# Effect of stocking rate on dry matter production, sward structure, sward morphology and tiller density throughout a whole grazing season[1]

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## Abstract

Stocking rate (SR) influences the sward through grazing intensity. A 4 ha grazing area, within a large grazing system experiment, was rotationally grazed by dairy cows from 10 February to 18 November (early spring to late autumn in the northern hemisphere) comparing the effects of three SR treatments: Low (L; 2.51 cows $ha^{-1}$), Medium (M; 2.92 cows $ha^{-1}$) and High (H; 3.28 cows $ha^{-1}$). There was no significant difference in herbage accumulated or harvested among treatments. High SR swards were grazed 0.5 cm shorter than M and 1.1 cm shorter than L. Leaf proportions increased from 60.7 to 66.0 and 70.5%, and stem proportions decreased from 24.8 to 20.0 and 17.7% for L, M and H paddocks, respectively. Tiller densities of weed grass tillers for L, M and H paddocks decreased from 3,350 to 2,780 and 1,771 tillers $m^{-2}$, respectively. Rejected areas significantly increased for L (27%) treatment compared to the M (20%) and H (10%) treatments. The findings confirm, over a full grazing season with a dairy herd, what has often only been demonstrated in short term studies or with sheep.

***Additional keywords:*** stocking rate, pre-grazing herbage mass, tiller density, entire season, rejected area, sward height, leaf proportion

## Introduction

Increasing the proportion of grazed grass in the dairy cow's diet can dramatically reduce production costs (Dillon *et al.*, 2005), as grass remains the cheapest source of feed for dairy cows (Shalloo *et al.*, 2004). Efficient utilisation of pasture is largely determined by stocking rate (SR), McMeekan and Walshe, 1963) and grazing management decisions (Hodgson, 1989).

A high relative SR can decrease herbage production (Hodgson and Wade, 1978; Korte *et al.*, 1984) and may reduce herbage availability at the next harvest (Greenhalgh *et al.*, 1966). Repeated lax defoliation, on the other hand, leads to poorer quality swards, with an increased proportion of dead material (Hunt and Brougham, 1967). Michell and Fulkerson (1987) found that a high relative grazing intensity (SR by duration of grazing) during spring produced higher growth rates of grass leaf but this was at the expense of total growth due to a reduction in stem production. Swards

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rotationally grazed by dairy cows, stocked at 5.9 cows $ha^{-1}$, contained significantly more green leaf and less dead material than those grazed by cows stocked at 4 cows $ha^{-1}$ over the first three rotations (Stakelum and Dillon, 1990). Similarly, O'Donovan and Delaby (2005) reported an increase of 5% leaf and a decrease of 2% stem with higher grazing intensity.

Most studies investigating the effects of defoliation frequency and intensity on sward characteristics have been limited to plot studies (Hernandez Garay *et al*., 1997) and glass houses (Fulkerson, 1994; Fulkerson and Slack, 1995) or, if performed under grazing, were of limited duration (Baker and Leaver, 1986; Hoogendoorn and Holmes, 1992; Pulido and Leaver, 2003) or used sheep (Frame and Hunt, 1971; Evans *et al*., 1998; Garcia *et al*., 2003). Additionally, most of these studies were mainly focused on animal variables (Greenhalgh *et al*., 1966) or the overall system efficiency (Macdonald *et al*., 2001).

The objective of this experiment was to examine the effect of varying levels of grazing intensity, resulting from different SR, on dry matter (DM) production, sward structure and morphology, and tiller density of a perennial ryegrass (*Lolium perenne* L.) pasture under an intensive grazing regime, across the entire grazing season.

## Materials and Methods

The experiment was conducted from 10 February to 18 November 2009 at Curtins Research Farm, Animal & Grassland Research and Innovation Centre, Teagasc, Moorepark, Fermoy, Co. Cork, Ireland (50° 7' N, 8°16' W). The experiment focused on sward characteristics and was a component of a larger study investigating the effect of SR and calving date on dairy cow performance (McCarthy *et al*., 2010). The grassland site was dominated by two-year old perennial ryegrass swards and did not contain clover. Weather data were recorded daily (Table 1).

