management must centre on the increasing the milk solids concentrations of the farm.

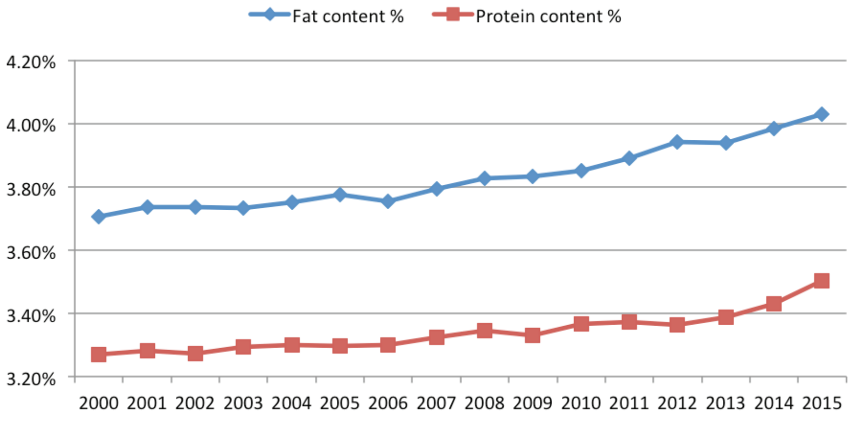

Figure 2: *Fat and protein concentration changes between the year 2000 and 2015 on Irish dairy farms*

Fixing milk price

The introduction of fixed price contracts has become much more common across most milk processors over the past five years. While these pricing mechanisms are new in Ireland, different formations have been available in other countries (particularly in the US) for a much longer period. A study completed by the United Farmers of America in 2014 showed that on average the milk price was 0.9% lower over a 14 year period when opting for the fixed price contract, but the same study noted that much of the extremes in price movement were avoided through fixing the price.

Carbery has launched two fixed price schemes over the past two years that allow producers to fix a proportion of their milk price. Because it is hard to evaluate such schemes over a relatively short period (two years) this paper presents the effect of fixed pricing in the Glanbia region and the effect on the Greenfield farm in Kilkenny. The Greenfield Dairy Farm in Kilkenny has availed of most (except 2013) of the Glanbia fixed milk price schemes that have been offered between 2011 and 2016. Each year there are different schemes offered by Glanbia based on deals done with customers. The Greenfield Dairy Farm has had different levels of milk locked into the different schemes each year based on availability and the amount of each scheme that was sought. There has been 0%, 15%, 27%, 24%, 25% and 23% locked into the fixed price contract in each year from 2010 to 2015 and there is approximately 23% locked between two fixed price schemes (2014-2017 and 2015-2018) for 2016 (Table 1).

Table 1. The effect of fixing milk price on overall milk revenue at the Greenfield Kilkenny Farm for 2011-2016

Year	Total Supply (L)	Supply at Base (L)	Supply Fixed (L)	Supply Fixed (%)	Base Price c/l	Fixed Price c/l	Diff c/l	Diff €
2011	1,328,654	1,126,142	202,512	15.2	38.69	36.77	-1.92	-3,891
2012	1,316,477	958,669	357,808	27.2	34.89	37.71	2.82	10,099
2013	1,469,612	1,111,804	357,808	24.4	44.25	39.78	-4.47	-15,982
2014	1,413,359	1,062,413	350,946	24.8	41.96	41.31	-0.64	-2,257
2015	1,490,829	1,152,251	338,578	22.7	32.37	39.01	6.64	22,487
2011 - 2015	7,018,931	5,411,279	1,607,652	22.9	38.46	39.11	0.65	10,455
2016	1,574,097	1,217,264	356,833	22.7	28.14	35.44	7.30	26,003
2011-2016	**8,593,028**	**6,628,543**	**1,964,485**	**22.9**	**36.58**	**38.44**	**1.86**	**36,457**

Overall in the fixed pricing schemes that the Greenfield Dairy Farm has been locked into, there has been a net benefit of €10,455 up until the end of 2015 and a projected net benefit of €36,457 at the end of 2016. The net effect in each year has been -€3,891, €10,099, -€15,982, -€2,257, €22,487 for 2011, 2012, 2013, 2014 and 2015 and based on current projections for 2016 it is estimated that net benefit will be €26,003 based on an average manufacturing price of 21.8c/l excluding vat and any share bonus. The schemes that have operated to date while costing money in a high milk price year (when the farm is in the best position to sustain a cost), have provided a cushion in years when they are needed (poor milk price). It is projected that in 2016 that the fixed price schemes will be worth approximately 1.9 c/l. In the Greenfield Dairy Farm, this scheme has both cushioned the farm in a poor milk price year and has actually increased the overall payout over the six years to the end of 2016.

