

The effect of grass cultivars differing in heading date and ploidy on the performance and dry matter intake of spring calving dairy cows at pasture

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Abstract — The system of milk production in Ireland is dependent on the efficient utilisation of grazed grass. Therefore the use of grass cultivars with different heading dates may have a large effect on dairy cow performance. The objective of this study was to determine the effect of grass cultivars differing in heading date and grass ploidy on milk production and grass dry matter intake (GDMI) of spring calving dairy cows. The study took place over two years. Seventy-two spring calving dairy cows in Year 1 and 80 in Year 2 were blocked into groups of four and were assigned randomly to one of four grass cultivar treatments. The grass cultivars differed in heading date (intermediate or late) and grass ploidy (diploid or tetraploid). The grazing season began in April 12 (Year 1) and April 25 (Year 2) and lasted until the end of September in both years. A total concentrate DM input of 248 kg and 45 kg·cow⁻¹ was offered to the herds in Year 1 and in Year 2, respectively. All concentrate was offered during the first 3 grazing rotations. Rotation had a significant effect ($P < 0.001$) on all milk production parameters in both years. In Year 1, late heading cultivars significantly ($P < 0.05$) increased milk yield, solids corrected milk yield (SCM), fat, protein and lactose yield. There was a significant interaction ($P < 0.05$) between heading date and grass ploidy for lactose yield and fat concentration. In Year 2, late heading cultivars had also increased milk yield ($P < 0.01$), lactose yield ($P < 0.05$), SCM ($P < 0.05$), protein yield ($P < 0.001$) and protein concentration ($P < 0.05$). In Year 1, the GDMI was higher ($P < 0.001$) for cows grazing the late heading cultivars. It is concluded that later heading grass cultivars have a beneficial effect on the milk production performance of spring calving dairy cows.

dairy cows / grazing / grass cultivars / intake / milk production

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Résumé — Influence de la date d'épiaison et de la ploïdie de variétés de ray-grass anglais sur les performances et l'ingestion d'herbe chez les vaches laitières au pâturage. En Irlande, les systèmes de production laitière reposent surtout sur l'utilisation efficiente du pâturage. Dans ces conditions, la date d'épiaison des variétés de ray-grass peut avoir des conséquences sur les performances du troupeau au pâturage. L'objectif de cette étude est de déterminer l'effet de 4 variétés de ray-grass anglais, différant par leur date d'épiaison et leur ploïdie, sur la production laitière et l'ingestion d'herbe chez les vaches laitières au pâturage. Cette étude s'est déroulée durant deux saisons complètes de pâturage. Soixante-douze vaches en année 1 et 80 vaches en année 2, vèlant au printemps, ont été mises en lot et affectées à l'un des 4 traitements expérimentaux. Les variétés de ray-grass ont différé par leur date d'épiaison (intermédiaire ou tardif) et leur ploïdie (diploïde ou tétraploïde). La saison de pâturage a commencé le 12 avril (année 1) et le 25 avril (année 2) et s'est achevée fin septembre. L'apport total de concentré, réalisé uniquement durant les 3 premiers cycles de pâturage, a été de, respectivement, 248 et 45 kg de MS par vache lors des années 1 et 2. Chaque année, le numéro de cycle a eu un effet significatif sur l'ensemble des paramètres de production laitière. L'année 1, les variétés à épiaison tardive ont induit une augmentation significative ($P < 0,05$) de la production de lait, de lait 4 %, de matières grasses, de protéines et de lactose. Une interaction significative ($P < 0,05$) entre la date d'épiaison et la ploïdie a été mise en évidence sur la production de lactose et le taux butyreux. Lors de l'année 2, les deux variétés à épiaison tardive ont accru significativement la production laitière ($P < 0,01$), la synthèse de lactose ($P < 0,05$), le lait 4 % ($P < 0,05$), les matières protéiques ($P < 0,001$) et le taux protéique ($P < 0,05$). En année 1, les quantités de MS d'herbe ingérées ont été significativement plus élevées chez les vaches pâturant les variétés tardives. En conséquence, les variétés plus tardives permettent des performances plus intéressantes pour les troupeaux laitiers vèlant au printemps.

vaches laitières / pâturage / variétés / production laitière / ingestion

1. INTRODUCTION

Increasing dairy cow performance at pasture in a grass based milk production system is central to improving dairy enterprise profitability [36]. This is successfully achieved when the cow consumes high levels of high quality grass. Grass when grazed efficiently is by far the cheapest feed available on the farm [35]. Therefore, the production and utilisation of grass has a central role in maintaining the competitiveness of the Irish dairy industry. Much of focus of recent grassland research has centred on grass production and utilisation. Very little attention has been given to identifying the most suitable grass cultivars for the grazing system. Perennial ryegrass cultivars are divided into three groups according to the date of ear emergence *viz.* early, intermediate and late. It is known that differences in sward characteristics exist between these maturity groups. Early heading cultivars

decline in digestibility earlier than late heading cultivars during the early summer period [15].