**Table 1:** Rainfall, daily maximum and minimum temperatures, and daily soil temperature at 5 cm for the period of the experiment (February to November 2009) compared with other periods.

| | | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Monthly rainfall (mm) | 2009 | 16 | 56 | 107 | 89 | 52 | 154 | 117 | 41 | 127 | 260 |
| | 1950-2009 | 82 | 82 | 62 | 68 | 64 | 63 | 82 | 86 | 102 | 102 |
| Daily maximum temp. (°C) | 2009 | 8.6 | 11.1 | 13.0 | 15.3 | 19.4 | 18.5 | 18.8 | 17.6 | 15.2 | 11.1 |
| | 1961-1990 | 7.5 | 9.3 | 11.3 | 13.8 | 16.6 | 18.5 | 18.2 | 16.0 | 13.1 | 9.9 |
| Daily minimum temp. (°C) | 2009 | 1.6 | 3.1 | 4.8 | 6.7 | 10.0 | 11.2 | 11.0 | 8.2 | 8.3 | 4.5 |
| | 1961-1990 | 2.5 | 3.1 | 4.2 | 6.5 | 9.2 | 11.1 | 10.9 | 9.4 | 7.5 | 4.5 |
| Daily soil temp. at 5 cm (°C) | | 5.1 | 7.3 | 10.2 | 13.4 | 18.3 | 17.7 | 17.5 | 14.9 | 12.8 | 8.0 |

## Treatments

A 4 ha grazing area was used to compare the effects of three SR treatments on sward production and characteristics. The three SR treatments were: Low (L; 2.51 cows $ha^{-1}$), Medium (M; 2.92 cows $ha^{-1}$) and High (H; 3.28 cows $ha^{-1}$). Three large paddocks, of similar size, were selected from the farm (1.36 ha ± 0.092) each was then sub-divided into three sub-paddocks (0.453 ha ± 0.062) of differing size, depending on the SR treatment i.e., the higher the SR the smaller the paddock. Two plots of identical size were created within each sub-paddock and measurements from these were averaged. The three sub-paddocks in each SR treatment were rotationally grazed by the same herd of cows for the 10 month grazing season. There was one herd of cows allocated to each treatment for the grazing season. Soil index was three or greater for all paddocks indicating high levels of P and K ( Coulter and Lalor, 2008).

## Grazing Management

Numbers of grazing events were 12, 11.7 and 11 for L, M and H treatment paddocks, respectively. The paddocks in the experiment were not harvested for silage or mechanically topped. The paddocks received 30 kg (± 0.9 kg) N $ha^{-1}$ each application, with N being applied after each grazing. The total N applied during the experiment was 250 kg $ha^{-1}$. Target pre-grazing HM was 1,100 kg DM $ha^{-1}$ (above 3.5 cm) and was a decision rule of the larger experiment (McCarthy *et al*., 2012).

## Measurements

### *Herbage production*

Pre- and post-grazing HM above 3.5 cm were determined by cutting one strip from each measurement plot (1.2 m wide x 10.0 m long). Before and after harvesting each cut strip, 10 grass compressed height measurements were recorded using a rising plate meter (Jenquip, New Zealand). Herbage harvested, or apparently utilised, was calculated as the difference between each pre- and post-grazing HM. Herbage accumulation between grazings was calculated as the difference between the current pre-grazing HM and the post-grazing HM of the previous rotation. Pre- and post-grazing sward heights were measured at each grazing.

### *Sward structure and morphology and tiller density*

Pre- and post-grazing extended tiller heights (ETH; cm from ground to lamina tip) and extended sheath heights (ESH) were measured on 100 primary tillers across the diagonals of each plot, free leaf lamina (FLL) being the difference between ETH and ESH, as described in Gilliland *et al*. (2002). The proportion of rejected areas after each grazing was visually assessed using a 1 x 1 m quadrat placed randomly at five points across the diagonal of each plot. A 40 g sample, cut to ground level with scissors before each grazing, was separated into two portions - above and below 3.5 cm, each portion was subsequently separated into leaf, stem and dead material. The rationale for separating components below 3.5 cm was to obtain an estimate of the green leaf present in this horizon, which could have a subsequent influence on sward production. Five sods of 10 x 10 cm $plot^{-1}$ were taken at the start, middle and end of the grazing season to estimate tiller density. The tillers were counted and divided into perennial ryegrass or weed grasses (*Poa pratensis* L, *Poa trivialis* L. and *Agrostis stolonifera* L.).

