# End of project report 5226

July 2008

# The effect of grass genotype and spring management on the nutritive value of mid-summer ryegrass swards

Authors

Michael O'Donovan[1],Gráinne Hurley[1] and Trevor Gilliland[2]

[1]Teagasc, Dairy Production Research Centre, Moorepark, Fermoy, Co Cork.
[2] Agri –Food & Biosciences Institute, Crossnacreevy, Northern Ireland.

## Table of Contents

## 1.0 SUMMARY

The objective of this project was to investigate the environmental, morphological and management factors that control reproductive initiation and development in *Lolium perenne* L. (perennial ryegrass) and their influence on mid-season sward quality. These factors were assessed on eight perennial ryegrass cultivars through spaced plant and plot studies. The first part of this project determined the effects of meteorological conditions and latitude on reproductive initiation and ear emergence of cultivars over two consecutive years. It was concluded that the critical day length requirement for reproductive initiation varies between perennial ryegrass cultivars and is independent of latitude and the normal range of conditions. Using this information a strong correlation ($r^2$ = 0.94) was found between the critical day length for ear initiation and the ten year standardised ear emergence dates of the cultivars. This correlation was sufficiently robust to predict the critical initiation date for any perennial ryegrass cultivar on a UK recommended list or on the EU common catalogue by using their heading dates from the UK Plant Breeders Rights trials at Crossnacreevy. Large variation was observed for secondary initiation and re-heading between cultivars of similar and varying maturity, which is a major factor reducing mid-season sward quality. The propensity for initiation of re-heading was strongly influenced by the severity of defoliation (intense to very lax), but there was also evidence to suggest that critical day length post-solstice, may determine the latest date when further reproductive initiation could occur. Differences in plant growth modes were clearly evident as the sward structure, plant morphology and nutritive compositions differed significantly between cultivars during the mid-season. Defoliation management also significantly affected mid-season sward structure, morphology and nutritive composition. While the effect of defoliation height on the sward physical and chemical compositions was inconclusive, an intensive (30 mm) defoliation resulted in plants returning to a vegetative growth mode earlier compared to a lax (60 mm) defoliation treatment. It was observed that defoliation at a critical growth stage can significantly affect subsequent sward structures. Delaying initial spring defoliation resulted in a greater leaf proportion and swards of greater herbage quality in the plot study. This study, therefore, established the need for more detailed evaluation of

cultivars by national testing authorities to allow farmers to select cultivars for grazing use that will optimise animal intake and performance.

## 2.0 INTRODUCTION

In Irish dairy production systems increased emphasis is being placed on ensuring that the price paid for milk reflects the market returns that can be obtained from that milk in terms of processed products (Kennedy 2005). Multi-component price systems of milk payment are used in many countries around the world which operate by putting a value on each kg of protein and fat supplied by the farmer to the processor and a negative price term on volume so as to reflect the cost of handling and removing water in product manufacture. Protein is the most valuable constituent in milk because of consumer demand for products derived from milk protein. It is essential, therefore, that milk composition, in particular protein content is maximised. With the onset of lower product prices and rising production costs, a low cost quality feed such as grazed grass must obtain these objectives.

The majority of milk is produced and supplied during the mid-season period (May to August), however, during this period milk protein content stagnates and doesn't increase in the manner expected. One of the main factors contributing to this decline in mid-season milk quality is a reduction in sward quality. During the main growing season as the sward matures prior to and during the inflorescence period sward quality declines. It is well known that the leaf fraction of grass has a greater voluntary intake and feeding value than stem fractions (Laredo & Minson 1975). Additionally, the structure of the sward influences intake (Stobbs 1973). The sward morphological composition fluctuates throughout the year as the plant changes from a vegetative to a reproductive growth stage and is also influenced by such factors as grass species, cultivar and management.

Large differences exist across cultivar maturity range in terms of seasonality of production and morphological composition. There may be an interaction, therefore, in which cultivars at different growth stages at different times of the growth season may respond differently to certain defoliation managements. In contrast, cultivars may respond quite independently of time of season and management imposed and retain their relative morphological and production characteristics.

Timing of defoliation is a critical factor in controlling reproductive tiller development. In the past, studies examining the effect of management on mid-season sward quality by means of pasture topping and high grazing pressure in spring (Korte 1981) have somewhat reduced sward quality deterioration, yet, they have failed to resolve the problem fully. Although the factors which control reproductive initiation and growth have been well documented (Cooper 1951), a more empirical approach is required for further inhibition of mid-season steminess by studying the early developmental stages of reproductive initiation and growth and the effects of management.

The initial phase of experimentation in this study was designed to quantify the factors which control reproductive initiation and growth in perennial ryegrass. The interacting factors of cultivar maturity, seasonality of productivity and early season defoliation strategies were subsequently studied throughout the growing season with particular focus on the physical and chemical composition of perennial ryegrass during the mid-season when herbage digestibility is known to be compromised.

## 3. Experiment I. Relationship between reproductive initiation and ear emergence development

### Materials and methods

The experiment was undertaken at two different latitudes in Ireland over three consecutive years; Northern Ireland Plant Testing Station, Crossnacreevy, Belfast (latitude 54°32’N) during 2005 and 2007, and Moorepark Dairy Production Research Centre, Fermoy, Co. Cork (latitude 50°07’N) during 2006 and 2007. Forty replicate plants of each cultivar (Table 1) were established at 0.75m spacing in outdoor sites at both locations and vernalised over winter before examinations began in the following springs.

**Table 1.** Details of Lolium perenne cultivars assessed

| Cultivar | Ear emergence date (1994 – 2003) |
|---|---|
| AberDart | 27 May |
| Fennema | 28 May |
| Corbet | 3 June |
| AberAvon | 5 June |
| Foxtrot | 7 June |
| Mezquita | 8 June |
| Melle | 17 June |
| Twystar | 19 June |

### Plant measurements

Sampling for cultivar ear initiation date began in mid March. On alternate days one tiller was removed from each plant and examined under the microscope for reproductive budding as described by Sweet *et al.* (1991). Leaves were removed until the growth apex was visible under close examination. The presence of a double ridge on the apex indicated that the tiller had initiated or turned reproductive. Examinations continued until all plants had initiated.

Critical day length, which is the minimum length of daylight required to trigger the growth of the reproductive apex, was subsequently calculated for each plant. Ear emergence date was recorded, as the date when three seed heads had visibly emerged on a spaced plant Cooper (1952). The heading date results for the eight test cultivars presented in Table 1 were used to produce the correlation between the ear initiation and ear emergence dates.

Plant energy requirements were calculated in terms mean daily temperature (>0°C) and photosynthetically active radiation (PAR) from ear initiation to ear emergence. Photosynthetically active radiation is the amount of useable light energy received by a plant and is dependent on light intensity and day length.

## Results

### Climatic conditions

Overall, a higher rainfall and greater mean air temperature was recorded in the months of January to June during 2007 compared to the same period in 2005 and 2006 at both sites. Moorepark had lower rainfall amounts and higher mean air temperatures from January to June compared to those recorded during the same period at Crossnacreevy. These records show, therefore, that the differences in these two key climatic parameters were of sufficient magnitude to induce differential timing of any climatically influenced physiological development. In addition to climatic variation, differences in latitude between the two experimental sites provided an additional factor in this investigation. Fig 1 shows the magnitude of difference in day length between the two trial sites caused by their difference in latitude. The southern site (Moorepark) has longer day lengths in the winter period than the northern site (Crossnacreevy), but this is reversed in the summer period.