It is a difficult task to make a meaningful comparison of grass cultivars under grazing. In Ireland, all of the comparative work is completed in terms of dry matter production under cutting. This is the method of evaluation used by Department of Agriculture Food and Rural Development (DAFRD) [8] in the completion of the Irish cultivar recommended list. There is an effect of grazing (in comparison to cutting), on sward structure which has an effect on the digestibility of the offered herbage as well as changing its intake capacity. It is essential to compare cultivars using animal intake and performance as a measure of their usefulness. Gately [15] examined an early heading (Cropper) and late heading (Vigour) ryegrass at two stocking rates with dairy cows. At a low stocking rate the cows grazing the late heading cultivar produced

9% more milk than the cows grazing the early heading cultivar. However, at the high stocking rate the cows grazing the early heading cultivar produced 7% more milk. The digestibility of the late heading ryegrass was significantly higher than that of the early heading ryegrass. Minson et al. [27] reported that early maturing S24 perennial ryegrass was lower in digestibility at a given date in spring than the late maturing S23 cultivar. Tetraploid grass cultivars nowadays constitute approximately 35 to 40% of all grass seed mixtures in Ireland [5, 6]. Vipond et al. [42] found an advantage in terms of lamb body weight gain in favour of tetraploid cultivars compared to diploid cultivars under continuous grazing. Lantinga and Groot [22] reported a milk yield advantage to tetraploids relative to diploids over a short experimental period. O'Riordan [30] found that tetraploid grasses predominated in the highest ranked cultivars in a grazing preference study, with a free choice of both ploidies of different cultivars. The objective of this study was to investigate the effect of perennial ryegrass cultivars differing in heading date and grass ploidy, on the milk production performance and dry matter intake (DMI) of spring calving dairy cows under rotational grazing.

2. MATERIALS AND METHODS

2.1. Site characteristics

The experiment was carried out at the Moorepark Research Centre, Fermoy, Co. Cork (lat. 50°07'N, long. 08°16'W) during the grazing season of 1999 (Year 1) and 2000 (Year 2). A permanent site (17.2 ha) was reseeded in August 1998. At sowing the area was divided equally into four farmlets consisting of 4.3 ha each. Each farmlet was divided into 10 paddocks, ranging in size from 0.37 to 0.48 ha. In 2000 a further 3.9 ha (0.98 ha per grass cultivar treatment) was added to the experimental area, this

increased the number of paddocks from 10 to 12 per grass cultivar treatment. The four perennial ryegrass cultivars were sown as monocultures; Millennium (late heading, tetraploid), Portstewart (late heading, diploid), Napoleon (intermediate heading, tetraploid), Spelga (intermediate heading, diploid). The heading date as listed by the DAFRD [8], grass ploidy, seeding rate of each grass cultivar is shown in Table I.

Table I. The heading date, grass ploidy and seeding rate of each grass cultivar.

Cultivar	Heading date	Ploidy	Seeding rate (kg·ha ⁻¹)
Spelga	May 17 (I)	Diploid	34
Napoleon	May 20 (I)	Tetraploid	42
Portstewart	June 07 (L)	Diploid	34
Millennium	June 10 (L)	Tetraploid	42

I: Intermediate; L: Late.

2.2. Animals

Seventy-two (Year 1) and eighty (Year 2) spring calving Holstein-Friesian cows were blocked on the basis of lactation number, calving date, body weight and previous 3 weeks milk yield. There were 18 and 20 blocks each of four cows in Year 1 and 2, respectively. One animal from each block was assigned at random to one of the four grass cultivars. Ten primiparous and 8 multiparous cows were used in Year 1, while 6 primiparous and 14 multiparous cows were used in Year 2. The mean calving date of both herds was February 8 (sd 22.6) and February 7 (sd 10.4) in Year 1 and Year 2, respectively.

2.3. Grazing management

In both years the primary spring herbage of each cultivar was grazed from late February/early March. The animals used for this

purpose were a combination of experimental and non-experimental animals from the main dairy herd. The objective of this preliminary grazing was to graze all cultivars to the same post-grazing height and to have an equal starting point for all cultivars. The milk yield and body weight data recorded during this period was part of the pre-experimental data used when assigning the animals to their respective blocks. Concentrate supplementation during this period averaged 5.8 (Year 1) and 4.7 kg concentrate DM·cow⁻¹·day⁻¹ (Year 2), respectively.

