Research Stimulus Fund

Final Report

Productivity of clover-based grassland under organic management and nitrate losses to ground water

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Please tick below the appropriate area on the research continuum where you feel this project fits

BASIC/FUNDMENTAL  APPLIED/PRE COMMERCIAL

Key words: (max 4)
Milk production, organic, white clover, nitrate leaching
1. **Rationale for Undertaking the Research**

Ireland is a net importer of organic dairy products at processing and retail levels. This contrasts sharply with conventional dairy production where approximately 80% of Irish products are exported. In Ireland, a premium price is paid for milk produced on organic dairy farms if 50% of the milk is supplied during the autumn and winter (September to March). The prevalent conventional system of milk production in Ireland is seasonal, with >90% of dairy cows calving during spring and, hence, a high price premium is necessary to encourage farmers to produce milk during the winter. Grazing cows on clover-based grassland is a key component of profitable organic milk production. Ireland’s climate is conducive to production from clover swards over a long growing season. Organic systems of production operate at low stocking rates compared with conventional systems. Low stocking rates offer the potential to extend the grazing season throughout the autumn, winter and early spring with the potential to substantially lower the cost of feed for organic winter milk production.

This project aimed at substantially lowering the cost of feed for organic winter milk production by supplying a large proportion (>50%) of the diet from grazed grass-clover during the autumn and winter. White clover (*Trifolium repens*) is the most important legume for grazing in temperate regions (Peyraud, *et al.*, 2009). The main attribute of white clover is that it facilitates biological nitrogen fixation (BNF) via associated *Rhizobia* bacteria. One of the main obstacles to achieving the benefits of clover in grazed grassland is difficulty in maintaining it in the sward at agronomically desirable levels (> 300 g kg\(^{-1}\) of herbage dry matter (DM)) from year to year (Frame and Newbould, 1986; Frame and Laidlaw, 1998; Rochon, *et al.*, 2004). Autumn, winter and early spring are critical times for clover as it has lower growth rates and is generally less competitive for light than perennial ryegrass over that period (Brock, *et al.*, 1989; Davies, 2001; Frame and Newbould, 1986; Hart, 1987; Woledge, *et al.*, 1989; Woledge, *et al.*, 1990). Lowering sward defoliation height has been shown to have a positive effect on clover content and herbage production in grass-clover swards during spring and summer (Acuña and Wilman, 1993; Frame and Boyd, 1987; Wilman and Acuña, 1993).

The objective of task 1 of this project was to investigate the productivity of white clover-based grassland under different management regimes for dairy production including a system where a large proportion (>50%) of the diet during the autumn and winter is grazed grass-clover swards. Furthermore the aim was to investigate the effects of grazing interval and post-grazing height during the autumn on herbage accumulation during the autumn, winter and following spring and to investigate trampling by dairy cows on soil properties and herbage production within this winter-grazing system on a soil with impeded drainage (task 2). Grazing during the winter, albeit at low stocking rates, carries the risk of losses of nitrate to groundwater. The objective of task 3 was to measure the impacts of this dairy production system involving grazing over the winter on nitrate losses to groundwater and nitrous oxide emissions to the air compared with more conventional systems on a poorly drained clay-loam soil with a high natural attenuation capacity at Solohead Research Farm (52°51′N, 08°21′W).

2. **Research Approach**

Fifty four primi- and multi-parous Holstein-Friesian dairy cows were used in a one factor experiment with 3 systems and repeated over two lactations (2008/09 and 2009/10). The three systems compared had: (i) a mean calving date of 17 February, stocking density of 2.15 dairy cows ha\(^{-1}\), receiving 90 kg ha\(^{-1}\) of annual fertilizer N input (ES100N); (ii) a mean calving date of 17 February, stocking density of 1.6 dairy cows ha\(^{-1}\), receiving no fertilizer N input (ES0N) and (iii) a mean calving date of 16 April, stocking density of 1.6 dairy cows ha\(^{-1}\) between calving and 1 September and stocking density of 1.2 dairy cows ha\(^{-1}\) between 1 September until dry-off in early February, receiving no fertilizer N input (LS0N).
The effects of defoliation interval (INT: 21, 42, 56 or 84-days), defoliation height (DH: 2.7, 3.6, 5.3 or 6.0 cm) and final defoliation (closing) date (FIN: 23 September, 4 November or 16 December) on herbage production in a grass-clover sward were studied. Treatments were only imposed between July and December 2008, with all plots under a common management in the following March to June 2009.

A dense network of shallow groundwater piezometers was installed to determine groundwater flow direction and N spatial and temporal variation. Estimated vertical travel times through the unsaturated zone allowed the correlation of management with groundwater N within a short space of time.