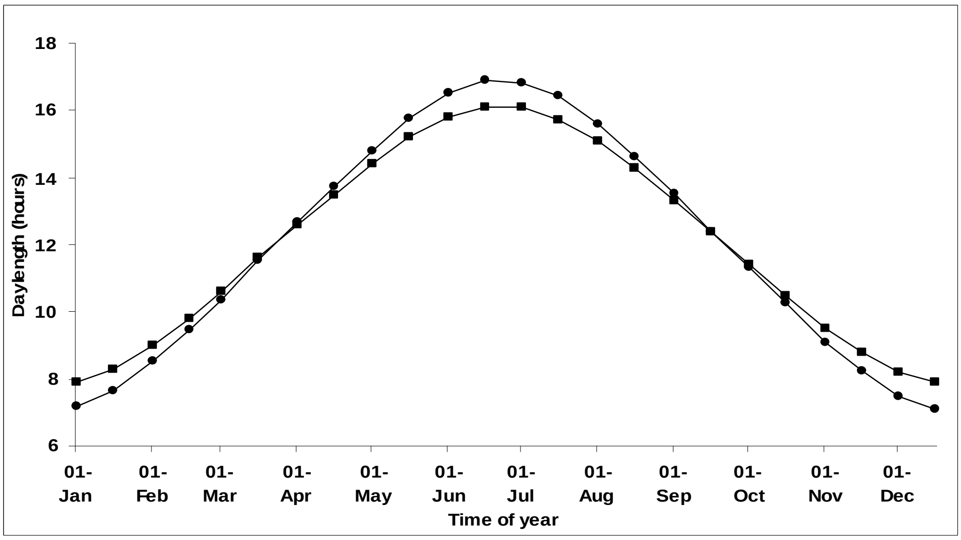


**Fig 1** Hours of daylight (day length) at Crossnacreevy (54°N) ● and Moorepark (50°N) ■

### Ear initiation

Table 2 shows the ear initiation date and critical day length of each cultivar at each site. On average plants initiatied four days earlier at both sites during 2007 compared to the previous experimental years and the critical day length requirement was 0.4 hours less (24 minutes) in 2007. When, however, the critical day lengths were compared between sites for each year, with adjustments for latitude, the average across all the cultivars was only 6 minutes (0.1 hour) earlier at Moorepark in 2006 than at Crossnacreevy in 2005 and with no differences in critical day length in 2007 between sites. Energy received (temperature and light intensity) from 1 January to EI was significantly different (P<0.001) between sites and years (data not shown).

**Table 2**. Ear initiation dates and ear initiation critical day lengths of eight test cultivars

| | Mean ear initiation date | | | | Mean critical day length (hours) | | | |
|---|---|---|---|---|---|---|---|---|
| | Crossnacreevy | | Moorepark | | Crossnacreevy | | Moorepark | |
| | 2005 | 2007 | 2006 | 2007 | 2005 | 2007 | 2006 | 2007 |
| AberDart | 31 Mar | 6 Apr | 5 Apr | 3 Apr | 12.6 | 12.7 | 12.8 | 12.8 |
| Fennema | 3 Apr | 3 Apr | 4 Apr | 1 Apr | 12.8 | 12.5 | 12.8 | 12.6 |
| Corbet | 14 Apr | 13 Apr | 18 Apr | 13 Apr | 13.6 | 13.5 | 13.8 | 13.4 |
| AberAvon | 15 Apr | 10 Apr | 13 Apr | 11 Apr | 13.6 | 13.3 | 13.4 | 13.3 |
| Foxtrot | 21 Apr | 15 Apr | 18 Apr | 14 Apr | 14.1 | 13.5 | 13.8 | 13.5 |
| Mezquita | 23 Apr | 18 Apr | 19 Apr | 13 Apr | 14.3 | 13.7 | 13.8 | 13.4 |
| Melle | 1 May | 21 Apr | 28 Apr | 20 Apr | 14.8 | 14.1 | 14.4 | 13.9 |
| Twystar | 3 May | 25 Apr | 29 Apr | 22 Apr | 14.9 | 14.2 | 14.5 | 13.9 |
| Mean | 17 Apr | 13 Apr | 16 Apr | 12 Apr | 13.8 | 13.4 | 13.7 | 13.4 |
| | | | | | | | | |
| SED | 1.60 | | | | 0.089 | | | |
| Year | *** | | | | *** | | | |
| Site | * | | | | *** | | | |
| Cultivar | *** | | | | *** | | | |
| Y*S | NS | | | | NS | | | |
| Y*C | *** | | | | *** | | | |
| C*S | ** | | | | *** | | | |

Y = Year; C = Cultivar; S = site; SED = Standard Error of Difference, *** = P<0.001; ** = P<0.01; * = P<0.05; NS = Non Significant

### Ear emergence

Cultivars generally headed in the pairs in which they were initially selected, but on average, cultivar emergence dates were three days later at Crossnacreevy in 2005 than the long-term emergence dates for these cultivars recorded by the United Kingdom national testing authority (6 June). The mean ear emergence date at Moorepark in 2006 was seven days earlier than the mean ear emergence date at Crossnacreevy in 2005 (Table 3). During 2007 the mean ear emergence date at both sites was significantly earlier than the recorded dates by the United Kingdom national testing authority. Ear emergence date was significantly (P<0.001) different between cultivars at both sites ranging from 31 May (Fennema) to 18 June (Twystar) in 2005 and from 9 May (AberDart) to 10 June (Twystar) in 2007 at Crossnacreevy. Similarly at Moorepark the EE date ranged from 24 May (Fennema) to 10 June (Melle/Twystar) in 2006 and from 17 May (Fennema) to 6 June (Twystar) in 2007. Ear emergence was, therefore, not concurrent at the two sites over the two years.

There was a shorter period between ear initiation and ear emergence for all cultivars in 2007 compared to 2005 and 2006 at both sites which was influenced by changing meteorological conditions. The range in the number of days between ear initiation and ear emergence of all cultivars was much greater at Crossnacreevy over both years (15 days in 2005 and 16 days in 2007) compared to that at Moorepark (8 days in 2006 and 4 days in 2007).