The experiment began on April 12 (Year 1) and April 25 (Year 2). Rotational grazing management was used as described by Dillon et al. [12]. The stocking rate applied in Year 1 was 4.95 cows·ha⁻¹ (April–May), 4.2 cows·ha⁻¹ (June–September). In Year 2, the stocking rate was 4.7 cows·ha⁻¹ (April–May), 4.2 cows·ha⁻¹ (June–July) and 3.8 cows·ha⁻¹ (August–September). Grass supply was monitored weekly by the completion of an estimate of farm grass cover [29]. Farm grass cover is the total supply of herbage available > 40 mm on the grazing area. When farm grass cover was determined, the availability of grass DM (kg DM·cow⁻¹) was calculated as follows; {kg DM·cow⁻¹ = farm grass cover/grazing stocking rate}. At specific periods individual cultivars had surplus grass. Extra “buffer” cows were introduced to graze the extra grass with the core herd, the calculation on the number of cows to add to the core herd was based on the kg DM·cow⁻¹ available. The period during which the “buffer” cows grazed with the core herd was termed as “extra cow grazing days”. The aim of this grazing strategy was to maintain similar post-grazing sward height and rest intervals across cultivar treatments. When an equal grass surplus occurred within all cultivars, the surplus grass was harvested as round bale silage. In late June of Year 1, a moisture deficit severely reduced grass supply. Round-baled silage previously conserved from each

cultivar was offered to their respective herds during the grass shortage. In Year 1, the mean length for each rotation was; rotation 1–30 days; 2–22 days; 3–22 days; 4–18 days, 5–17 days; 6–21 days; 7–26 days. In Year 2, the mean rotation length was; rotation 1–20 days; 2–20 days, 3–19 days; 4–24 days; 5–26 days; 6–24 days; 7–26 days.

2.4. Fertiliser application

Initial fertiliser application was in the form of granulated urea at a rate of 57 kg N·ha⁻¹. During the grazing season calcium ammonium nitrate (CAN) with 5% sulphur was applied after each grazing. In Year 1, 50 kg N·ha⁻¹ was applied from April to mid September, 33.3 kg N·ha⁻¹ was applied thereafter. In Year 2, 50 kg N·ha⁻¹ was applied until mid July and 33 kg N·ha⁻¹ was applied until late September. No fertiliser containing phosphorous (P) and potassium (K) was applied as soil tests showed P and K levels to be at high levels.

2.5. Animal measurements

Milk yield was recorded daily at both morning and evening milking. Milk fat, protein and lactose concentration was determined in one successive morning and evening sample of milk per week using the Milkoscan 203 (Foss Electric, DK 3400-Hillerod, Denmark). Solids corrected milk (SCM) was calculated using the equation of Tyrell and Reid [40]. Body weight was recorded weekly. The average of two consecutive morning weightings was used. Body condition score was measured fortnightly using the method described by Lowman et al. [23].

Individual animal intake was determined in all cows on three occasions at pasture in the first year of the study using the n-alkane technique of Mayes et al. [24] as modified by Dillon and Stakelum [13]. The intake measurement took place in mid-May (M1 – Rotation 2), late-June (M2 – Rotation 4)

and early-September (M3 – Rotation 7). The cows were dosed with a “controlled release capsule” (Captec (NZ) Ltd., Auckland) on day zero. Each capsule releases n-dotriacontane (C_{32}) and n-hexatriacontane (C_{36}) within the rumen, at a constant rate, for a period of approximately 20 days. The mean release rate of (C_{32}) was $340.9 \text{ mg}\cdot\text{day}^{-1}$. Faecal grab samples were collected twice daily (after milking) from day seven until day twelve after dosing. Faecal samples from each cow were bulked, dried at 60°C and ground through a 1 mm sieve. Herbage samples representative of that being grazed were manually collected from each paddock (both am and pm) on days six to eleven of the intake measurement period. Concentrate was offered during M1 and M2 at a rate of $1.8 \text{ kg DM}\cdot\text{cow}^{-1}\cdot\text{day}^{-1}$ and $0.37 \text{ kg DM}\cdot\text{cow}^{-1}\cdot\text{day}^{-1}$, respectively. A representative concentrate sample was obtained daily while been offered.

