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

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

D. Enriquez-Hidalgo,*† T. Gilliland,†‡ M. H. Deighton,*§ M. O'Donovan,* and D. Hennessy*[1]
*Animal & Grassland Research and Innovation Centre, Teagasc, Moorepark, Fermoy, Co. Cork, Ireland
†Queen's University Belfast, Belfast, BT7 1NN, United Kingdom
‡Agri-Food and Biosciences Institute, Plant Testing Station, Crossnacreevy, Belfast, BT5 7QJ, United Kingdom
§Future Farming Systems Research Division, Department of Environment and Primary Industries, Ellinbank, Victoria 3821, Australia

ABSTRACT

An experiment was undertaken to investigate the effect of white clover inclusion in grass swards (GWc) compared with grass-only (GO) swards receiving high nitrogen fertilization and subjected to frequent and tight grazing on herbage and dairy cow productivity and enteric methane (CH_4) emissions. Thirty cows were allocated to graze either a GO or GWc sward (n = 15) from April 17 to October 31, 2011. Fresh herbage [16 kg of dry matter (DM)/cow] and 1 kg of concentrate/cow were offered daily. Herbage DM intake (DMI) was estimated on 3 occasions (May, July, and September) during which 17 kg of DM/cow per day was offered (and concentrate supplementation was withdrawn). In September, an additional 5 cows were added to each sward treatment (n = 20) and individual CH_4 emissions were estimated using the sulfur hexafluoride (SF_6) technique. Annual clover proportion (±SE) in the GWc swards was 0.20 ± 0.011. Swards had similar pregrazing herbage mass (1,800 ± 96 kg of DM/ha) and herbage production (13,110 ± 80 kg of DM/ha). The GWc swards tended to have lower DM and NDF contents but greater CP content than GO swards, but only significant differences were observed in the last part of the grazing season. Cows had similar milk and milk solids yields (19.4 ± 0.59 and 1.49 ± 0.049 kg/d, respectively) and similar milk composition. Cows also had similar DMI in the 3 measurement periods (16.0 ± 0.70 kg DM/cow per d). Similar sward and animal performance was observed during the CH_4 estimation period, but GWc swards had 7.4% less NDF than GO swards. Cows had similar daily and per-unit-of-output CH_4 emissions (357.1 ± 13.6 g of CH_4/cow per day, 26.3 ± 1.14 g of CH_4/kg of milk, and 312.3 ± 11.5 g of CH_4/kg of milk solids) but cows grazing GWc swards had 11.9% lower CH_4 emissions per unit of feed intake than cows grazing GO swards due to the numerically lower CH_4 per cow per day and a tendency for the GWc cows to have greater DMI compared with the GO cows. As a conclusion, under the conditions of this study, sward clover content in the GWc swards was not sufficient to improve overall sward herbage production and quality, or dairy cow productivity. Although GWc cows had a tendency to consume more and emitted less CH_4 per unit of feed intake than GO cows, no difference was observed in daily or per-unit-of-output CH_4 emissions.
Key words: CH_4 emission, herbage production, milk and milk solids production, white clover

INTRODUCTION

Temperate dairy grazing systems based on perennial ryegrass (*Lolium perenne* L.; **PRG**) swards are highly profitable (Cunningham et al., 1994; Dillon et al., 2005). The productivity of systems based on grass-only (**GO**) swards relies on high and frequent N fertilizer application (Frame, 1991; Whitehead, 1995). The European Union Nitrate Directive (Council Directive 91/676/EEC) limits N fertilizer use in grassland to 250 kg of N/ha per year; therefore, alternative means of increasing N supply and, therefore, herbage production, warrant investigation. Recent work examining the combination of PRG and white clover (*Trifolium repens* L., hereafter referred to as clover) has shown promising transgressive overyielding (Kirwan et al., 2009; Gierus et al., 2012). Clover inclusion in PRG swards can increase overall herbage quality due to its high protein and low fiber content (Ulyatt, 1970; Thomson, 1984). Interest in the inclusion of clover in GO swards has been renewed due to clover's ability to fix atmospheric N and potentially increase the N supply to the growing sward.

Grazing cattle have a 70% partial preference for clover compared with PRG when the 2 swards are available simultaneously (Rutter, 2006). Clover fodder has a faster rumen passage rate compared with PRG, as the former is more easily broken down due to its lower fiber content (Beever et al., 1986; Dewhurst et al., 2003). As a result, cows grazing mixed grass and clover swards (**GWc**) can potentially increase DMI and milk yield

Received May 16, 2013.
Accepted November 11, 2013.
[1]Corresponding author: deirdre.hennessy@teagasc.ie

relative to GO swards (Harris et al., 1997; Phillips and James, 1998; Ribeiro Filho et al., 2003). Those studies reported higher milk yields when cows grazed GWc swards compared with GO swards. Furthermore, previous work has shown that clover preference and DMI is affected by the clover availability and content in GWc swards (Harris et al., 1997; Rutter, 2006).