### *Weather*

Rainfall, during the study (1,017 mm), was 22% above the 1950-2009 average. Mean daily maximum temperature was 1.6°C higher than the 1961-1990 average (Table 1).

### Statistical analysis

All sward measurements were analysed using analysis of variance in Statistical Analysis Systems Inc. (2005). Data were analysed with a mixed model that included the fixed effect of treatment, the random effect of paddock and the random effect of the interaction treatment and paddock. The significance of treatment effect was tested against the mean squares of the interaction treatment by paddock.

## Results

### *Herbage production*

Herbage accummulated, between grazings, was not different among treatments, and was appromixately 7.6 t DM $ha^{-1}$ (Table 2). Throughout the season, pre-grazing HM of L paddocks (1,127 kg DM $ha^{-1}$) was 106 and 169 kg DM $ha^{-1}$ higher than that from the M and H paddocks, respectively ($P<0.05$, Table 2). Post-grazing HM of the laxly grazed paddocks (502 kg DM $ha^{-1}$) was 181 and 278 kg DM $ha^{-1}$ higher ($P<0.001$) than the M and H paddocks, respectively. The herbage harvested, or apparently utilised, was similar for all treatments (8.1 t DM $ha^{-1}$) (Table 2). Rejected areas (areas around dung deposits) were 10% for H paddocks, increased by 10 percentage units for M paddocks and by 17 percentage units for L paddocks ($P<0.001$).

### *Sward structure and morphology and tiller density*

Low SR paddocks, when compared with the other two treatments, had higher pre-grazing compressed heights (+0.5 cm, $P<0.01$), ETH (+2 cm, $P<0.01$) and ESH (+2.7 cm, $P<0.001$), (Table 2). High SR swards were grazed 0.5 cm shorter than M and 1.1 cm shorter than L ($P<0.001$). Free leaf lamina in the H paddocks tended to be greater prior to grazing ($P=0.05$), but was 1 cm shorter than the other two treatments post-grazing (4.9 cm), ($P<0.001$).

Above the 3.5 cm horizon, the H paddocks had the greatest proportion of leaf and the lowest proportion of stem (70.5 and 17.7%, respectively; $P<0.001$), while the L paddocks had the lowest proportion of leaf and the greatest proportion of stem (60.7 and 24.8%, respectively; ($P<0.001$). Available leaf in each grazing did not differ among treatments at 677 kg DM $ha^{-1}$. Stem and dead components were highest in the L paddocks (166 and 24 kg DM $ha^{-1}$, respectively) and lowest for the H paddocks (118 and 14 kg DM $ha^{-1}$, respectively). In each cm above the 3.5 cm horizon, H swards contained 20 kg $ha^{-1}$ more leaf yield than the other two levels of grazing intensity (162 versus 140 kg DM $ha^{-1}$ $cm^{-1}$), ($P<0.01$) and 12 and 19 kg less stem yield than M and L treatments, respectively ($P<0.001$). The perennial ryegrass tiller population density was not significantly affected by the SR treatments (average 5,060 tillers $m^{-2}$). The weed grass populations were 3,350, 2,780 and 1,771 tillers $m^{-2}$ ($P<0.001$) for the L, M and H treatments, and so decreased as SR increased.

**Table 2:** Pre- and post-grazing herbage mass, sward structure and sward morphology of the paddocks averaged for the entire season under three stocking rates.