Cash management

When milk price volatility is not managed on farm, periods of significant acute cash surpluses and deficits become much more common. If not managed correctly, these periods could result in increased costs at farm level coupled with increased stress for those working in the business. This will be exacerbated by the requirement to make tax returns potentially in periods of low prices based on profits generated when milk prices were higher. Therefore, a key strategy on farm to manage volatility should involve creating a cash reserve when prices are high. Ultimately this puts power back in the farmer's hands and creates a situation that the farmer is less vulnerable when price drops. While this strategy is possible at farm level, there is a requirement to have the taxation structure of the business set up in an efficient manor to allow the business to create cash reserves. Internationally, there are taxation structures (Farm Management Deposit Scheme and Income Equalisation Scheme) operated in Australia and New Zealand that facilitate the creation of cash buffers in a tax efficient manner, with similar schemes required for Ireland and in reality right across the EU in order to manage volatility.

Short term volatility management strategies

In a low milk price year the price received for milk is likely to be less than the total cost of production including the farmers own labour for most farmers in Ireland. As long as the industry maintains its competiveness it is likely that the periods of low milk prices will be relatively short lived as the low milk price will cause a supply correction in the least competitive industries. In reality there is no magic bullet that will sort out the entire farm problems in a low milk price, the objectives of management in a low milk price year should be to generate adequate family drawings and to ensure the long term potential of the farm business is not significantly damaged.

Reduce costs

Within a year like 2016, there is no one silver bullet that would lead to a massive reduction in costs. In reality, no one option will fit all farms and therefore there is no one solution. All costs should be considered for potential saving and the impact of a reduction on each input should be assessed. Certain costs will have limited effect on the long term productivity of the farm and these should be prioritised for savings. In a low milk price year, it is certain that the margin in producing milk from purchased feed will be negative so the aim should be to match the stocking rate on the farm to the grass growth potential of the farm. Sell cows that may not have a long term future in the herd, older cows, late calving etc. and sell them while their sale will help reduce feed demand on the farm. Cost savings are available by refocusing the business to producing milk from grazed grass and ensuring that pre-grazing yields, post grazing residuals and overall growth is optimised.

Careful consideration should be given to decisions around, for example, breeding and health related expenditures across the farm, with plans in mind for dairy heifer requirements in the subsequent years. Silage requirements should be calculated for 2016/2017 based on stock numbers planned, including current reserves and building in a buffer to ensure that adequate areas are being conserved. Investigation around the potential to reduce fertiliser costs by switching from CAN to Urea should be considered when conditions are suitable.

Develop short term cash flow budget

It is imperative that every farmer creates a cash flow synopsis of how the farm will perform this year as soon as possible. In reality this opening exercise should be used to identify a potential problem as well as the level of the problem and depending on the outcome will determine the urgency of the requirement to complete a cash flow budget for the farm. The farm tax accounts for 2015 should be completed immediately and used as the starting point to create a financial picture of the farm for 2016 followed by the completion of a source and application of funds for the 2015 accounts which can then be used for the 2016 projections coupled with changes in milk outputs, milk values, livestock sales and any cost category changes. Table 2 and Table 3 provide templates that can be used to create a picture of the financial performance of the farm in 2016 by firstly completely a source and application of funds for 2015 followed by 2016 including the adjustments based on changes in receipts and costs.

Table 2. Source and application of funds for 2015 based on completed tax accounts

Source & Application of funds 2015	€
Net Profit from accounts 2015	
Plus Depreciation	
Plus Bank Interest	
Less Bank Repayments	
Disposable Cash 2015	
Less Family Drawings	
Less Tax	
Surplus/Deficit Cash 2015	

Table 3. Source and application of funds for 2016 based on completed tax accounts for 2015 and adjustments based on expected changes to costs and receipts on farm

Source & Application of funds 2016	€
Net Profit from accounts 2016	
Adjustments Receipts	
Adjustments Costs	
Plus Depreciation	
Plus Bank Interest	
Less Bank Repayments	
Disposable Cash 2016	
Less Family Drawings	
Less Tax	
Surplus/Deficit Cash 2016	

Adjustments that may be included in Table 3 (e.g. may be a lower milk price 5c/l*400,000l=€20,000, More milk produced 50,000*27c/l=€13,500, lower fertiliser costs €50/tonne*37t=€1,850, etc).