**Table 3**. Ear emergence dates and number of days between ear initiation and ear emergence of eight test cultivars

| | Mean ear emergence date | | | | Ear initiation to Ear emergence (days) | | | |
|---|---|---|---|---|---|---|---|---|
| | Crossnacreevy | | Moorepark | | Crossnacreevy | | Moorepark | |
| | 2005 | 2007 | 2006 | 2007 | 2005 | 2007 | 2006 | 2007 |
| AberDart | 1 June | 9 May | 26 May | 19 May | 61 | 33 | 50 | 46 |
| Fennema | 31 May | 11 May | 24 May | 17 May | 58 | 38 | 50 | 46 |
| Corbet | 8 June | 23 May | 1 June | 25 May | 55 | 40 | 45 | 42 |
| AberAvon | 10 June | 26 May | 3 June | 26 May | 56 | 45 | 50 | 45 |
| Foxtrot | 8 June | 30 May | 1 June | 27 May | 57 | 45 | 44 | 43 |
| Mezquita | 11 June | 28 May | 4 June | 28 May | 49 | 41 | 46 | 45 |
| Melle | 17 June | 9 June | 10 June | 5 June | 47 | 49 | 43 | 46 |
| Twystar | 18 June | 10 June | 10 June | 6 June | 46 | 46 | 42 | 45 |
| Mean | 9 June | 26 May | 2 June | 26 May | 54 | 42 | 46 | 45 |
| SED | 1.45 | | | | 1.61 | | | |
| Year | *** | | | | *** | | | |
| Site | *** | | | | *** | | | |
| Cultivar | *** | | | | *** | | | |
| Y*S | *** | | | | *** | | | |
| Y*C | *** | | | | *** | | | |
| C*S | *** | | | | ** | | | |

Y = Year; S = site; C = Cultivar; SED = Standard Error of Difference, *** = P<0.001; ** = P<0.01; * = P<0.05; NS = Non Significant

**Relationship between ear initiation and ear emergence date**

It was found that when a regression analysis was performed using the average critical day length data from the current study against the 10 year mean UK heading dates (Fig 2) a very strong relationship was observed ($r^2$ = 0.94) The resulting critical day length can then be converted to the initiation date for the appropriate latitude, based on the conversion table compiled by Lam (12 Nov. 2006) and the formula published by Meeus (1991).

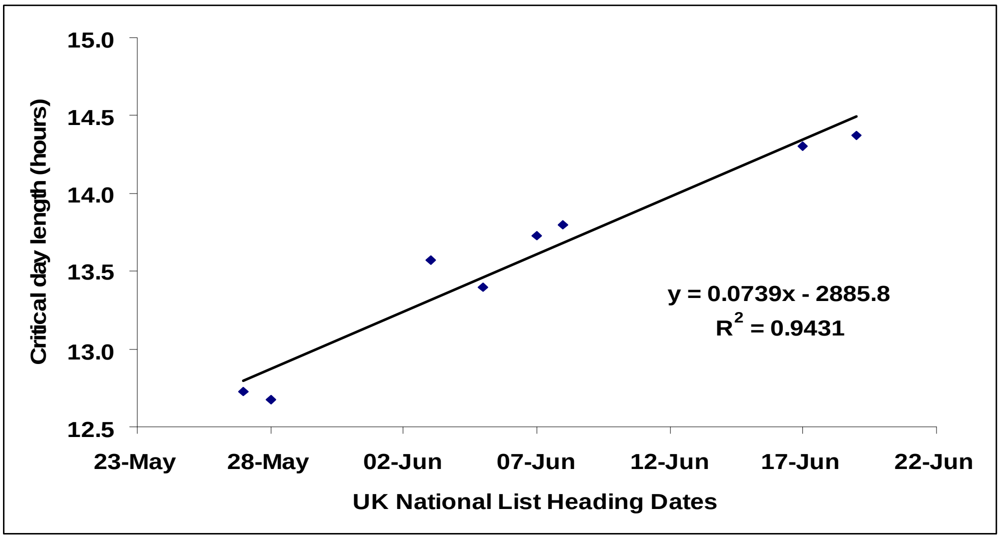


**Fig 2**. Relationship between ear initiation critical day lengths and UK National List published heading dates for the eight perennial ryegrass cultivars tested

## 4. Experiment II. Effect of defoliation treatment on secondary reproductive initiation and further reproductive development

### Materials and methods

The experimental design was a factorial combination of four cultivars (AberDart, Fennema, Melle and Twystar) and involved three defoliation treatments in a randomised block design with four replicate plants per cultivar. The ear initiation date which was predetermined in experiment one, marked the commencement of this experiment.

- Treatment one (Intensive): Plants were defoliated to 30 mm one week after the first tiller initiated; simulating a high grazing intensity. New emerging tillers (tillers not severed by prior defoliation) were then examined for secondary and subsequent tiller reproductive initiation two weeks after defoliation. This process continued until reproductive growth ceased i.e. tillers finished reproductive initiation and returned to a vegetative growth mode.
- Treatment two (Lax): Plants were defoliated to 60 mm once the stem of three tillers on each plant had elongated i.e. two or more reproductive nodes present.
- Treatment three (Very lax): Plants were defoliated to 60 mm once the plant headed i.e. three seed heads had visibly emerged on each plant.

Both the lax and very lax treatments simulated a low grazing intensity management.

### Results

Ear initiation date was not significantly different between treatments, however, there was a significant difference ($P<0.001$) between cultivars (Table 4) where the ear initiation date increased with cultivar maturity.

Treatment had a significant ($P<0.001$) effect on the number of defoliations per plant. There were less plant defoliations under the intensive treatment due to a lower cutting height (30 mm) therefore more reproductive apices would have been decapitated at defoliation. Plants were defoliated most frequently under the lax treatment as they were defoliated at a more advanced growth stage and cutting height was greater (60 mm). At the time of defoliation, tillers were at different stages of growth as the reproductive growth apices of some tillers would have been under the cutting height.

Tillers with the reproductive growth apex still attached, would have continued to elongate or head out resulting in another successive defoliation. Cultivar significantly affected ($P<0.001$) the number of defoliations per plant. In each treatment, the late heading cultivars, Melle and Twystar had the lowest number of defoliations per treatment while Fennema was cut most frequently. These results would indicate that a large genetic variation exists between cultivars for re-heading whereby Fennema continued reproductive growth regardless of treatment while the later heading cultivars returned to a vegetative growth mode earlier.

There was a significant effect of treatment on the number of days between defoliations ($P<0.01$), the final defoliation date ($P<0.001$) and the period between ear initiation and final defoliation (A – B; $P<0.001$). The intensive treatment had a lower defoliation or simulated grazing height (30 mm) therefore reproductive apices were decapitated more frequently (21 days) and more severely within in a shorter period (64 days). Plants from the lax and very lax treatments which had a higher defoliation or simulated grazing height (60 mm) had longer regrowth intervals between defoliations (23 and 30 days respectively) during an extended reproductive growth period (118 and 119 days respectively). The final date of defoliation after reproductive growth ceased was 10 June for the intensive treatment, while plants from the lax and very lax treatments continued to produce reproductive material longer into the mid-season period (+56 days and +57 days respectively). Cultivar also had a significant ($P<0.01$) effect on defoliation intervals. In all treatments Fennema had the shortest period between defoliations due to its high propensity to return to a reproductive growth mode after each defoliation. There was, however, no significant effect of cultivar on the final defoliation date, all cultivars returned to a vegetative growth mode at a similar time. The reproductive period between ear initiation and final defoliation (A – B) was significantly ($P<0.001$) longer for early heading cultivars (AberDart and Fennema) than later heading cultivars in all treatments due to a significantly earlier ear initiation date.