2.6. Sward measurements

Pre-grazing herbage mass ($> 40 \text{ mm}$) was determined on each grazing paddock based on four random strips of grass harvested (0.60 m wide and 5 to 6 m long) with an Agria mower (Agria-Werke, Moeckmuel, Germany). The grass from each strip was weighed, sampled and a sub-sample was dried overnight at 90°C in a force-dried oven to determine dry matter content. The remaining herbage from the four samples from each paddock was bulked and a sub sample taken. This sample (c. 100 g) was freeze dried and used for chemical analysis. Individual samples were later composited for each cultivar for each week of the experiment. A further sub-sample of this herbage was subjected to morphological separation [39] before drying overnight at 90°C . The components separated from the samples comprised of live leaf, live stem and dead material, non-grass weeds fractions and clover plant parts. In each paddock a total of 30 pre- and post-grazing sward surface

heights were recorded (15 per diagonal) using a HFRO sward stick [20]. Daily grass allowance $> 40 \text{ mm}$ was calculated as follows; $\{\text{Paddock grazing area (ha)} \times \text{Pre-grazing herbage mass (kg DM}\cdot\text{ha}^{-1}) / \text{Paddock residency time (days)} \times \text{number of cows}\}$.

2.7. Laboratory procedures and analyses

The faecal samples were analysed for n-alkanes [11]. Herbage samples (cut at the post-grazing sward height to which the animals grazed to) which represented the herbage consumed during periods of intake measurement were collected and analysed for residual moisture at 103°C and incinerated at 550°C for 16 h in a muffle furnace to determine ash content. Neutral detergent fibre (NDF) was determined using Ankom equipment and procedures outlined by Ankom Technology Corporation (NY, USA). The neutral detergent cellulase digestibility (OMD) was determined by the method of Morgan et al. [28], crude protein was determined as outlined by Sweeney [38]. Concentrates were sampled weekly when offered and analysed for DM, total nitrogen, crude fibre, neutral cellulase gammonase determination (NCGD) [1], oil and ash contents by standard procedures.

2.8. Concentrate supplementation

Concentrate supplementation levels offered were equal for each herd. A total input of $248 \text{ kg concentrate DM}\cdot\text{cow}^{-1}$ was offered in Year 1 and $45 \text{ kg concentrate DM}\cdot\text{cow}^{-1}$ during the experiment in Year 2. The majority of this concentrate was offered in the first three rotations of both years. Concentrates were offered in individual stalls (Dairymaster, Causeway, Co. Kerry) in the milking parlour in two equal feeds. The ingredient composition ($\text{kg}\cdot\text{t}^{-1}$) of the offered concentrate during both years of the study was barley 250, unmolassed

beet pulp 250, corn gluten feed 250, rape-seed meal 100, soya bean meal 100, fat 20 and minerals and vitamins 30. The chemical composition of the offered concentrate was: DM 923 g·kg⁻¹ (sd 15.3), crude protein 185 g·kg⁻¹ (sd 8.6), NDF 259 g·kg⁻¹ (sd 21.8), ash 99.9 g·kg⁻¹ (sd 17.1), crude fibre 102 g·kg⁻¹ (sd 17.9), NCGD 825 g·kg⁻¹ (sd 14.6), oil 38.5 g·kg⁻¹ (sd 6.3).

2.9. Statistical analysis

All statistical analysis was carried out using SAS [37]. The sward measurements were analysed according to a split plot design using the following model: $Y_{ijkl} = \text{Mean} + \text{HD}_i + \text{PL}_j + \text{HD}_i \times \text{PL}_j + \text{PD}_k(\text{HD}_i \times \text{PL}_j) + e_{ijkl}$,

where: HD_i = heading date effect (i = 1 to 2); PL_j = ploidy effect (j = 1 to 2); HD_i × PL_j = interaction of heading date × ploidy; PD_k(HD_i × PL_j) paddock effect (within heading date and ploidy) and e_{ijkl} = error term.

Daily milk yield, SCM yield, milk constituent yield, milk composition, body weight and body condition score was analysed using a mixed model procedure using the following model: $Y_{ijkl} = \text{Mean} + \text{HD}_i + \text{PL}_j + \text{HD}_i \times \text{PL}_j + \text{R}_k + \text{HD}_i \times \text{R}_k + \text{PL}_j \times \text{R}_k + \text{HD}_i \times \text{PL}_j \times \text{R}_k + b_1 X_{ijl} + b_2 \text{DIM}_{ijl} + \text{Cow}_1(\text{HD}_i \times \text{PL}_j) + e_{ijkl}$,

where: HD_i = heading date effect (i = 1 to 2); PL_j = ploidy effect (j = 1 to 2); HD_i × PL_j = interaction of heading date × ploidy; R_k = rotation effect (k = 1 to 7); HD_i × R_k = interaction of heading date × rotation; PL_j × R_k = interaction of ploidy × rotation; HD_i × PL_j × R_k = interaction of heading date × ploidy × rotation; Cow₁(HD_i × PL_j) was a random cow effect (within heading date and ploidy); X_{ijl} were the pre-experimental Y_{ijkl} values and DIM_{ijl} are days in milk and e_{ijkl} = error term.

