Persistency of white clover in an intensive animal grazing system

ABSTRACT

High nitrogen (N) fertiliser levels and high stocking rates have been shown to optimize herbage dry matter (DM) production in grass-only systems. Conversely, swards including white clover (*Trifolium repens* L.) are commonly suited to production systems at low N fertiliser levels (< 150 kg N/ha) and low stocking rates (< 2 livestock units [LU]/ha). Despite this, the use of N fertiliser on grass-clover swards has generally increased during the last few decades, particularly in more intensively managed swards under dairy farming. An increase in inorganic N can reduce sward white clover content in grass-white clover swards whilst an increase in stocking rate on grass-white clover swards can result in white clover plant damage. However, under high N levels, an increased stocking rate can also potentially minimize the negative effects of increased companion grass growth on sward white clover contents. The objective of this study was to investigate the persistency of white clover in an intensive animal grazing system, under a high inorganic N fertiliser (250 kg N/ha) regime and at a high stocking rate (2. 75 LU/ha) over a 3-year period (2014-2016). The study was a 2 × 2 factorial design, consisting of two perennial ryegrass ploidies (diploid, tetraploid) and two white clover treatments (grass-clover, grass-only). Four sward treatments (diploid-only, tetraploid-only, diploid + white clover, tetraploid + white clover) were evaluated over a full grazing season at a system scale. Sward measurements were taken at each grazing occasion for three years. Over the three years, grass- white clover swards produced an additional 1, 468 kg DM/ha when compared with grass-only swards. Sward white clover content decreased by 17% over three study years, leading to a decrease in contribution to cumulative herbage DM production.

Keywords: *Trifolium repens* L., herbage DM production, white clover persistency

INTRODUCTION

In temperate regions worldwide, grass-based livestock production systems can improve the financial efficiency and sustainability of agriculture through lower input costs (Shalloo *et al* . 2004, Dillon et al., 2005) when compared with confinement systems. Efficient temperate dairy production systems are based on producing and utilising large quantities of herbage which allow dairy producers to deliver high-quality milk and dairy products from low-cost grazed herbage (Macdonald et al., 2008, Shalloo et al., 2004). The appropriate use of forage species in dairy production systems, in particular white clover, *Trifolium repens* L., in swards of perennial ryegrass, can increase herbage dry matter (DM) production (Enriquez-Hidalgo et al., 2016, Frame and Newbould, 1986, Ledgard and Steele, 1992) and further improve herbage nutritive value (Beever et al., 1986, Guy et al. 2018). Additionally, increased dairy production has been reported by recent studies examining white clover use for intensive grass-based dairy production systems (McClearn et al. 2018, Egan et al., 2018, Enriquez-Hidalgo et al., 2016). However, unlike the studies listed above, the majority of previous studies have been undertaken at low nitrogen (N) fertiliser levels (<150 kg N/ha) and a low stocking rate (<2 livestock units [LU]/ha). Current intensive grass-based dairy production systems that support high levels of dairy production and high stocking rates generally rely on high inorganic N levels, however increasing artificial N directly decreases sward white clover content (Carlsson and Huss-Danell, 2003, Frame and Boyd, 1986, Lüscher et al., 2014). However, it has been shown that under high N fertiliser levels and high stocking rates, a system of rotational frequent, tight grazing (Phelan et al., 2014) can maintain a high sward white clover content under grazing scenarios in dairy systems (Egan et al., 2018, Enriquez-Hidalgo et al., 2016). The use of N fertiliser on grass-white clover swards has generally increased during the last few decades, particularly in more intensively managed swards under dairy farming. An increase in global demand for dairy products has led to an increase in stocking rate; however, there may be scope to increase the carrying capacity of grass-white clover swards using N fertiliser whilst also retaining the benefit of white clover inclusion on herbage DM production.

Thus, the objective of this study was to investigate the persistency of white clover in an intensive animal grazing system, under high N fertiliser (250 kg N/ha) and at a high stocking rate (2. 75 LU/ha) over a 3-year period (2014-2016).

MATERIALS AND METHODS

Site and experimental design

The study was conducted at Teagasc, Clonakilty Agricultural College, Co. Cork, Ireland, over a 3-year period (2014–2016) as per Guy et al. (2018). The soil was a free-draining acid brown earth of light loam to gley soil loam in texture. For 2014–2016, mean annual precipitation was 1, 191 mm, mean air temperature was 10. 1°C and mean soil temperature was 11. 3°C. Soil fertility indexes (Morgan's P and K) improved from 2013 to 2016; soils classified as Index 1 reduced from 25% of the total farm area in 2013 to 0% of the total farm area in 2016.