**Table 4.** Ear initiation date, number of plant defoliations, date of final cut and the time between EI and final defoliation of four cultivars across three treatments

| | Mean ear initiation date (A) | | | Mean number of defoliations | | | Mean defoliation intervals (days) | | | Mean final defoliation (B) | | | Reproductive period days (A – B) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | T1 | T2 | T3 | T1 | T2 | T3 | T1 | T2 | T3 | T1 | T2 | T3 |
| AberDart | 22/3 | 31/3 | 29/3 | 3.8 | 5.0 | 4.3 | 21 | 24 | 33 | 8/6 | 27/7 | 16/8 | 78 | 118 | 140 |
| Fennema | 22/3 | 27/3 | 24/3 | 4.3 | 7.3 | 5.0 | 19 | 20 | 27 | 12/6 | 17/8 | 8/8 | 82 | 143 | 137 |
| Melle | 26/4 | 20/4 | 24/4 | 2.0 | 4.8 | 3.5 | 22 | 22 | 28 | 8/6 | 4/8 | 30/7 | 43 | 106 | 97 |
| Twystar | 23/4 | 21/4 | 23/4 | 2.5 | 4.3 | 3.3 | 21 | 26 | 32 | 15/6 | 5/8 | 2/8 | 53 | 106 | 101 |
| *Mean* | *7/4* | *9/4* | *9/4* | *3.1* | *5.4* | *4.0* | *21* | *23* | *30* | *10/6* | *5/8* | *6/8* | *64* | *118* | *119* |
| SED | 1.40 | | | 0.33 | | | 1.37 | | | 7.06 | | | 7.33 | | |
| T | NS | | | *** | | | ** | | | *** | | | *** | | |
| C | *** | | | *** | | | * | | | NS | | | *** | | |
| T*C | * | | | NS | | | NS | | | NS | | | NS | | |

T1 = Intensive treatment 1; T2 = Lax treatment 2; T3 = Very lax treatment 3; C = Cultivar; T = Treatment, SED = Standard Error of Difference; *** = P<0.001; * = P<0.05; NS = Non Significant

## 5. Experiment III. Effect of spring defoliation pattern and cultivar on the mid-season morphological and chemical composition

### Materials and methods

The experimental design was a factorial combination of eight perennial ryegrass cultivars (Table 1) with six spring 'start date' managements in a randomised block design with three replicates. In 2005, six spring managements commenced on the 15 February (management A), 22 February (management B), 1 March (management C), 15 March (management D), 22 March (management E) and 29 March (management F). Plot DM yield, morphological (proportion of leaf lamina, reproductive stem, pseudostem and dead material) and chemical composition (organic matter digestibility (OMD), crude protein, acid detergent fibre (ADF), neutral detergent fibre (NDF) and ash) were measured on all plots during six mid-season intervals each comprising of three weeks (interval one (26/4-10/5), interval two (17/5-31/5), interval three (7/6-21/6), interval four (28/6-12/7), interval five (26/7-9/8) and interval six (23/8-06/9)).

### Results

The proportion of leaf lamina, pseudostem and reproductive stem was significantly different ($P<0.001$) between the six mid-season intervals (Table 5). Leaf proportion progressively declined from interval one to three (0.73) but increased again to interval five. Pseudostem proportion increased to a maximum during interval two (0.14) and steadily declined until interval five (0.07) which was followed by a secondary increase during interval six (+0.03). Reproductive stem proportion reached a maximum (0.16) during interval three and declined thereafter. The sward chemical composition variables measured were all significantly different ($P<0.001$) during the six mid-season sampling intervals. Crude protein content rapidly declined from interval one (288 g $kg^{-1}$ DM) until interval four (-116 g $kg^{-1}$ DM) but increased to interval five. A further decline in crude protein content was observed from interval five to six. Both the ADF and NDF significantly increased from interval two to reach a maximum during interval four, and declined thereafter. There was a significant decline in OMD from interval two until interval five (-116 g $kg^{-1}$ DM). Ash content was greatest during interval four. Such results were expected, given that each rotation represents a different period of the growing season.

**Table 5.** Dry matter yield, morphological and chemical composition of perennial ryegrass swards during six mid-season intervals

| | Interval | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | Sig | SED |
| Morphological composition (proportions) | | | | | | | | |
| Leaf | $0.86^{a}$ | $0.81^{bd}$ | $0.73^{c}$ | $0.79^{b}$ | $0.86^{a}$ | $0.82^{d}$ | *** | 0.007 |
| Pseudostem | $0.12^{a}$ | $0.14^{b}$ | $0.09^{c}$ | $0.09^{ce}$ | $0.07^{d}$ | $0.10^{e}$ | *** | 0.005 |
| Reproductive stem | $0.00^{a}$ | $0.04^{b}$ | $0.16^{c}$ | $0.08^{d}$ | $0.03^{b}$ | $0.01^{a}$ | *** | 0.005 |
| Chemical composition (g $kg^{-1}$ DM) | | | | | | | | |
| Crude protein | $288^{a}$ | $234^{b}$ | $186^{c}$ | $172^{d}$ | $212^{e}$ | $201^{f}$ | *** | 4.28 |
| Acid detergent fibre | $226^{a}$ | $228^{a}$ | $252^{b}$ | $294^{c}$ | $262^{d}$ | $247^{b}$ | *** | 3.55 |
| Neutral detergent fibre | $426^{a}$ | $419^{a}$ | $462^{b}$ | $514^{c}$ | $494^{d}$ | $485^{d}$ | *** | 6.04 |
| OMD | $826^{a}$ | $829^{a}$ | $793^{b}$ | $736^{c}$ | $713^{d}$ | $749^{e}$ | *** | 6.64 |
| Ash | $102^{a}$ | $91^{bd}$ | $92^{b}$ | $124^{c}$ | $98^{a}$ | $86^{d}$ | *** | 2.86 |

Interval 1-6 as described in materials and methods; DM = dry matter; OMD = organic matter digestibility; SED = Standard error of difference; *** = P<0.001

Cultivar had a significant effect on the morphological composition with Fennema having a significantly lower leaf production during four mid season sampling periods compared to the other cultivars. Management also had a large effect on the morphological composition during intervals one to five but it was inconclusive of which management realised greater leaf and lower stem proportions. Management had a greater effect on the sward chemical composition compared to the effect of cultivar, however, as with the morphological composition the effect of management was inconclusive on sward quality.

## 6. Experiment IV. Effect of spring defoliation pattern on the vertical distribution of herbage, morphological and chemical fractions

### Materials and methods

The experimental design was a factorial combination of four perennial ryegrass cultivars (Fennema, Corbet, Foxtrot, Melle) with three spring 'start date' managements in a randomised block with three replicates. In 2005, the three spring managements commenced on the 15 February (Early), 1 March (Medium) and 29 March (Late). Sampling took place during cut three (5 April-17 May), cut five (17 May-28 June), cut six (7 June-19 July) and cut seven (28 June-9 August) with a fixed 21 day regrowth interval. A quadrant was randomly placed within each plot where a grass sample was taken and the vertical profile subsequently determined. Samples were dissected into three horizons; lower horizon 0 – 8cm; middle horizon 8-15cm; upper horizon 15cm +. The DM yield and morphological composition and leaf and stem chemical composition was determined in each layer. Plots were then defoliated (>40mm) to determine plot DM yield.