While it is prudent to always generate a monthly cash flow budget for the farm, this becomes significantly more important in a low milk price year. This is a forecast of the money entering and leaving your bank account each month. This can be completed using tools like the Teagasc Cost Control Planner or other such budgeting software, but could also be completed using a pen, paper and a calculator. All cash revenue and costs should be included for the farm as well as capital and interest payments, family drawings and a provision for tax. Be conservative in the way you budget; it's better to underestimate production plus milk price and overestimate expenses. Don't wait until there is no cash in the account, complete while there are options and decisions that can be made which will not damage the long term potential while ensuring that the short term cash deficit can be managed. Once the cash flow budget is developed and the size of the potential problem is identified a range of options can be considered. No one option will fit all farms and therefore there is no one solution and thus the budget will help with the decision making process around deciding on the best next steps. The plan should be reviewed quarterly and adjustments made when the forecasted budget deficit is increasing.

Evaluate options to sell surplus livestock

There may be potential to free up some cash from the sales of beef or other stock that are surplus to requirements on the farm especially if the farm is being operated at a high overall stocking rate. Consideration should be given to selling some of those earlier rather than later, thus helping reduce feed demand on the farm and ultimately generating cash while reducing costs.

Reduce/eliminate capital investment

There should be no/minimal capital expenditure completed unless the cash flow plan allows or is based on structured borrowings and all farm maintenance should be minimised. In reality on most farms there will be little scope for significant development, while in most cases this will have been financed by long term debt, there is a justification for postponing all development in the short term to allow the business get over this time of depressed prices. If still considering farm development projects a significant contingency fund should be included in the budget and ensure that there are financial resources available to cover the contingency if required. Given the current market situations it may be prudent to ensure that any expansion planned for the farm is right based on the new and current circumstances. Any investment should be prioritised based on its potential to provide a significant return to the farm as a whole.

Liaise with your bank

The cash flow budget should be discussed with your bank. There may be a requirement for short term credit facilities and, where debt servicing is a significant proportion of total costs there may be a possibility to take a moratorium from capital repayments in the short term. There may also be potential to retrospectively finance development work completed on the farm in the past two years from cash flow with medium term debt. It is extremely important that farmers are proactive with the bank and that contact is made at the earliest possible opportunity in order to put a plan in place to get over the short term issues.

Communication with others

Dealing with these issues can be extremely stressful and should not be dealt with in isolation by any individual. While it is not second nature to share problems with others there is in general positive outcomes from the sharing of the individual problems.

Sustainability on Carbery farms

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Summary

- Policymakers and retail companies increasingly require food suppliers to evaluate various sustainability metrics of their production sytems, particularly carbon footprint.
- To facilitate the quantification of a verifable carbon footprint for a group of 12-18 Carbery milk suppliers, a life cycle assessment model was applied annually for each supplier from 2012-2015. The results to date show that the mean carbon footprint of Carbery farms with sequestration declined from a high of 1.15 kg of CO_2 equivalent/kg of milk in 2013 to 1.01 kg in 2015. The footprint reduction was largely related to improvements in milk solids output/ha from pasture.
- The main categories of electricity use were milk cooling (33%), the milking machine (23%), water heating (18%) and other equipment such as winter sheds and lighting (27%).
- The average cost of electricity for the farms in this study over the entire monitoring period was 0.51 cent per litre, with the minimum being 0.33 cent per litre and maximum 0.84 cent per litre.
- The average water consumption in the 2012-2014 period was 6.5 litres of water per litre of milk produced, while in 2015 the average figure was 6.9 litres of water per litre of milk produced, all of which are dramatically below any internationally published corresponding numbers.

Introduction

In 2015, Irish dairy farmers expanded by close to 15%, unhindered by milk quotas for the first time in a generation. The key requirement for the expansion process is that it is sustainable from all aspects of the business perspective. In practice, this means that the business should focus on the efficient conversion of home grown feed to saleable products that are recognised as high quality and safe to consume. It is also necessary that the production system results in minimal nutrient losses to water (nitrate, phosphorous) and emissions to the atmosphere (greenhouse gases (GHG), ammonia), and that the production system operated is broadly acceptable to society as a whole (i.e., good animal welfare, preservation of the ecosystem biodiversity). The production system must be profitable, afford a good work-life balance and provide a good working environment for the farmer and any staff that are directly employed in the business (Figure 1).