A farm-system grazing study (43. 6 ha) commenced in 2014; 75% of the farm area was sown in 2012 and the remaining 25% was sown in 2013 (full cultivation, i. e. ploughing and tilling, was used to establish the swards). Paddock sizes ranged from 0. 43 ha to 0. 71 ha.

The study was a 2 × 2 factorial design; two perennial ploidies (diploid and tetraploid) and two white clover treatments (grass-white clover, grass-only) resulting in four sward treatments (diploid-only (DO); tetraploid-only (TO); diploid + white clover (DC); tetraploid + white clover (TC)), sown in 20 blocks. Diploid cultivars were sown at 30 kg/ha and tetraploid cultivars were sown at 37. 5 kg/ha as monocultures in five paddocks each around the farm. This was repeated using the same diploid and tetraploid cultivars, at the same sowing rate as above, plus white clover (50: 50 mix of Chieftain and Crusader medium-leaved white clover cultivars; sown at 5 kg/ha). This resulted in a total of 80 paddocks. Thus, 20 blocks (balanced for location, soil type and soil fertility) of four paddocks each were created, and each treatment was assigned randomly to one of the four paddocks within each block. Blocks were designed to keep each of the four sward treatments adjacent to each other to maintain similar grazing management. Thus, four separate farmlets comprising of 20 paddocks each were created and permanently fenced and each farmlet remained on the same sward treatment for the duration of the study. Total farmlet area for each sward treatment was 10. 9 ha. Each year, 120 spring-calving dairy cows were assigned to one of the four sward treatments, after calving. Inorganic N fertiliser was applied at 250 kg N/ha. year across all four sward treatments between mid-January and mid-September. Inorganic phosphorus (P) and potassium (K) were also applied at similar rates across all four sward treatments (12 kg P/ha and 60 kg K/ha) as indicated by the soil test.

Sward measurements

Sward white clover content : Sward white clover content in each grass-white clover paddock was determined at each grazing (with the exception of February and March 2014) by taking random samples in a “ Z” formation across each paddock at 4 cm above ground level using a Gardena (Accu 60, Gardena International GmbH, Ulm, Germany) hand shears. White clover and perennial ryegrass components (and other grass or weed species) were separated from two 70 g samples. These components were dried at 60°C for 48 hr and the DM content of each component of the sward was calculated.

Herbage DM production : Annual and seasonal herbage DM production was calculated weekly from the increase in herbage mass on ungrazed paddocks using the method of O’Donovan et al. (2002) and Hanrahan et al. (2017). The grazing year was divided into 3 seasons, spring (February and March), summer (April-August) and Autumn (September to November).

Herbage growth rate : Daily herbage growth rate (kg DM/ha. day) was calculated by dividing the herbage mass prior to a grazing event by the number of days between that grazing event and the previous grazing event.

Statistical analyses

Analyses were undertaken on all variables (sward white clover content, herbage DM production and herbage growth rate) using the mixed model procedure (PROC MIXED) in the statistical package SAS 9. 4 (SAS, 2014). Fixed effects included in the model were perennial ryegrass ploidy, white clover inclusion, rotation, year, and white clover inclusion × year interaction, with block as a random effect. Differences were not considered significant if $p > 0.05$.

RESULTS

Perennial ryegrass ploidy did not have an effect on sward white clover content or herbage DM production and so is omitted from this manuscript.

Sward white clover content

Sward white clover content reduced from 2014 to 2016 by 17% (Fig. 1; $p < 0.001$; 2014: 37 ± 1. 5%; 2015: 27 ± 1. 3%; 2016: 21 ± 1. 4%). The contribution of white clover to herbage DM production differed across the grazing season (Fig. 1; $p < 0.001$). August had the greatest (37 ± 1. 5%) and April had the lowest (17 ± 1. 7%) sward white clover content across the three study years. The effect of sward white clover content on herbage DM production varied across each study year. In 2014, an increase of 1% in sward white clover content increased annual herbage DM production by 56 kg DM/ha ($R^2 = 0.257$; $p < 0.001$). However, this contribution to herbage DM production was lower in 2015 as an increase of 1% increase in sward white clover content yielded a 43 kg DM/ha increase in herbage DM production ($R^2 = 0.091$; $p < 0.001$). In 2016, there was no relationship between sward white clover content and total herbage DM production ($R^2 = 0.003$; $p > 0.05$).

Insert Fig. 1 here.