Agriculture accounts for 13.5% of the worldwide greenhouse gas (**GHG**) emissions (IPCC, 2007), and methane (CH_4) and nitrous oxide are the primary GHG related to the sector. The agricultural sector accounts for 29% of the worldwide CH_4 emissions (UNFCCC, 1997) and in 2010, gas from enteric CH_4 fermentation (hereafter referred to as CH_4 emissions) accounted for approximately 13.9% of total Irish GHG emissions (EEA, 2012). In grass-based dairy production systems such as those in Ireland, CH_4 emissions account for up to 49% of the total GHG emissions (Casey and Holden, 2005). Previous studies have reported that net CH_4 emissions can be reduced on a per-product basis if animals can be more efficient (Eckard et al., 2010; Buddle et al., 2011; e.g., achieving greater output for the same feed intake). Methane emissions related to gross energy intake of animals fed legumes are lower than animals fed grasses (Waghorn et al., 2006; Beauchemin et al., 2008). However, although some work has shown that clover inclusion in pasture can reduce dairy cow CH_4 emissions (Lee et al., 2004) others have found no effects (van Dorland et al., 2007).

Clover contribution to the grazing systems is ultimately related to its content and availability in swards. Nitrogen fertilizer can affect sward clover content through accelerated grass growth and increased grass height, which results in shading of clover and, consequently, a reduction in its growth (Frame and Newbould, 1986; Thompson, 1993; Wilman and Acuña, 1993). Clover content reduction in GWc is usually more severe when high herbage masses are allowed to accumulate (Holmes et al., 1992; Laidlaw et al., 1992; Steen and Laidlaw, 1995). Some studies have suggested that frequent (Harris, 1987; Harris and Clark, 1996; McKenzie et al., 2003b) and tight (Frame and Boyd, 1987; Yu et al., 2008; Phelan et al., 2013) grazing can enhance sward clover content and yield. Sward clover content varies widely throughout the grazing season (Frame and Newbould, 1986; Gilliland et al., 2009) and so it is possible that this variation could affect DMI, CH_4 emissions, and ultimately animal production from grazing livestock.

The objective of this experiment was to investigate the effect of clover inclusion in grass swards compared with GO swards receiving high N fertilization and subjected to frequent and tight grazing on herbage production, CH_4 emissions, and dairy cow productivity. It was expected that GWc swards receiving high N fertilizer input and subjected to frequent and tight grazing would (1) attain sufficient clover content to improve herbage production and quality compared with GO swards and, therefore, (2) increase dairy cow productivity, and (3) reduce CH_4 emission.

MATERIALS AND METHODS

The experiments were undertaken at the Dairygold Research Farm (Teagasc, Animal and Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork, Ireland; 52°09′N; 8°16′W). Three 2-ha paddocks were divided (approximately 1 ha each, hereafter referred to as base paddocks) according to a randomized block design and sown with 2 sward treatments of GO and GWc in May 2010. The GO sward was a 50:50 mixture of AstonEnergy (tetraploid) and Tyrella (diploid) PRG cultivars sown at a rate of 37 kg/ha. The GWc sward contained the same PRG mixture as the GO sward and a 50:50 medium leaf clover mixture of Chieftain and Crusader cultivars sown at a rate of 5 kg/ha. Swards received 260 kg of N/ha evenly applied after each grazing rotation between March and mid September as 60 kg of N/ha of urea (46% N) applied until April and 200 kg of N/ha of calcium ammonium nitrate (27% N) thereafter. Swards were grazed once in late February, before the start of the experiment.

Animals and Grazing Management

In April 2011, 30 spring-calving dairy cows were balanced by breed (Holstein-Friesian, Norwegian Red, and Norwegian Red × Holstein-Friesian), calving date [February 19 (SD = 19.7 d)], lactation number [3.7 (SD =1.44)], milk yield [29.6 kg (SD = 3.90)], and milk solids (**MS**) production [2.2 kg (SD = 0.25)] using data available for the 3 wk before the start of the experiment. Cows (n = 30) were randomly assigned to 2 herds (n = 15), which rotationally grazed either the GO or GWc sward treatments between April 17 and October 31, 2011. Cows occasionally grazed an identical reserve of GO and GWc paddocks when a shortage of herbage in the base paddocks occurred. Cows received a herbage allowance (**HA**) of 16 kg of DM/cow per day (4 cm above ground level) and an individual allocation of 1 kg of concentrate/cow per day (CP = 154.1, NDF = 40.9, and ash = 102.8 g/kg of DM). Paddocks were strip grazed within rotation, with fresh herbage offered daily following morning milking, after the target postgrazing sward height (**PostGSH**) of 4 cm above ground level (hereafter referred to as tight grazing) was attained. Temporary electric fences were used to determine the daily area offered to be grazed, based on the HA and