### Results

Table 6 shows the effect of perennial ryegrass cultivar and spring 'start date' management on DM yield (kg ha $^{-1}$) and morphological composition in three herbage horizons at specific mid-season defoliation intervals. In the middle horizon Fennema had significantly (P<0.01) less leaf content and significantly more stem than the other three cultivars (P<0.001). The early management resulted in a significantly (P<0.001) lower leaf content in the middle horizon compared to the other two horizons. Stem content was significantly (P<0.001) lower with the early management in the middle horizon and declined significantly (P<0.001) from the early to the late management in lower horizon. In the upper horizon leaf proportion declined from rotation three to rotation seven which was mirrored in an increase in the stem content. In the middle and lower horizons, leaf proportion declined from rotation three, reached a minimum during rotation five and increased to rotation seven. In the lower horizon stem content decreased proportionally from rotation three to seven while in the middle horizon stem content peaked during rotation five and decreased until rotation seven.

Cultivar had no effect on the nutritive composition of leaf in any of the three herbage horizons. Management however had a significant (P<0.01) effect on leaf OMD in the upper horizon (Table 7) where plots defoliated under the early management had a significantly higher ($P<0.01$) leaf OMD compared to plots initially defoliated later in spring. Leaf NDF content was significantly ($P<0.05$) higher during rotations six and seven. Management and rotation had a greater impact on the chemical composition of leaf in the middle horizon than in the upper horizon. Crude protein was significantly higher ($P<0.001$) in the medium management and lowest in the late management (-31 g kg DM) while the early management was intermediate. Leaf NDF content was lower ($P<0.01$) in the early management compared to both the medium and late management. Leaf from the late management had significantly ($P<0.05$) higher ash concentration compared to leaf defoliated under the early and medium managements. Crude protein concentration was significantly higher during rotation three compared to the other sampling periods. The fibre (ADF and NDF) concentration was lowest during rotation three and highest during rotations six and seven. Leaf OMD was significantly ($P<0.05$) higher during rotation three (5 April – 17 May) and proportionally declined until rotation seven (28 June – 9 August). The ash concentration was lowest during rotation three and highest during rotation six. In the lower horizon management had no significant effect on the ADF, OMD and ash content of leaf and stem. Crude protein content was significantly ($P<0.01$) lower in the leaf and stem fractions when subjected to the late management. Leaf NDF was significantly ($P<0.001$) lower in the early management than either the medium or late managements. Rotation had a significant effect on the chemical composition of leaf and stem in the lower horizon and the ranking of these variables across the rotations was similar to that found in the middle horizon (Table 8).

**Table 6.** Effect of perennial ryegrass cultivar and spring 'start date' management on DM yield (kg ha $^{-1}$) and morphological composition in three herbage horizons at specific mid-season defoliation intervals

| | **Cultivar** | | | | | **Management** | | | | **Rotation** | | | | | **Interactions** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Fennema** | **Corbet** | **Foxtrot** | **Melle** | **Sig** | **Early** | **Medium** | **Late** | **Sig** | **3** | **5** | **6** | **7** | **Sig** | **C*M** | **C*R** | **M*R** | **SED** |
| **Mean mid-season DM yield to ground level** | | | | | | | | | | | | | | | | | | |
| | 5639 | 5337 | 5227 | 5438 | NS | $5790^{a}$ | $5066^{b}$ | $5376^{ab}$ | * | $4769^{a}$ | $5992^{b}$ | $5694^{bc}$ | $5188^{ac}$ | *** | NS | NS | *** | 419.6 |
| **Upper Horizon (15+ cm)** | | | | | | | | | | | | | | | | | | |
| DM yield (kg ha $^{-1}$) | 621 | 550 | 601 | 584 | NS | 624 | 564 | 579 | NS | $457^{a}$ | $731^{b}$ | $632^{bc}$ | $537^{ac}$ | *** | NS | NS | *** | 100.5 |
| Leaf prop | 0.85 | 0.90 | 0.87 | 0.89 | NS | 0.85 | 0.86 | 0.92 | NS | $0.94^{a}$ | $0.90^{a}$ | $0.87^{ab}$ | $0.81^{b}$ | * | NS | * | NS | 0.030 |
| Stem prop | 0.10 | 0.06 | 0.08 | 0.06 | NS | 0.09 | 0.09 | 0.04 | NS | $0.02^{a}$ | $0.07^{a}$ | $0.06^{a}$ | $0.15^{b}$ | * | NS | ** | NS | 0.029 |
| Dead prop | 0.05 | 0.04 | 0.05 | 0.05 | NS | 0.06 | 0.05 | 0.04 | NS | 0.05 | 0.03 | 0.06 | 0.05 | NS | NS | NS | ** | 0.013 |
| **Middle Horizon (8 – 15cm)** | | | | | | | | | | | | | | | | | | |
| DM yield (kg ha $^{-1}$) | 1027 | 1019 | 1115 | 1085 | NS | $1160^{a}$ | $1001^{b}$ | $1024^{b}$ | * | $1123^{a}$ | $1173^{a}$ | $1071^{a}$ | 878b | *** | * | NS | *** | 97.0 |
| Leaf prop | $0.76^{b}$ | $0.83^{a}$ | $0.81^{a}$ | $0.86^{a}$ | ** | $0.77^{a}$ | $0.84^{b}$ | $0.84^{b}$ | *** | $0.91^{a}$ | $0.74^{b}$ | $0.79^{bc}$ | $0.83^{c}$ | *** | NS | NS | *** | 0.023 |
| Stem prop | $0.19^{c}$ | $0.11^{ab}$ | $0.14^{a}$ | $0.08^{b}$ | *** | $0.16^{a}$ | $0.11^{b}$ | $0.12^{b}$ | ** | $0.05^{a}$ | $0.20^{b}$ | $0.16^{bc}$ | $0.12^{c}$ | *** | NS | NS | *** | 0.018 |
| *Leaf/Stem Ratio* | 7.5 | 18.3 | 17.4 | 17.8 | NS | 12.9 | 16.8 | 16.0 | NS | $34.6^{a}$ | $0.99^{b}$ | $15.2^{b}$ | $10.2^{b}$ | *** | NS | NS | *** | 6.14 |
| Dead prop | 0.05 | 0.05 | 0.04 | 0.06 | NS | $0.07^{a}$ | $0.05^{ab}$ | $0.04^{a}$ | * | 0.04 | 0.06 | 0.05 | 0.05 | NS | NS | * | NS | 0.009 |
| **Lower Horizon (0 – 8cm)** | | | | | | | | | | | | | | | | | | |
| DM yield (kg ha $^{-1}$) | 3992 | 3768 | 3588 | 3870 | NS | $4063^{a}$ | $3576^{b}$ | $3773^{b}$ | ** | $3296^{a}$ | $4088^{b}$ | $4059^{bc}$ | $3773^{ac}$ | *** | * | NS | *** | 242.4 |
| Leaf prop | 0.20 | 0.22 | 0.18 | 0.21 | NS | 0.19 | 0.22 | 0.20 | NS | $0.22^{a}$ | $0.16^{b}$ | $0.19^{ab}$ | $0.24^{a}$ | ** | * | NS | *** | 0.019 |
| Stem prop | 0.40 | 0.41 | 0.41 | 0.40 | NS | $0.46^{a}$ | $0.41^{b}$ | $0.35^{c}$ | *** | $0.50^{a}$ | $0.43^{b}$ | $0.36^{c}$ | $0.30^{c}$ | *** | NS | NS | *** | 0.014 |
| *Leaf/Stem Ratio* | 0.54 | 0.62 | 0.48 | 0.59 | NS | $0.43^{a}$ | $0.55^{ab}$ | $0.68^{b}$ | ** | $0.50^{a}$ | $0.42^{a}$ | $0.52^{a}$ | $0.79^{b}$ | *** | NS | NS | *** | 0.067 |
| Dead prop | 0.40 | 0.37 | 0.41 | 0.39 | NS | $0.35^{a}$ | $0.37^{a}$ | 0.45b | *** | $0.27^{a}$ | $0.41^{b}$ | $0.45^{b}$ | $0.44^{b}$ | *** | ** | * | *** | 0.020 |

