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Meta-analysis of the effect of white clover inclusion in perennial ryegrass swards on milk production

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ABSTRACT

There is increased demand for dairy products worldwide, which is coupled with the realization that consumers want dairy products that are produced in a sustainable and environmentally benign manner. Forage legumes, and white clover (*Trifolium repens* L.; WC) in particular, have the potential to positively influence the sustainability of pasture-based ruminant production systems. Therefore, there is increased interest in the use of forage legumes because they offer opportunities for sustainable pasture-based production systems. A meta-analysis was undertaken to quantify the milk production response associated with the introduction of WC into perennial ryegrass swards and to investigate the optimal WC content of dairy pastures to increase milk production. Two separate databases were created. In the grass-WC database, papers were selected if they compared milk production of lactating dairy cows grazing perennial ryegrass-WC (GC) swards with that of cows grazing perennial ryegrass-only swards (GO). In the WC-only database, papers were selected if they contained milk production from lactating dairy cows grazing on GC swards with varying levels of WC content. Data from both databases were analyzed using mixed models (PROC MIXED) in SAS (SAS Institute, Cary, NC). Within the grass-WC database, where mean sward WC content was 31.6%, mean daily milk and milk solids yield per cow were increased by 1.4 and 0.12 kg, respectively, whereas milk and milk solids yield per hectare were unaffected when cows grazed GC compared with GO swards. Stocking rate and nitrogen fertilizer application were reduced by 0.25 cows/ha and 81 kg/ha, respectively, on GC swards compared with GO swards. These results highlight the potential of GC production systems to achieve similar levels of production to GO systems but with reduced fertilizer nitrogen inputs, which is beneficial from both an economic and environmental point of view. In the context of increased demand for dairy products, there may be potential to increase the productivity of GC systems by increasing fertilizer nitrogen use to increase stocking rate and carrying capacity while also retaining the benefit of WC inclusion on milk production per cow.

Key words: meta-analysis, white clover, dairy cow, milk production, grazing

INTRODUCTION

There is increased demand for dairy products worldwide, which is coupled with the realization that consumers want dairy products that are produced in a sustainable and environmentally benign manner (Godfray et al., 2010). As a consequence, European pasture-based livestock production systems have changed considerably over the past 2 decades and will continue to evolve in response to these societal and environmental pressures (Lüscher et al., 2014). Traditionally, white clover (*Trifolium repens* L.; **WC**) was included in perennial ryegrass (*Lolium perenne* L.; **PRG**) mixtures as a means of improving sward nutritive value and reducing nitrogen (N) fertilizer use. However, cheap N fertilizer, which improves pasture production and simplifies grazing management, has led to a reduction in the use of WC, with declining levels of WC reported in temperate grazing regions such as Western Europe and New Zealand. Forage legumes, and WC in particular, can make an important contribution to the sustainability of pasture-based ruminant production systems (Peyraud et al., 2009). Therefore, there is increased interest in the use of forage legumes because they offer opportunities for sustainable pasture-based production systems by (1) increasing pasture yield, (2) substituting inorganic N fertilizer inputs with symbiotic N_2 fixation, (3) mitigating and facilitating adaptation to climate change, and (4) increasing the nutritive value of pasture and

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raising the efficiency of conversion of pasture to animal protein (Lüscher et al., 2014; Delaby et al., 2016).

Previous research has reported conflicting evidence of the effect of pasture WC content on milk production per cow. Harris et al. (1997a) reported that increased pasture WC content results in higher milk yields due to a combination of higher pasture intake and increased nutritive value of the pasture. Recently, Egan et al. (2015b) reported annual milk solids (kg of fat + protein; **MS**) production of 487 kg/cow from a PRG-WC (**GC**) sward in comparison with 454 kg/cow on a PRG-only (**GO**) sward. Other previous research has also indicated that including WC in a PRG sward can result in an increase in daily milk production per cow (Riberio-Filho et al., 2003; Cosgrove et al., 2006). However, other experiments report little to no effect of GC swards on milk production when compared with GO swards (Ledgard et al., 1998; Humphreys et al., 2009; Enriquez-Hidalgo et al., 2014). The interpretation of results (e.g., milk yield per cow and per hectare, pasture yield) from experiments involving WC must take into account the underlying management practices associated with WC swards. Stocking rate and N fertilizer application rates, 2 of the most important factors in determining milk production within pasture-based systems (Bryant et al., 1981; Macdonald et al., 2008), often differ between experimental treatments with and without WC, and this has an effect on the results obtained. Riberio-Filho et al. (2003) concluded that the high individual performance of the cows obtained on GC swards was, however, offset by a major reduction in the stocking rate that results from the reduced pasture productivity of GC swards. In accordance with this, Ryan (1989) reported that a GC system had a reduction in carrying capacity in the region of 20 to 25% compared with that of a PRG N-based system. Ryan (1989) also stated that a GC system produced 84% of the milk per hectare obtained from an N-based system.

The effect or lack of effect of WC on milk production is possibly attributable to the WC content of the sward. Research undertaken by Lee et al. (2004) reported that with increasing WC proportions in the diet, milk and MS yield increased from 17.6 to 20.4 kg/cow per day and 1.32 to 1.52 kg/cow per day, respectively, as the proportion of WC increased from 0 to 60%. Harris et al. (1997a) reported that 50% sward WC content was the most realistic option for optimum milk yield as cows grazing such a pasture could be expected to produce 95% of maximum possible milk yield. However, high sward WC contents (i.e., >50%) may have implications in terms of animal health because of the increased risk of bloat (Clarke and Reid, 1974) and on the environment because increased N inputs (regardless of the N source) lead to increased N leaching in pasture-based production systems (Ledgard et al., 2009). Therefore, obtaining the optimum sward WC content to increase animal performance without compromising animal health and the environment is an overriding objective.

Results from a single experiment will not provide a definitive understanding of the effect of WC inclusion on milk production because the conditions under which observations are made in a single experiment are inevitably narrow (Sauvant et al., 2008). A meta-analysis approach (Glass, 1976), summarizing the results across published studies in a particular area and in combination with new statistical techniques, allows increased precision of analysis of effects across multiple experiments (St-Pierre, 2001; Sauvant et al., 2008; Lean et al., 2009). The objective of this study, therefore, was to quantify the milk production response associated with the introduction of WC into PRG swards from the published literature and to find the optimal sward WC content of dairy pastures to increase milk production.

MATERIALS AND METHODS

Literature Search, Data Criteria, and Database Design

An electronic literature search [Web of Science (http://thomsonreuters.com/web-of-science/) and Google Scholar (http://scholar.google.com/)] was conducted to identify papers for data extraction in which the effect of WC inclusion on milk production in lactating dairy cows was studied. The search was undertaken using the following key words in different combinations: *white clover*, *milk production*, *perennial ryegrass*, *grazing*, and *dairy cow*. More papers were identified by reviewing the reference list in the publications resulting from the search. These papers were also used to study the effect of differing sward WC content on milk production.

Papers were selected if (1) they compared milk production from a GC sward with that from a GO sward, (2) lactating dairy cows were under strip or rotational-grazing management, and (3) they compared at least 2 WC contents under similar experimental conditions. The inherent management associated with GC swards (i.e., reduced stocking rate and N fertilizer application rates) made it difficult to locate data, so a decision was made to compare milk production from GO and GC swards under different stocking rate and N fertilizer regimens with all other experimental conditions the same to have sufficient data. After accounting for publications with duplicate data or insufficient information provided, a starting database was constructed. The database was conceptualized with rows representing treatments within an experiment and