Grass dry matter intake (GDMI) and total dry matter intake (TDMI) was analysed with covariate analysis for each measurement period using the following

model: $Y_{ijk} = \text{Mean} + \text{HD}_i + \text{PL}_j + \text{HD}_i \times \text{PL}_j + b_1 \text{PreMY}_{ijk} + b_2 \text{PreBW}_{ijk} + e_{ijk}$,

where: HD_i = heading date effect (i = 1 to 2); PL_j = ploidy effect (j = 1 to 2); HD_i × PL_j = interaction of heading date × ploidy; PreMY_{ijk} was the pre-experimental milk yield; PreBW_{ijk} was the pre-experimental bodyweight and e_{ijk} = error term.

Herbage representative of that consumed was analysed using the following model: $Y_{ijk} = \text{Mean} + \text{HD}_i + \text{PL}_j + \text{HD}_i \times \text{PL}_j + e_{ijk}$, where: HD_i = heading date effect (i = 1 to 2); PL_j = ploidy effect (j = 1 to 2); HD_i × PL_j = interaction of heading date × ploidy and e_{ijk} = error term.

Likely milk yield (LMY), as described by Delaby et al. [9], was calculated from the PreMY and the duration (d, in weeks) between start and mid-point of the experiment, by assuming a theoretical persistence of 0.98 per week (0.985 in the case of 1st parity cows)

$$\text{LMY} = \text{PreMY} \times 0.98^d.$$

The relationship between experimental milk yield (EMY) and an estimate of LMY was examined using the following model: $\text{EMY}_{ijk} = \text{intercept} + \text{HD}_i + \text{YR}_j + b_1 \text{LMY}_{ijk}$, examining individual effects of heading date and year using the general linear model procedure of SAS [37]. Multiple regression relationships were derived to explain DMI (dependent variable) from PreMY, pre-experimental body weight (PreBW) and the interaction of heading date and ploidy.

3. RESULTS

3.1. Weather

Total rainfall for Year 1 and Year 2 was 973 and 1082 mm, respectively compared to the 33 year average (1977–2000) of 1001 mm. Duration of sunshine (h) in Year 1 and Year 2 was 1184 and 1318 hours, respectively compared to the 33 year average

of 1297 h. Mean daily temperature ($^{\circ}\text{C}$) for Year 1 and Year 2 was 10.3 and 9.9 degrees, respectively compared to the 33 year average of 10.0 degrees.

3.2. Grazing management

The experimental period in both years comprised of 7 rotations. During this period in Year 1, 7.5 paddocks were mechanically topped once and 2.5 paddocks were harvested as round bale silage for each cultivar. In Year 2, only 3 paddocks were topped and 2 paddocks from each cultivar were harvested as round bale silage. There was no significant difference between the amount of grass allocated to the cow grazing cultivars of differing heading date. The grass allowances were (22.6 vs. 23.6 $\text{kg DM}\cdot\text{cow}^{-1}\cdot\text{day}^{-1}$) in Year 1 and (24.8 vs. 24.7 $\text{kg DM}\cdot\text{cow}^{-1}\cdot\text{day}^{-1}$) in Year 2 for late and intermediate heading cultivars, respectively. The effect of grass ploidy approached significance for grass allowance in both

years. Grass allowance in Year 1 was (24.0 vs. 22.3 $\text{kg DM}\cdot\text{cow}^{-1}\cdot\text{day}^{-1}$) and in Year 2 (25.6 vs. 23.9 $\text{kg DM}\cdot\text{cow}^{-1}\cdot\text{day}^{-1}$) for diploid and tetraploid grass cultivars, respectively. There was no significant effect of grass cultivars on the post-grazing sward height in either year of the study. In Year 1, the mean post-grazing sward height was 73 mm and in Year 2 the cows grazed to a mean post-grazing height of 77 mm. In Year 1, the number of extra cow grazing days was 74, 48, 146 and 168 for the intermediate diploid (ID), intermediate tetraploid (IT), late diploid (LD) and late tetraploid (LT), respectively. In Year 2, the number of extra cow grazing days was 20, 64, 25 and 87 for the ID, IT, LD and LT, respectively.

3.3. Sward measurements

Table II shows the effects of grass cultivars on sward characteristics. Rotation had a significant effect ($P < 0.001$) on all sward measurements. Cultivar heading

Table II. The effect of grass cultivars on sward characteristics in Year 1 and 2.