C = Cultivar; M = Management; R = Rotation; SED = Standard Error of Difference; *** = P<0.001; **P<0.01; * = P<0.05; NS = Non Significant;

**Table 7.** Effect of cultivar and management on the DM yield (kg ha$^{-1}$) and chemical analysis of leaf lamina in the upper horizon (+15cm)

| | Cultivar | | | | | Management | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **FN** | **CB** | **FX** | **ML** | **Sig** | **Early** | **Medium** | **Late** | **Sig** |
| Total DM yield (kg ha$^{-1}$) | 621 | 550 | 603 | 580 | NS | 625 | 562 | 579 | NS |
| Organic matter digestibility (g kg$^{-1}$ DM) | 791 | 802 | 797 | 812 | NS | 814$^{a}$ | 823$^{a}$ | 765$^{b}$ | ** |
| Ash concentration (g kg$^{-1}$ DM) | 119 | 115 | 124 | 122 | NS | 119 | 113 | 128 | NS |
| Crude protein concentration (g kg$^{-1}$ DM) | 249 | 227 | 230 | 233 | NS | 235 | 244 | 226 | NS |
| ADF concentration (g kg$^{-1}$ DM) | 254 | 248 | 245 | 249 | NS | 240 | 252 | 256 | NS |
| NDF concentration (g kg$^{-1}$ DM) | 532 | 514 | 514 | 515 | NS | 512 | 528 | 516 | NS |
| | **Rotation** | | | | | **Interactions** | | | |
| | **3** | **5** | **6** | **7** | **Sig** | **C*M** | **C*R** | **M*R** | **SED** |
| Total DM yield (kg ha$^{-1}$) | 449$^{a}$ | 739$^{b}$ | 629$^{bc}$ | 537$^{ac}$ | ** | NS | NS | *** | 59.3 |
| Organic matter digestibility (g kg$^{-1}$ DM) | # | 808 | 793 | # | NS | NS | NS | ** | 4.58 |
| Ash concentration (g kg$^{-1}$ DM) | # | 119 | 124 | 117 | NS | NS | NS | ** | 5.44 |
| Crude protein concentration (g kg$^{-1}$ DM) | # | 239 | 228 | 238 | NS | NS | NS | NS | 8.00 |
| ADF concentration (g kg$^{-1}$ DM) | # | 241 | 257 | # | NS | NS | NS | ** | 4.95 |
| NDF concentration (g kg$^{-1}$ DM) | # | 500$^{a}$ | 528$^{b}$ | 528$^{b}$ | * | NS | NS | * | 10.22 |

FN = Fennema; CB = Corbet; FX = Foxtrot; ML = Melle; C = Cultivar; M = Management; R = Rotation; SED = Standard Error of Difference; DM = Dry Matter *** = P<0.001; **P<0.01; * = P<0.05; NS = Non Significant

**Table 8.** Effect of cultivar and management on the DM yield (kg ha$^{-1}$) and chemical analysis of leaf lamina in the middle horizon (8-15 cm)

| | Cultivar | | | | | Management | | | |
|---|---|---|---|---|---|---|---|---|---|
| | FN | CB | FX | ML | Sig | Early | Medium | Late | Sig |
| Total DM yield (kg ha$^{-1}$) | 1027 | 1019 | 1114 | 1054 | NS | 1159 | 977 | 1023 | NS |
| Organic matter digestibility (g kg$^{-1}$ DM) | 711 | 781 | 743 | 765 | NS | 761 | 781 | 708 | NS |
| Ash concentration (g kg$^{-1}$ DM) | 134 | 128 | 135 | 132 | NS | 129$^{a}$ | 127$^{a}$ | 142$^{b}$ | * |
| Crude protein concentration (g kg$^{-1}$ DM) | 245 | 238 | 236 | 241 | NS | 242$^{a}$ | 254$^{b}$ | 223$^{c}$ | *** |
| ADF concentration (g kg$^{-1}$ DM) | 282 | 280 | 278 | 273 | NS | 289 | 267 | 278 | NS |
| NDF concentration (g kg$^{-1}$ DM) | 521 | 522 | 525 | 529 | NS | 507$^{a}$ | 535$^{b}$ | 532$^{b}$ | ** |
| | Rotation | | | | | Interactions | | | |
| | 3 | 5 | 6 | 7 | Sig | C*N | C*R | M*R | SED |
| Total DM yield (kg ha$^{-1}$) | 1095$^{a}$ | 1169$^{a}$ | 1071$^{a}$ | 878$^{b}$ | * | NS | NS | ** | 84.9 |
| Organic matter digestibility (g kg$^{-1}$ DM) | 809$^{a}$ | 768$^{ab}$ | 737$^{ab}$ | 686$^{b}$ | * | NS | NS | NS | 34.49 |
| Ash concentration (g kg$^{-1}$ DM) | 122$^{a}$ | 133$^{ab}$ | 143$^{b}$ | 131$^{ab}$ | * | NS | NS | *** | 6.13 |
| Crude protein concentration (g kg$^{-1}$ DM) | 320$^{a}$ | 211$^{b}$ | 211$^{b}$ | 218$^{b}$ | *** | NS | NS | *** | 5.56 |
| ADF concentration (g kg$^{-1}$ DM) | 256$^{a}$ | 276$^{ab}$ | 291$^{b}$ | 289$^{b}$ | ** | NS | NS | *** | 8.55 |
| NDF concentration (g kg$^{-1}$ DM) | 459$^{a}$ | 525$^{b}$ | 558$^{c}$ | 556$^{c}$ | *** | NS | NS | *** | 7.48 |

FN = Fennema; CB = Corbet; FX = Foxtrot; ML = Melle; C = Cultivar; M = Management; R = Rotation; SED = Standard Error of Difference; DM = Dry Matter *** = P<0.001; **P<0.01; * = P<0.05; NS = Non Significant

## 7. Experiment V. Effect of spring defoliation pattern, pre-defoliation herbage mass and defoliation height on the morphology and nutritive composition

### Materials and methods

**Sub-experiment 1: Effect of spring defoliation pattern and defoliation height**

The experimental design was a factorial combination of four perennial ryegrass cultivars, three spring ‘start date’ managements and two defoliation heights in a randomised block design with three replicates. The four cultivars assessed were AberDart, Fennema, Melle and Twystar. In 2006, the three spring ‘start date’ managements commenced on the 14 February (Early), 7 March (Medium) and 28 March (Late). Plots were defoliated to either 35 mm or 60 mm so as to determine DM yield. Examination of sward morphological composition and nutritive content commenced on 16 May. The DM yield, sward morphological and nutritive composition were examined on six occasions during the mid-season with a fixed 21 day regrowth interval.