Figure 1: *The three pillars of sustainability: economic, environmental and social*

The competitive advantage of Ireland's dairy industry lies in the ability to utilise grazed pasture as the major feed source. However, many questions are asked about the environmental consequences of the expansion process. The dairy sector is a significant source of GHG estimated to account for 3% of emissions worldwide. On a national scale, the sector is a key source of GHG emissions responsible for approximately 10% of Irish emissions. Ireland has legally committed that by 2020 GHG emissions from the non-emission trading sector, which includes dairy farming, will be 20% lower than 2005 levels. However, there is also a need to increase milk production to meet the demands of a growing world population. To fulfil both of these goals the dairy sector needs to reduce GHG emissions/unit of milk (i.e. the carbon footprint of milk). In the areas of energy and water use on farm, these are key ways to improve the cost competitiveness of the Irish dairy sector as well as reducing the overall carbon footprint. Understanding and reducing electricity costs and water consumption will have the potential to reduce overall energy use and reduce production costs while minimising environmental impact. Carbery farmers have engaged with the Teagasc research team since 2011 on these important issues and have led the way on measuring and increasing the sustainability of their farms. Detailed information around inputs, practices, energy and water usage have been collated across 12-18 farms that supply Carbery as part of the Carbery Greener Dairy Farms project over four years (from 2012 to 2015). This information allowed computations of the overall farm energy and water use efficiency as well as GHG emissions, N and P efficiency over periods of time. This paper will present GHG emissions, N and P efficiency and water and energy use over the four years to date.

Carbon footprints

The most widely used whole farm method to quantify GHG is life cycle assessment (LCA). LCA was employed to quantify the carbon footprints of milk of the Carbery farms from 2012 to 2015. The LCA methodology was applied according to recognised guidelines using a GHG model developed by Teagasc and Bord Bia. The GHG model was independently verified by the Carbon Trust to comply with an international LCA standard for GHG emissions known as PAS 2050 developed by the British Standards Institute.

To achieve PAS 2050 certification, the GHG model calculated all annual emissions associated with the Carbery farms up to the point until milk was sold from the farm. The model computed GHG emissions from on-farm sources such as the amount of methane generated from cattle belching and off-farm emissions from the manufacture of inputs brought on to the farm e.g., concentrate feedstuffs. The annual CO_2 equivalent emission allocated to milk was expressed per kg of energy corrected milk (ECM; 4% fat and

3.3% protein) to calculate the carbon footprint of milk.

The mean carbon footprint of milk in kg of CO_2-equivalent/kg of ECM for the Carbery farms in 2015 was well below the European average of 1.4 kg in 2010 and 11-12% lower than the groups mean for the 2012-2014 period (Table 1). The reduction in carbon footprint was largely due to improvements in milk solids yield/cow and per ha, more efficient use of N fertiliser, lower annual replacement rates, and lower concentrate feeding rates. However, across years there was a significant spread in farm carbon footprints ranging from 0.89-1.71 kg of CO_2-equivalent/kg of ECM. Similarly, there was a significant range in key farm efficiency measures, which indicates that there is potential to further improve farm productivity and reduce carbon footprint.

Table 1. The influence of farm performance on the greenhouse gas emissions and carbon footprint of milk in kg of CO_2 - equivalent/kg of energy corrected milk (ECM)

Item	Average	Average
Year(s)	2012-2014	2015
Number of farms	12	18
Milk solids, kg/cow	428	445
Milk solids, kg/ha	704	788
Annual replacement rate	27%	15%
N fertiliser rate, kg/t of ECM	25.1	22.8
Concentrate feed, kg/t of ECM	138	123
Grazing days	265	267
Nitrogen efficiency	21%	24%
PAS 2050 carbon footprint of milk	1.24	1.10
Carbon footprint of milk with sequestration	1.15	1.01

The primary greenhouse gas emitted by dairy farms was methane (55%) followed by nitrous oxide (27%) and CO_2 (18%). Figure 1 shows the largest source of the group's carbon footprint was enteric methane belched by cattle (51%) followed by GHG from the manufacture and spreading of N fertilisers (18%). The production and transport of concentrate feed was responsible for 7% of the group's footprint and manure excreted by grazing cattle caused 10% of the farms total emissions. Greenhouse gas emissions from the storage and spreading of manure generated 5% of dairy farms emissions and CO_2 from lime use was responsible for 4% of the group's carbon footprint. Carbon dioxide from diesel and other fossil fuels used by farmers and contractors was responsible for 2% of the group's footprint. Electricity use accounted for 2% of the farms emissions. The remaining 1% of the group's carbon footprint was generated by various farm sources including feed residues, detergents, plastic silage covers and pesticides.