Herbage DM production

Grass-white clover swards produced an additional 1, 468 kg DM/ha (Fig. 1; $p < 0.001$) compared with grass-only swards, on average over the three years of the study. Total herbage DM production differed between study years ($p < 0.01$; 2014: 17, 319; 2015: 17, 429; 2016: 16, 114 DM/ha). The difference in total herbage DM production between grass-only and grass-white clover swards decreased from 2, 490 kg DM/ha in 2014 to 626 kg DM/ha in 2016. Herbage DM production was significantly greater on grass- white clover swards in 2014 and 2015 when compared with grass-only swards. However, in 2016 there was no significant difference between grass- white clover and grass-only swards. This mirrors the results in the previous section.

Daily herbage growth rates

Mean daily herbage growth rates for grass- white clover swards was significantly greater than grass-only swards over the three years (grass-only: 55.1 ± 0.73 kg DM/ha; grass- white clover: 63.7 ± 0.66 kg DM/ha. Herbage growth rates differed between seasons, with the highest daily herbage growth rate achieved in summer (grass-only: 69.3 ± 0.88 kg DM/ha; grass-white clover: 77.7 ± 0.77 kg DM/ha). Over-winter herbage growth rate (December and January) was significantly lower for grass- white clover swards when compared with grass-only swards ($p < 0.001$; grass- white clover: 1. 55 ± 0. 380 kg DM/ha/day; grass-only: 4. 88 ± 0. 380 kg DM/ha/day). Herbage growth rate in spring did not differ with the inclusion of white clover (grass-only: 23. 7 ± 1. 90; grass- white clover: 23. 8 ± 1. 90 kg DM/ha/day).

Insert Fig. 2 here.

DISCUSSION

The use of N fertiliser on grass- white clover swards has generally increased during the last few decades, particularly in more intensively managed swards under dairy farming. This is to improve grass growth rates to maintain the high stocking rates that are currently being operated on intensive grass-based dairy production systems. However, previous studies have shown that using high N fertiliser levels in swards incorporating white clover can depress sward white clover content and therefore its contribution to daily herbage growth rate and herbage DM production (Frame & Newbould 1986; Carlsson & Huss-Danell 2003; Lüscher et al. 2014). Reduction of sward white clover content of 27-41% has been reported when N fertiliser has been used on grass- white clover swards (180–200 kg N/ha; Elgersma et al. 2000; Ledgard 2001; Enriquez-Hidalgo et al. 2016). The frequent and tight grazing resulting from the increased stocking rates at high N levels has been shown to minimize the negative effects of increased grass growth on sward white clover content (Harris & Clark 1996; Phelan et al., 2014) and this may have led to increased light penetration to the sward base in the current study, favouring white clover growth. However, despite this grazing management, the reduction of 17% sward white clover content reflects the findings of these previous studies. Previous management at the site (cropping and silage systems) is likely a factor in the eventual decrease in sward white clover content observed. Although soil C and N were not measured at the start or during the experiment, this previous management at the site would indicate that the soil available N may have been limiting at the beginning of the study. This would have encouraged sward white clover growth at establishment. However, the changes in the relative proportions of grass and clover in the sward over time are explainable by grass- white clover interactions mediated by N availability and the resulting shifts in the competitive advantage of the grass and white clover components of the sward (Schwinning and Parsons, 1996).

The additional herbage DM produced on grass- white clover swards (+ 1, 468 kg DM/ha. year) was as a result of increased herbage growth rates of these when compared with the grass-only swards from May until October. The increase in sward white clover content from May onwards led to this increased herbage DM production (Andrews et al., 2007, Harris and Thomas, 1973, Ribeiro Filho et al., 2003). Although white clover inclusion increased herbage DM production and daily herbage growth rate, the increase declined by 1, 864 kg DM/ha over the three study years as sward white clover content decreased by 17%

CONCLUSION

The inclusion of white clover in perennial ryegrass swards resulted in an increase in herbage DM production of 1, 468 kg DM/ha compared with grass-only swards. This was observed over three grazing seasons at 250 kg N/ha. year and at a stocking rate of 2. 75 LU/ha. Although, this study has shown it is possible to improve mid-season productivity by including white clover in grass-based production systems at high N fertiliser levels, in association with high stocking rates, the initial extra herbage DM production on grass- white clover swards decreased each year. This is likely due to the increased N fertiliser use reducing the sward white clover content of the grass- white clover swards. Further study could investigate the grass- white clover interactions as mediated by N availability and the resulting changes in the competitive advantage of the two species that could lead to fluctuations over time in the relative proportions of grass and white clover in the sward. This study was undertaken over a short period of time and the results presented could be seen as the initial stage of establishing a longer-term equilibrium between the grass and white clover species. Longer term studies could provide greater insight into the dynamics of grass- white clover swards. This would also provide an opportunity to further study whether the white clover persistence decline observed in this study is progressive over a longer time period as this could be a limitation to fully exploiting the production improvements reported in the current study, under practical farm conditions.

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