**Sub-experiment 2: Effect of pre-defoliation herbage mass and defoliation height**

The experimental design was a factorial combination of four perennial ryegrass cultivars, two pre-defoliation herbage masses and two defoliation heights in a randomised block design with three replicates. The four test cultivars used were Corbet, AberAvon, Foxtrot and Mezquita. All plots were initially defoliated on 7 March 2006. Following a 28 day regrowth plots were again defoliated (≥40 mm) and allowed to regrow for 21 days until the next defoliation when two pre-defoliation herbage masses were established. Plots were defoliated to either 35 mm or 60 mm once they reached a pre-defoliation height of 1100 mm (Low herbage mass; LHM) or 1400 mm (High herbage mass; HHM). Examination of the morphological and chemical composition took place during four mid-season sampling intervals interval 1 (8 May – 16 May), interval 2 (21 May – 26 May), interval 3 (8 June – 14 June) and interval 4 (3 July – 19 July).

**Results**

In sub-experiment one the morphological composition varied significantly between the four cultivars during intervals one to four (16 May – 18 July) with Fennema having a significantly lower leaf proportion during these periods. In sub-experiment two there was no significant difference in the morphological composition between cultivars during interval one to three (Table 6), however, during interval four (3 July – 19 July) Mezquita had a significantly higher reproductive stem proportion (P<0.001) and lower (P<0.01) leaf proportion compared to the other three cultivars which would indicate its tendency to return to a reproductive growth mode. Initial spring defoliation management had little impact on the morphological composition during the mid-season period. During most of the mid-season sampling intervals, the LHM swards had significantly greater leaf and lower pseudostem and reproductive stem proportions compared to the HHM swards (Table 9). In both sub-experiments defoliation height had a significant effect on the morphological composition, however, results were arbitrary and displayed no definite relationship between defoliation height, cutting interval or period of season.

**Table 9.** Effect of perennial ryegrass cultivar and pre-defoliation herbage mass on the morphological composition at specific mid-season defoliation intervals

| | Cultivar | | | | | Management | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Corbet | AberAvon | Foxtrot | Mezquita | Sig | LHM | HHM | Sig | SED |
| **Interval 1 (8 May – 16 May)** | | | | | | | | | |
| Leaf prop | 0.88 | 0.86 | 0.89 | 0.88 | NS | 0.91[a] | 0.85[b] | ** | 0.04 |
| Pseudostem prop | 0.10 | 0.12 | 0.09 | 0.11 | NS | 0.10 | 0.12 | NS | 0.04 |
| Reproductive stem prop | 0.01 | 0.01 | 0.00 | 0.00 | NS | 0.00[b] | 0.01[a] | * | 0.02 |
| **Interval 2 (21 May – 26 May)** | | | | | | | | | |
| Leaf prop | 0.83 | 0.83 | 0.85 | 0.83 | NS | 0.82 | 0.84 | NS | 0.03 |
| Pseudostem prop | 0.14 | 0.12 | 0.12 | 0.14 | NS | 0.12 | 0.14 | NS | 0.03 |
| Reproductive stem prop | 0.00 | 0.01 | 0.01 | 0.00 | NS | 0.02[a] | 0.00[b] | ** | 0.01 |
| **Interval 3 (8 June – 14 June)** | | | | | | | | | |
| Leaf prop | 0.75 | 0.79 | 0.75 | 0.74 | NS | 0.78[a] | 0.74[b] | ** | 0.04 |
| Pseudostem prop | 0.10 | 0.08 | 0.10 | 0.11 | NS | 0.09[b] | 0.11[a] | * | 0.03 |
| Reproductive stem prop | 0.11 | 0.09 | 0.11 | 0.11 | NS | 0.10 | 0.11 | NS | 0.04 |
| **Interval 4 (3 July – 19 July)** | | | | | | | | | |
| Leaf prop | 0.73[b] | 0.70[b] | 0.63[b] | 0.55[a] | *** | 0.68[a] | 0.62[b] | * | 0.08 |
| Pseudostem prop | 0.02 | 0.02 | 0.03 | 0.02 | NS | 0.02 | 0.02 | NS | 0.01 |
| Reproductive stem prop | 0.16[b] | 0.18[b] | 0.24[b] | 0.34[a] | ** | 0.24 | 0.22 | NS | 0.09 |

LHM = Low herbage mass; HHM = High herbage mass; SED = Standard Error of Difference; *** = P<0.001; ** = P<0.01; * = P<0.05; NS = Non Significant

Cultivar had a significant effect on the chemical composition during intervals two to six in sub-experiment one and this was most evident during intervals three (27 June) and four (18 July). In sub-experiment two the fibre (ADF and NDF) and ash content were significantly different between cultivars during intervals three and four (8 June – 19 July). Delaying initial spring defoliation tended to increase mid-season sward quality in terms of greater crude protein content and OMD. There was a lesser effect of management on the sward nutritive composition in sub-experiment two. The LHM swards had a significantly greater crude protein content during interval one ($P<0.01$) and interval four ($P<0.001$) and lower NDF ($P<0.05$) during interval three compared to the HHM swards. During interval two (21 May – 26 May), however, the HHM swards had a greater ($P<0.001$) crude protein content than the LHM swards. Defoliation height had a significant effect on the herbage nutritive composition in sub-experiment one, however, as with its effect on the morphological composition, results were also arbitrary. In sub-experiment two, defoliating to 60mm compared to 35mm resulted in herbage with a greater crude protein content during all four sampling intervals and a significantly ($P<0.01$) greater OMD content during interval three.

## 8. CONCLUSIONS AND IMPLICATIONS

Results from Experiment I confirmed that the critical day length requirement for reproductive initiation varies between perennial ryegrass cultivars but not between latitudes. A strong correlation was found between critical day length for ear initiation and the 10 year standard ear emergence date. Although ear emergence was shown to vary greatly between locations and seasons for individual cultivars, this correlation was sufficiently robust to predict critical initiation date for any perennial ryegrass cultivar on a UK recommended cultivar list. This calibration will be a valuable tool in grassland research as a prediction of when cultivars turn reproductive and may assist in future studies to indicate potential strategies for maintaining leafier high quality swards.

Results from Experiment II illustrated the extent of which reproductive growth and secondary re-heading varies between cultivars similar and varying maturity. Repeated tiller initiation indicated that secondary initiation and subsequently secondary heading occurred in all four cultivars assessed. Fennema had a significantly greater number of defoliations compared to the other cultivars regardless of treatment imposed which indicated the greater number of tillers growing reproductively. Defoliating spaced plants closely (30 mm), simulating a high grazing intensity during the early tiller growth stage, resulted in plants returning to a vegetative growth mode earlier than when plants were subjected to a more lax defoliation (60 mm) treatment. Defoliating plants during an early developmental stage of tiller reproductive growth also returned plants to a vegetative growth mode quicker than when plants were defoliated when reproductive tillers had elongated. Results would suggest that defoliating swards under a high grazing intensity with a short grazing interval (21 days) while selecting cultivars with low re-heading vigour should result in less reproductive material produced during a shorter period during the mid-season.