3. Research Achievements

There were no \( P > 0.05 \) differences between systems in production of milk yields and milk composition or live-weight and body condition score (BCS) during or at the end of lactation. The LSON system produced 48% of milk between 1 September and mid February, suggesting a later calving date than 16 April is necessary to produce 50% of annual milk between September and March. The LSON system had no major effect on milk production and milk processing characteristics offering Irish dairy producers a viable option to produce organic milk sustainably.

Despite similar soil moisture levels, trampling in winter resulted in less of a reduction in pre-grazing herbage yield than trampling in spring due to lower soil surface deformation and longer recovery periods. During the main grazing season (April to September) trampling across the three systems increased soil bulk density, lowered air-filled soil porosity and lowered gravimetric water content. Soil susceptibility to trampling damage decreased with mean groundwater table depth to a nadir of 1 m \( P < 0.05 \). Although trampling did not result in large changes in clover contents or clover stolon mass and roots it did reduce annual grass and clover herbage production by 5 to 14%. The reduction in herbage yield following each trampling event was significantly related to soil surface deformation and recovery period between grazing events which resulted in a greater effect of trampling with short recovery periods in spring than long recovery periods in winter despite similar soil moisture levels. There was substantial recovery before the next grazing season attributable to the high organic matter content and shrink-swell capacity of the soil. Grazing during the winter resulted in significant increases in clover content, herbage production and N-fixation estimates. The results show that grazing during the winter can increase clover content, BNF and herbage production and is therefore a useful management tool for maintaining or increasing clover contents of swards.

The 42-day INT achieved the highest total herbage yield. The 56 and 84-day INT reduced clover herbage yield whereas the 21-day INT reduced grass herbage yield. Lowering DH from 6.0 to 2.7 cm increased total herbage yield and resulted in higher sward clover content in the following June. FIN did not affect sward clover content or annual herbage yield. Spring-summer clover herbage yield was correlated with spring-summer clover stolon mass \( R^2 = 0.54, P < 0.001 \) and light penetration of the sward in the previous winter \( R^2 = 0.16, P < 0.05 \). A 42-day INT with low DH (2.7 to 3.5 cm) gave the highest annual (July to July) herbage production. Short (21-day) INT and long (5.3 to 6.0) DH should be avoided as they both reduced clover stolon mass in the following spring-summer. The 42-day rotation with a low cutting height (2.7 to 3.5 cm) in autumn gave the most desirable results in terms of herbage yield and stolon mass in the following spring/summer.

There were no relationships between grazing management and soil N dynamics in the soil profile or N concentrations in the groundwater due to high natural buffering capacity of the soils associated with heavy texture, high SOC, high soil pH, anaerobic conditions and presence of shallow groundwater. For this reason, grazing over the winter period on this site had no effect on N losses to groundwater. Mean concentrations of DON, NH\(_4\)-N, NO\(_2\)-N and NO\(_3\)-N were 2.16, 0.35, 0.01 and 0.37 mg L\(^{-1}\) respectively. Soil attenuation processes such as denitrification and DNRA resulted in increased NH\(_4\)-N levels. For this reason, DON and NH\(_4\)-N represented the highest proportion of N losses from the site. Some of the spatial and temporal variation of N concentrations was explained by correlations with selected chemical
and hydro-topographical parameters (NO$_3$–N/Cl$^-$ ratio, distance of the sampling point from the closest receptor, watertable depth, depth of sampling piezometer, DOC concentration). A high explanatory power of NO$_3$–N/Cl$^-$ ratio and the distance of the sampling point from the closest receptor indicated the influence of point sources and groundwater–surface water interactions.

4. **Impact of the Research**

Producing organic milk at low cost over the winter to meet processor demand is an important objective of organic dairy farmers. Organic dairy farmers have shown a lot of interest in the approach developed in this project. On a broader front, new information is available on best management practices of white clover for pasture-based dairy production, which is of direct relevance to organic milk producers and, with the rapid increase in the cost of fertilizer N, is of increasing relevance grassland farmers in Ireland. New information on best management practices includes information on optimum rotation lengths, post-grazing heights, closing dates in the autumn and winter. The negative effect of poaching damage on herbage production was also quantified and recommendations made on how best to minimise impact. The above best management practices recommendations are of direct relevance to managing cows or cattle at pasture on white clover based swards during the late autumn and winter.

There have been very few studies of productivity and environmental impact of winter grazing by dairy cows. Grazing grass clover swards at a low stocking density of dairy cows over the winter had little impact on nitrate losses to water under the conditions at Solohead Research Farm. Nitrous oxide emissions were also minimal. The results indicate that grazing over the winter at low stocking densities typical of organic dairy farms in Ireland is likely to have minimal environmental impact in terms of N losses to water and nitrous emissions to the atmosphere.