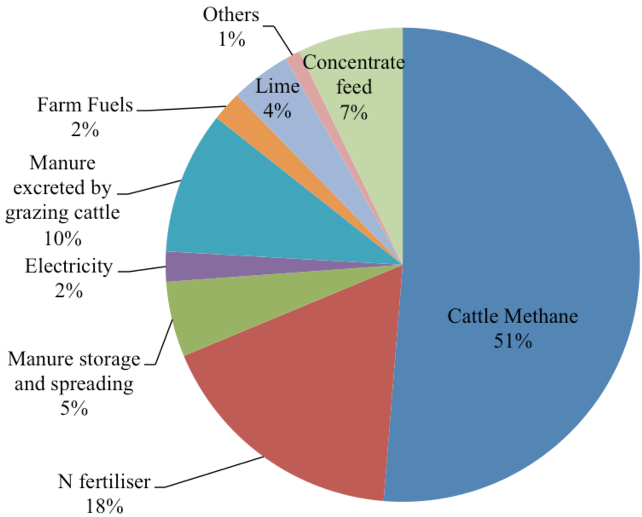

Figure 1: *The percentage contribution of on and off-farm greenhouse gas sources to the Carbery farms mean carbon footprint of milk*

Soil Fertility and Nitrogen Efficiency

Approximately 75% of soil samples had a pH of less than 6.0 in the Carbery region in 2012-2014. The optimum soil pH for grassland is at or above 6.0. The release of nutrients from the soil and the response to applied fertilisers will be reduced where the soil pH is low. It was recommended that farmers apply lime to raise the soil pH to 6.5. The level of lime use on farms increased from an average of 8 tonnes per farm in 2012 to an average of 111 tonnes per farm in 2013. The average Soil Test Phosphorus (STP) level was 6.5 mg P/L in 2015, and overall 57% of all samples analysed were in Index 3 and 4 for Phosphorus (P). The distribution of STP levels in the soils samples on individual farms varied considerably (range of 1.9 to 12.4 mg P/L). This suggests that slurry is being recycled on fields closer to the yard as the fields furthest away from the yard had lower STP levels. Slurry applications should be targeted at fields that are low in P and K (Index 1 or 2). Overall, these changes along with a reduction in concentrate feeding contributed to nitrogen efficiency increasing from an overall average of 21% in 2012-2014 to 24% in 2015, which contributed to the decline in the groups mean carbon footprint. Phosphorus use efficiency declined to 59% in 2015 from an average of 66% for 2012-2014, but was at the higher end of the range (i.e. 24-70%) for European dairy farms.

Energy and water Use

Figure 2 shows the breakdown of energy consumption on dairy farms in the period before quota abolition and the period after it. The trends in electricity consumption and electricity costs pre and post quota abolition (i.e. 2012-2014 compared with 2015) are presented in Table 2. On average less energy per litre of milk was used in 2015 when compared with previous years. Moreover, kilowatt hour consumption per cow also dropped from an average of 199 to 187 kWh per cow per year. These efficiency gains have been realised primarily through improvements in milk cooling efficiency. Plate cooler water consumption is approaching optimum on these farms (i.e. a ratio of 2:1 water: milk flow through the plate cooler). However there is still some scope for efficiency gains in milk cooling since some farms were seen to have water: milk ratios of 0.5:1. Throughout the project, milk cooling efficiencies have been improving as more farmers install plate coolers and increase water flow through the plate cooler. Finding efficient recycling strategies for this plate cooler water is key to reducing the direct water consumption of dairy farms while maintaining energy efficiency. A number of Carbery Greener Dairy Farmers have already implemented water recycling projects and have maintained net water efficiency while allowing more water to flow through the plate cooler resulting in reductions in cooling energy consumption, these strategies will be key in maintaining low water consumption post quota abolition.