Results from Experiment III, IV and V show that large differences exist in the physical and chemical composition of perennial ryegrass cultivars of similar and varying maturities. It is imperative, therefore, that cultivars are specifically selected with a tendency for greater leaf production mid-season with a low tendency for aftermath re-heading. This work highlights the need for more detailed testing of cultivars that are recommended on cultivar authority listings. Defoliation management had a significant effect on mid-season sward quality. Delaying initial spring defoliation resulted in a greater leaf and lower stem content during the mid-season than an early initial defoliation. During a more detailed examination (experiment IV), however, it was found that leaf quality was greater with an earlier initial defoliation. In experiment V swards with a lower herbage mass produced more leaf and less stem than swards with a greater herbage mass during the mid-season, but this study could not confirm which approach was likely to support the highest animal productivity, but it’s likely adapting the approach of lowering HM swards should produce animal production benefits.

## 9. REFERENCES

**Cooper, J.P. 1951** Studies on growth and development in *Lolium* II. Pattern of bud development of the shoot apex and its ecological significance. *Journal of Ecology* **39:** 228-270

**Cooper, J.P. 1952** Studies on growth and development in *Lolium perenne* III. Influence of season and latitude on ear emergence. *Journal of Ecology* **40**: 352-379

**Kennedy, J. 2005**. Maximising milk price – producer (part 2) In: *Winning in changing times*, Teagasc National Dairy Conference, Waterford & Cavan, pp 39-59

**Korte, C. J. 1981** Spring pasture management to improve summer pasture production. In: *Dairyfarming Annual*, Massey University, Palmerston North, New Zealand, pp 25-27

**Lam, S.** Day Length for Various Latitudes. http://www.orchidculture.com/COD/daylength.html. Cited 12 November 2006

**Laredo, M. A. and Minson, D. J. 1975** The voluntary intake and digestibility by sheep of leaf and stem fractions of *Lolium perenne. Journal of British Grassland Society* **30:** 73-77

**Meeus, J. 1991:** Astonomical algorithms. Richmond, Va.: Willmann-Bell. ISBN 0943396352

**Stobbs, T.H. 1973** The effect of plant structure on the intake of tropical pastures I. Variation in the bite size of grazing cattle. *Australian Journal of Agricultural Research* **24:** 809-819

**Sweet, N. Wiltshire, J.J.J. and Baker, C.K. 1991** A new descriptive scale for early reproductive development in *Lolium perenne* L. *Grass and Forage Science* **46**: 201-206

## 10. PUBLICATIONS FROM THIS PROJECT

**Hurley G.** PhD Thesis; Factors controlling reproductive development in lolium Perenne L. and their influence on mid season sward quality (Queens University Belfast)

**Hurley G., Gilliland T.J. and O'Donovan M** (2008**)**. Relationship between Reproductive Initiation and Ear Emergence Development in Lolium Perenne L. L. Journal of Agricultural Science Cambridge **146**, 1-11.

**Hurley, G., O'Donovan, M. and Gilliland, T.J**. Effect of spring defoliation pattern on the mid-season sward production and morphology of perennial ryegrass cultivars of different maturity *Grass and Forage Science* (in press), 2008.

**Hurley, G., O'Donovan, M. and Gilliland, T.J** Effect of defoliation treatment on secondary reproductive initiation and further reproductive development in lolium Perenne L. Journal of Agricultural Science (Cambridge) (submittted), 2008

**Hurley, G., Gilliland, T.J. and O'Donovan, M. 2008** Effect of defoliation treatment on reproductive initiation and further development of perennial ryegrass daughter tillers. In*: Proceedings of Irish Grassland and Animal Production Association 34th Annual Research Meeting - Agricultural Research Forum,* Tullamore, p74

**Hurley, G., O'Donovan, M. and Gilliland, T.J** Prediction of reproductive initiation from relative ear emergence timing in *Lolium perenne* L. cultivars. Submitted for 2008 International Grassland Conference, China (2008)

**Hurley, G., O'Donovan, M. and Gilliland, T.J 2007** Effect of defoliation treatment on the reproductive initiation of perennial ryegrass daughter tillers In: *Permanent and temporary grassland plant, environment and economy, Proceedings of the European Grassland Federation, Ghent, Belgium* pp 66-69

**Hurley, G., O'Donovan, M. and Gilliland, T.J 2007** Evaluation of the meteorological factors influencing reproductive initiation and ear emergence of perennial ryegrass cultivars In: *Book of Abstracts, Permanent and temporary grassland plant, environment and economy, Proceedings of the European Grassland Federation, Ghent, Belgium* pp 29-30

**Hurley, G., O'Donovan, M. and Gilliland, T.J 2007** Effect of perennial ryegrass cultivar maturity and defoliation pattern on sward nutritive composition In: *Book of Abstracts of the 58th annual meeting of the European Association for Animal Production, Dublin p.* 297

**Hurley, G., O'Donovan, M. and Gilliland, T.J 2007** Factors influencing ear initiation and ear emergence development of perennial ryegrass cultivars at two different latitudes In: *Programme and book of abstracts of 16th International Farm Management Association, Cork* pp. 80-81

**Hurley, G., Gilliland, T.J. and O'Donovan, M. 2007** The influences of latitude and growing conditions on reproductive initiation and ear emergence development in perennial ryegrass In*: Proceedings of Irish Grassland and Animal Production Association 33rd Annual Research Meeting - Agricultural Research Forum,* Tullamore, p65

**Hurley, G., O'Donovan, M. and Gilliland, T.J 2006** The vertical distribution of grass dry matter, leaf and stem fractions of mid-summer perennial ryegrass swards; interaction with cultivar, spring management and time of defoliation In: *Proceedings of 8th British Grassland Society Research Conference, Cirencester pp. 5-6*

**Hurley, G., Gilliland, T.J. and O'Donovan, M. 2006** Quantification of the initiation date, heading date and critical day length of ryegrass cultivars In: *Proceedings of the 21st General Meeting of the European Grassland Federation, Badajoz, Spain* pp182-184

**Hurley, G., O'Donovan, M. and Gilliland, T.J 2006** The effects of grass genotype and spring management on the morphology and inflorescence development of mid-summer ryegrass swards In: *Proceedings of Irish Grassland and Animal Production Association 32nd Annual Research Meeting - Agricultural Research Forum,* Tullamore, p45

**Hurley, G., O'Donovan, M. and Gilliland, T.J 2006** Quantification of the initiation date, heading date and critical day length of ryegrass cultivars In: *Proceedings of Irish Grassland and Animal Production Association 32nd Annual Research Meeting - Agricultural Research Forum,* Tullamore, p113

**Hurley, G., O'Donovan, M. and Gilliland, T.J 2005** Mid-summer grass quality, a genotype or management problem? In: Meeting of British Society of Plant Breeders, Crossnacreevy Plant testing station, Belfast