Two PhD theses, 9 papers submitted to peer-reviewed scientific journals and numerous conference papers (see below)

5. **Exploitation of the Research**

There are only 20 organic dairy farmers in Ireland and the potential economic impact from the perspective of organic milk production is limited. Over the last decade the price of fertilizer N has been increasing at an annual rate of 9% per year, whereas the farm-gate price for milk and beef have been relatively static. It seems likely that the rate of increase in the cost of fertilizer N is likely to continue. This has triggered a re-evaluation of fertilizer N practices and increasing interest in using white clover on farms, particularly on drystock farms. Between 1999 and 2009 national fertilizer N use has fallen by up to 30%. It is likely that clover-BNF will make an increasing contribution to the N economy of Irish grasslands in the future.

6. **Summary of Research Outputs**

(a) Intellectual Property applications/licences/patents

(b) Innovations adopted by industry

(c) Number of companies in receipt of information
(d) Outcomes with economic potential

(e) Outcomes with national/policy/social/environmental potential

(f) Peer-reviewed publications, International Journal/Book chapters.


(g) Scientific abstracts or articles including those presented at conferences


(h) National Report

(i) Popular non-scientific publications


(j) Workshops/seminars/ open days at which results were presented (excluding those in (g))
1. The results of this research will be presented at the Teagasc National Organic Conference at the Tullamore Court Hotel on 11 September 2012 http://www.teagasc.ie/events/2012/20120719.asp. The presentation entitled ‘Clover research – latest update’ will be given by Dr. Patrick Conaghan, Teagasc, Oakpark, Co. Carlow.

2. Findings from this research were presented at the openday atSolohead Research Farm on 12 July 2012. It was attended by approximately 1600 people.

3. Main findings were presented to international researchers at the Fourth General meeting of DAIRYMAN project at Solohead Research farm on 19 April 2011.
4. There were one presentation at the Teagasc Agri-environment Conference 2010 that was held at Ballykisteen Hotel and at Solohead Research Farm in September 2010. [http://www.teagasc.ie/publications/2010/20100907/index.asp](http://www.teagasc.ie/publications/2010/20100907/index.asp)

5. There were presentations on the three tasks in this project at the international conference entitled ‘Forage Legumes in Temperate Pasture-based systems’ conference visit to Solohead Research Farm on 16 October 2009.

6. The results of the first year of this experiment were presented to the organic farmers’ discussion group when they visited Solohead Research Farm with Pat Barry on 28 May 2009.

7. There was a major open-day held at Solohead Research Farm on 23 April 2009 entitled ‘Using clover to cut costs on dairy and beef farms’ Aspects of this research was highlighted. It was attended by approximately 1000 people.

8. Some results from this experiment were presented to Teagasc Dairy and Beef advisory specialists at Teagasc, Oakpark on 12 December 2008.

9. A description of this experiment and some initial data from this experiment was presented at the Teagasc National Organic Conference held at Tullamore Court Hotel on 2 December 2008.

10. Open day about organic dairy production from clover swards on Peter Young’s (Irish Farmers Journal) farm on 2 September 2008

### 7. Permanent Researchers

<table>
<thead>
<tr>
<th>Institution Name</th>
<th>Number of Permanent staff contributing to project</th>
<th>Total Time contribution (months)</th>
<th>Average time contribution per permanent staff member</th>
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<tr>
<td>Teagasc</td>
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<td>4.36</td>
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<td>WIT</td>
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**Total** 8 49.08

### 8. Researchers Funded by RSF

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<td>Contract Researchers</td>
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<tr>
<td>Other</td>
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**Total** 3 116.64
9. **Postgraduate Research**

Total Number of PhD theses: 2

Magdalena Necpalova submitted her thesis entitled “Investigations into aspects of nitrogen and carbon dynamics in grassland used for dairy production on a clay loam soil” to the Waterford Institute of Technology for the Degree of Doctor of Philosophy on 26 June 2012 and passed her viva with minor changes on 18 September 2012. She is scheduled to graduate in January 2013.

Paul Phelan intends to submit his PhD thesis entitled “Investigations into aspects of grazing management to improve the productivity and persistence of white clover in Irish grassland” to the Waterford Institute of Technology for the Degree of Doctor of Philosophy in November 2012. His viva has not been scheduled yet.

Total Number of Masters theses: 0

10. **Project Expenditure**

Total expenditure of the project: €416,613.15

Total Award by RSF €418,713.48

Other sources of funding (specify) €

Breakdown of Total Expenditure

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<th>Name Institution 4</th>
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<tr>
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<td><strong>416,613.15</strong></td>
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11. **Future Strategies**
The results of this research are being used to improve the effectiveness of recommendations for managing white clover swards at farm level presented, for example, at the open day at Solohead Research Farm on 12 July 2012, which was attended by approximately 1600 farmers and advisors. We aim to continually improve the effectiveness of these recommendations.

Research by Teagasc into organic farming practices is being cut back due to the financial crisis.

12. **Industry Collaboration**
There was no industry collaboration in this project.