| | | Stocking rate treatments (cows $ha^{-1}$) | | | | |
|---|---|---|---|---|---|---|
| | | Low (2.51) | Med (2.92) | High (3.28) | SED | P-value |
| | Herbage grown | 7,245 | 7,997 | 7,556 | 523.5 | 0.3932 |
| | Herbage harvested | 7,734 | 8,271 | 8,171 | 444.1 | 0.4720 |
| Pre-grazing | Herbage mass (> 3.5 cm; kg DM $ha^{-1}$) | 1,127a | 1,021b | 958c | 52.0 | 0.029 |
| | Herbage mass (to ground level; kg DM $ha^{-1}$) | 3,251a | 3,127ab | 2,954b | 88.0 | 0.025 |
| | Height (cm) | 8.38a | 7.89b | 7.87b | 0.073 | 0.015 |
| | Extended tiller height (cm) | 24.6a | 22.5b | 22.6b | 0.53 | 0.005 |
| | Extended sheath height (cm) | 10.1a | 7.7b | 7.0b | 0.32 | <0.001 |
| | Free leaf laminae (cm) | 14.3 | 14.3 | 15.1 | 0.30 | 0.053 |
| | Leaf % > 3.5 cm | 60.7a | 66.0b | 70.5c | 0.01 | <0.001 |
| | Stem % > 3.5 cm | 24.8a | 20.0b | 17.7c | 0.01 | <0.001 |
| | Dead % > 3.5 cm | 14.7 | 14.3 | 12.0 | 0.01 | 0.086 |
| Post-grazing | Herbage mass (> 3.5 cm; kg DM $ha^{-1}$) | 502a | 321b | 224c | 32.0 | <0.001 |
| | Height (cm) | 4.70a | 4.11b | 3.59c | 0.033 | <0.001 |
| | Extended tiller height (cm) | 14.2a | 12.6b | 9.6c | 0.37 | <0.001 |
| | Extended sheath height (cm) | 9.4a | 7.5b | 5.7c | 0.35 | <0.001 |
| | Free leaf laminae (cm) | 4.8a | 4.9a | 3.8b | 0.16 | <0.001 |
| | Rejected areas (%) | 26.7a | 20.0b | 10.0c | 0.02 | <0.001 |

Values with different letters are significantly different at P<0.05; SED = standard error of the difference.

## Discussion

The lack of a response in herbage accumulation to the SR treatments supports the conclusion of Bircham and Hodgson (1983) that pasture production is insensitive to grazing management over a broad range of conditions. This finding contrasts with recent studies reporting that increased pasture production was a result of a relatively high SR (Lee *et al*., 2008; Macdonald *et al*., 2008). A possible explanation for the differing results could be that, in this experiment, mean pre-grazing HM (above 3.5 cm) was low and below recommendations (O'Donovan and Kennedy, 2009). Curran *et al*. (2010) and McEvoy (2009) reported that pre-grazing HM between 1,400 and 1,600 kg DM ha$^{-1}$ (above 4 cm) gave maximum sward production. In the present study, a consistently lower pre-grazing HM across the season may have supressed growth in the most intensively grazed paddocks. This is supported by data from Tuñon *et al*. (2011) who observed that plots with a mean pre-cutting HM of 561 kg DM ha$^{-1}$ accumulated 35% less grass DM than plots which had a mean pre-cutting HM of 1,731 kg DM ha$^{-1}$.

Stocking rate had a positive effect on sward characteristics - the proportion of leaf in the sward increased as the post-grazing height decreased. There were 0.6 and 1.1 cm differences when the L pasture height was compared to the M and H paddocks, respectively. Based on the higher leaf content and lower stem content of the H grazed swards, the pasture grazed in this treatment was possibly of higher nutritional value than the M and L pastures (Hodgson, 1989). These results agree with previous studies in the Southern Hemisphere (Holmes and Hoogendorn, 1983; Michell and Fulkerson, 1987) and in the Northern Hemisphere (Stakelum and Dillon, 1990). Consistent with previous research, the highest SR resulted in fewer rejected areas (Baker and Leaver, 1986) and in lower weed grass tiller density (Korte *et al*., 1984; Lee *et al*., 2008). There is the potential to improve the nutritive value of a pasture without affecting total production, although a high SR may result in a lower intake cow$^{-1}$ (Macdonald *et al*., 2008). McCarthy *et al*. (2010), in a meta-analysis comprising 131 studies, reported a 7% decrease in milk yield cow$^{-1}$ but a 20% increase in milk yield ha$^{-1}$ for each one cow ha$^{-1}$ increase in the SR.

## Conclusion

In summary, post grazing height declined by 0.1 cm 0.1 unit$^{-1}$ increase in the SR, when SR ranged from 2.5 to 3.3 cows ha$^{-1}$. This effect did not significantly impact on herbage accumulated or harvested. Leaf proportion in the sward increased by 10.5%, the amount of rejected pasture declined by 17% and weed grass invasion declined by almost 50% with a high SR across the season compared to a lower SR. The results emphasised that the main impact of SR was on sward characteristics rather than herbage production. These findings confirm, over a full grazing season of a dairy herd, what has often been demonstrated in short term studies or with sheep.

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