	ID	IT	LD	LT	Sed	Heading	Ploidy	HD×PL
Year 1								
Herbage mass ($\text{kg DM}\cdot\text{ha}^{-1}$)	2152	1955	2407	2214	92.4	***	**	NS
Pre-grazing height (mm)	188	191	191	192	3.9	NS	NS	NS
Post-grazing height (mm)	72	71	75	73	1.4	+	+	NS
Leaf content ($\text{g}\cdot\text{kg}^{-1}$)	623	602	571	647	18.0	NS	*	***
Stem content ($\text{g}\cdot\text{kg}^{-1}$)	276	311	318	260	18.5	NS	NS	***
Year 2								
Herbage mass ($\text{kg DM}\cdot\text{ha}^{-1}$)	2506	2291	2623	2378	79.1	NS	***	NS
Pre-grazing height (mm)	217	215	219	215	4.6	NS	NS	NS
Post-grazing height (mm)	78	74	77	77	1.7	NS	+	+
Leaf content ($\text{g}\cdot\text{kg}^{-1}$)	622	623	618	682	19.0	*	*	*
Stem content ($\text{g}\cdot\text{kg}^{-1}$)	267	274	291	238	13.0	NS	*	**

ID: Intermediate Diploid (Spelga); IT: Intermediate Tetraploid (Napoleon); LD: Late Diploid (Portstewart); LT: Late Tetraploid (Millennium); HD×PL: interaction of heading date × ploidy.

Sed: standard error of the difference; NS: not significant ($P > 0.10$); +: $P < 0.10$; *: $P < 0.05$; **: $P < 0.01$; ***: $P < 0.001$.

date had a significant effect on herbage mass (HM) in Year 1. Late heading cultivars had significantly higher (2310 vs. 2054 kg DM·ha⁻¹, $P < 0.001$) HM than intermediate heading cultivars in Year 1. Diploid cultivars had significantly higher HM than tetraploid cultivars in Year 1 (2280 vs. 2084 kg DM·ha⁻¹, $P < 0.01$) and also in Year 2 (2565 vs. 2335 kg DM·ha⁻¹, $P < 0.001$). Tetraploid cultivars had significantly higher leaf content in Year 1 (625 vs. 597 g·kg⁻¹, $P < 0.05$) and in Year 2 (652 vs. 620 g·kg⁻¹, $P < 0.05$). In Year 2, late heading cultivars had significantly higher leaf content (650 vs. 622 g·kg⁻¹, $P < 0.05$) than intermediate heading cultivars. In Year 2, tetraploid cultivars had significantly lower stem content (256 vs. 279 g·kg⁻¹, $P < 0.05$). In Year 1, there was no significant effect of heading date or grass ploidy on any chemical parameter measured in the pre-grazing sward. In Year 2, grass ploidy had a significant ($P < 0.01$) effect on NDF content of the sward, tetraploid cultivars had a lower NDF content compared to diploid cultivars (409 vs. 434 g·kg⁻¹).

3.4. Milk yield and milk composition

Table III shows the effect of grass cultivars on milk production parameters in both years. Rotation had a significant ($P < 0.001$) effect on all milk production parameters measured in both years of the study. As rotation is a time imposed effect, the remainder of the paper will focus on the effects of heading date and grass ploidy. In Year 1, cows grazing late heading cultivars had significantly higher milk yield (+0.85 kg·cow⁻¹·day⁻¹, $P < 0.05$), SCM yield (+0.95 kg·cow⁻¹·day⁻¹, $P < 0.05$), fat yield (+0.04 kg·cow⁻¹·day⁻¹, $P < 0.05$), protein yield (+0.04 kg·cow⁻¹·day⁻¹, $P < 0.05$) and lactose yield (+0.05 kg·cow⁻¹·day⁻¹, $P < 0.05$). There were significant ($P < 0.05$) interactions between heading date and ploidy for lactose yield and fat concentration. Significance was approached for the interaction between heading date and ploidy for milk

yield and protein concentration. In Year 2, cows grazing late heading cultivars had significantly higher milk yield (+1.35 kg·cow⁻¹·day⁻¹, $P < 0.01$), SCM (+1.20 kg·cow⁻¹·day⁻¹, $P < 0.05$), milk protein yield (+0.06 kg·cow⁻¹·day⁻¹, $P < 0.001$), lactose yield (+0.07 kg·cow⁻¹·day⁻¹, $P < 0.05$) and protein concentration (+0.06 g·kg⁻¹, $P < 0.05$). There was a significant ($P < 0.05$) interaction between heading date and ploidy for lactose concentration.