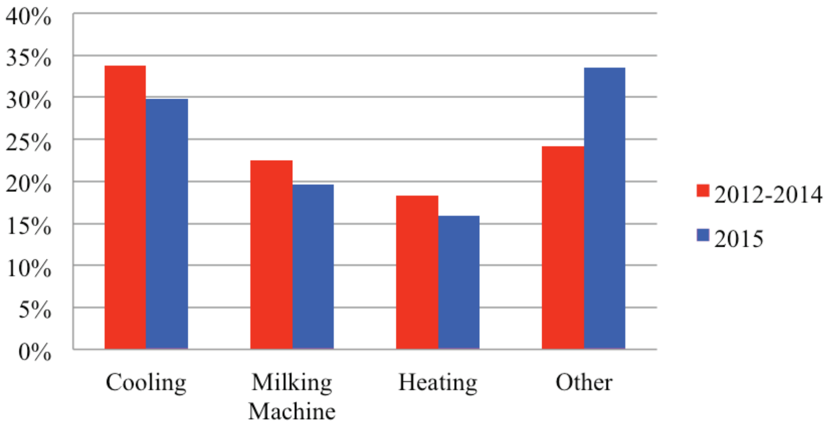

Figure 2: *Percentage breakdown of electricity consumption by dairy farm components from 2012 to 2015*

Unfortunately, the reduction in energy consumption has not resulted in a reduction in the cost of electricity per litre of milk, which increased from 0.50 cent per litre in the 2012 to 2014 period to 0.54 cent per litre in 2015 (Table 2). This was a result of an increase in day rate electricity consumption from 64% to 73% not helped by an increase in day rate electricity consumption by water heaters from 30% to 34%. In order to benefit from half price electricity at night rate, all water heaters should be fitted with timers synced with night rate hours. Similarly, farmers could also aim to complete the morning milking by 8 am to maximise night rate electricity gains.

Table 2. Breakdown of electricity consumption per litre of milk produced on Carbery farms including cost of electrical energy consumed				
	Electricity Consumption (Wh/L)[1]		Electricity Cost (€ c/L)[2]	
	2012-2014	2015	2012-2014	2015
Cooling	13	11	0.17	0.17
Vacuum	9	7	0.12	0.12
Heating	7	6	0.06	0.07
Other	9	12	0.14	0.18
Total	38	36	0.50	0.54

[1]Wh/L = Watt hours / Litre, [2]€ c/L = Euro cent per Litre of milk

Figure 3 provides a breakdown of on-farm water use by dairy farm components for the periods 2012-2014 and 2015. The analysis shows that direct water use per litre of milk produced has increased over the period. However, when compared to the few internationally published studies in this area, Irish water use is very low relative to the international benchmarks per litre of milk.

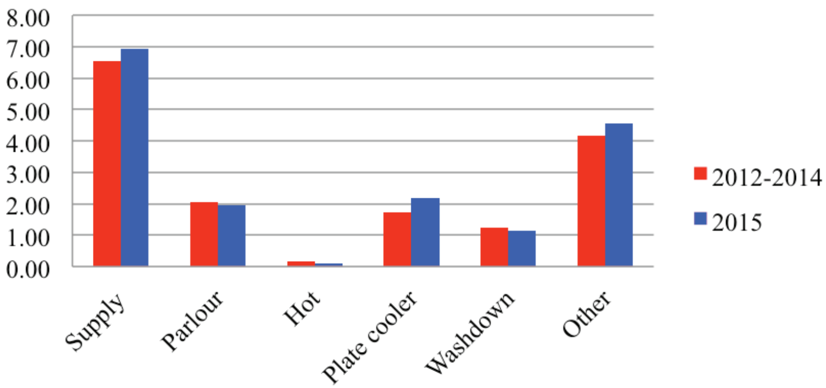

Figure 3: *Breakdown of on-farm water use by dairy farm components for the periods 2012-2014 and 2015*

Zero investment savings

Energy costs can be reduced significantly through simple management actions without any investment. Analysing the results of the Carbery energy audits showed that the average farm in the study could save €560 per year by moving to the most competitive supplier and €170 per year by adjusting the night rate timer correctly. The maintenance of the farm water supply network is also important for efficient energy and water use. Leaks which go unchecked can add to the pumping cost of water. A leak of 10 L/min could cost up to €526/annum in pumping costs. A hot water leak of 60 mL/min (1 drip/sec) could cost up to €240/annum in associated pumping and heating costs. There is no investment cost involved in these changes making them the priority focus, especially when cash flow is tight.

Conclusions

Across energy and nitrogen use, and the carbon footprint there was significant increases in efficiency when 2015 is compared to the proceeding years. There was a small deterioration in direct water use and P efficiency in 2015, but the group's water and P use efficiency was amongst the top performers in international evaluations. Overall, the key focus at farm level must be on technologies that increase the overall sustainability of the business. The project identified key areas that farmers can improve to reduce carbon footprint and increase N and P efficiency. While small changes to practices with minimal investments will increase the overall energy and water use efficiency. Making these improvements will increase the sustainability of these farms for current and future generations of farmers in the Carbery region.

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