3.5. Body weight and body condition score

In Year 1, there was a significant ($P < 0.001$) interaction between heading date and rotation for body weight. There was also a significant ($P < 0.01$) interaction between grass ploidy and rotation. Cows grazing intermediate heading cultivars had a higher body weight than cows grazing late heading cultivars, except during rotation 3. In Year 2, there was a significant ($P < 0.001$) interaction between heading date, ploidy and rotation for body weight. Rotation had a significant ($P < 0.001$) effect on body condition score in both years of the experiment. In Year 1, body condition score varied between rotations, while in Year 2 body condition score increased during each rotation.

3.6. Dry matter intake

Table IV shows the mean grass dry matter intake (GDMI) and total dry matter intake (TDMI) estimates for 3 intake measurements in Year 1. Cows grazing late heading cultivars recorded a significantly ($P < 0.001$) higher TDMI than cows grazing intermediate heading cultivars during M1 (16.0 vs. 14.0 kg DM·cow⁻¹·day⁻¹) and M2 (18.3 vs. 15.2 kg DM·cow⁻¹·day⁻¹). Cows grazing intermediate heading cultivars recorded a higher GDMI than cows grazing late heading cultivars in M3 (18.2 vs. 17.3 kg DM·cow⁻¹·day⁻¹). However, this difference only approached significance ($P = 0.06$). A

Table III. Effect of grass cultivars on milk production parameters, body weight and condition score in Year 1 and 2.

	ID	IT	LD	LT	Sed	Heading	Ploidy	HD×PL
Year 1								
Daily milk yield (kg)	22.1	21.2	22.2	22.8	0.54	*	NS	+
Daily SCM yield (kg)	19.8	19.6	20.6	20.7	0.51	*	NS	NS
Fat yield (kg)	0.82	0.83	0.87	0.86	0.024	*	NS	NS
Protein yield (kg)	0.72	0.69	0.74	0.74	0.021	*	NS	NS
Lactose yield (kg)	1.02	0.98	1.03	1.06	0.027	*	NS	*
Fat concentration (g·kg ⁻¹)	37.7	39.6	39.2	38.2	0.97	NS	NS	*
Protein concentration (g·kg ⁻¹)	32.5	33.0	33.4	32.7	0.45	NS	NS	+
Lactose concentration (g·kg ⁻¹)	46.2	46.3	46.3	46.6	0.27	NS	NS	NS
Body weight (kg)	510	509	506	507	5.3	NS	NS	NS
Condition score	2.89	2.90	2.89	2.98	0.051	NS	NS	NS
Year 2								
Daily milk yield (kg)	21.0	20.7	22.2	22.2	0.64	**	NS	NS
Daily SCM yield (kg)	19.6	19.2	20.5	20.7	0.66	*	NS	NS
Fat yield (kg)	0.83	0.80	0.85	0.87	0.031	+	NS	NS
Protein yield (kg)	0.70	0.70	0.75	0.76	0.011	***	NS	NS
Lactose yield (kg)	0.97	0.96	1.03	1.03	0.034	*	NS	NS
Fat concentration (g·kg ⁻¹)	39.7	39.5	39.1	39.6	0.93	NS	NS	NS
Protein concentration (g·kg ⁻¹)	33.5	34.0	34.3	34.3	0.37	*	NS	NS
Lactose concentration (g·kg ⁻¹)	45.5	46.5	46.2	46.2	0.33	NS	+	*
Body weight (kg)	532	535	536	541	4.0	NS	NS	NS
Condition score	2.90	2.87	2.91	2.94	0.045	NS	NS	NS

ID: Intermediate Diploid (Spelga); IT: Intermediate Tetraploid (Napoleon); LD: Late Diploid (Portstewart); LT: Late Tetraploid (Millennium); HD×PL: interaction of heading date × ploidy.

Sed: standard error of the difference; NS: not significant ($P > 0.10$); +: $P < 0.10$; *: $P < 0.05$; **: $P < 0.01$; ***: $P < 0.001$.

SCM: solids corrected milk yield.

significant proportion of the variation in DMI within individual measurements was explained by multiple regression analysis of pre-experimental milk yield and body weight and the interaction of heading date and grass ploidy (Tab. V). Differences between slopes for all possible interactions were tested but were not significant.

3.7. Herbage chemical composition

Table VI shows the chemical analysis of the herbage representative of that consumed by the cows during each intake measurement in Year 1. During M1, the herbage selected by cows grazing late heading cultivars was significantly higher in organic

Table IV. Effect of grass cultivars on grass and total dry matter intake during three measurement periods in Year 1.

		ID	IT	LD	LT	Sed	Heading	Ploidy	HD×PL
M1	GDMI (kg)	12.2	12.2	13.5	14.8	0.58	***	NS	NS
	TDMI (kg)	14.0	14.0	15.4	16.7	0.58	***	NS	NS
M2	GDMI (kg)	15.7	13.9	17.6	18.4	0.77	***	*	NS
	TDMI (kg)	16.1	14.3	18.0	18.5	0.77	***	*	*
M3 ¹	GDMI (kg)	17.7	18.8	16.7	17.8	0.73	+	*	NS

ID: Intermediate Diploid (Spelga); IT: Intermediate Tetraploid (Napoleon); LD: Late Diploid (Portstewart); LT: Late Tetraploid (Millennium); HD×PL: interaction of heading date × ploidy.

Sed: standard error of the difference; NS: not significant ($P < 0.10$); +: $P < 0.10$; *: $P < 0.05$; **: $P < 0.01$; ***: $P < 0.001$.

GDMI: grass dry matter intake, TDMI: total dry matter intake.

¹ No concentrate supplementation in M3 (TDMI = GDMI).

M1: Rotation 2; M2: Rotation 4; M3: Rotation 7.

Table V. Effect of grass cultivars on the relationship between pre-experimental dairy cow characteristics and total dry matter intake during three intake measurement periods in Year 1.

	Intercept				PreMY	PreBW	Rse	R ²
	ID	IT	LD	LT				
M1	-7.77	-7.81	-6.42	-5.14	0.333	0.023	1.755	0.64
M2	-2.88	-0.97	-4.69	0.46	0.207	0.023	2.323	0.49
M3	-4.19	-3.12	-5.17	-4.11	0.309	0.024	2.176	0.50

ID: Intermediate Diploid (Spelga); IT: Intermediate Tetraploid (Napoleon); LD: Late Diploid (Portstewart); LT: Late Tetraploid (Millennium).

PreMY: Pre-experimental milk yield; PreB: Pre-experimental body weight.

Rse: residual standard error; R²: determination coefficient.

M1: Rotation 2; M2: Rotation 4; M3: Rotation 7.

matter digestibility (OMD) (+21.5 g·kg⁻¹, $P < 0.05$) and ash content (+8.0 g·kg⁻¹, $P < 0.05$) but had significantly lower (-22 g·kg⁻¹, $P < 0.01$) neutral detergent fibre (NDF) content. During M2, the crude protein content of selected herbage was significantly higher (+24 g·kg⁻¹, $P < 0.05$) for cows grazing intermediate heading cultivars compared to late heading cultivars. During M3, the herbage selected by cows grazing late heading cultivars approached significance (+13 g·kg⁻¹, $P < 0.10$) compared to the herbage selected by the cows grazing the intermediate heading cultivars.

Rotation had a significant ($P < 0.001$) effect on all chemical parameters of the

offered swards in both years except for ash content in Year 2. There was no significant effect of heading date or grass ploidy on any chemical parameter in Year 1. In Year 2, however, tetraploid cultivars had significantly higher ($P < 0.01$) NDF content than diploid cultivars. No other chemical parameter was significant in Year 2.

4. DISCUSSION

The present study was designed to explore the effects of grazing four grass cultivars classified under contrasting heading dates and grass ploidy. It is fully recognised by the

Table VI. Effect of grass cultivars on nutritive characteristics of herbage consumed during three dry matter intake measurement periods in Year 1.

	ID	IT	LD	LT	Sed	Heading	Ploidy	HD×PL
M1 CP (g·kg ⁻¹)	183	185	178	197	16.7	NS	NS	NS
NDF (g·kg ⁻¹)	382	372	355	355	4.5	**	NS	NS
OMD (g·kg ⁻¹)	834	839	855	861	10.0	*	NS	NS
Ash (g·kg ⁻¹)	79	86	87	94	4.0	*	+	NS
M2 CP (g·kg ⁻¹)	207	225	193	191	7.7	*	NS	NS
NDF (g·kg ⁻¹)	381	352	370	357	29.8	NS	NS	NS
OMD (g·kg ⁻¹)	836	848	845	849	6.7	NS	NS	NS
Ash (g·kg ⁻¹)	76	78	79	77	3.5	NS	NS	NS
M3 CP (g·kg ⁻¹)	250	243	269	237	14.9	NS	NS	NS
NDF (g·kg ⁻¹)	378	369	376	379	7.5	NS	NS	NS
OMD (g·kg ⁻¹)	840	843	852	857	7.7	+	NS	NS
Ash (g·kg ⁻¹)	89	86	88	77	3.5	NS	*	NS

ID: Intermediate Diploid (Spelga); IT: Intermediate Tetraploid (Napoleon); LD: Late Diploid (Portstewart); LT: Late Tetraploid (Millennium); HD×PL: interaction of heading date × ploidy.

Sed: standard error of the difference; NS: not significant ($P < 0.10$); +: $P < 0.10$; *: $P < 0.05$; **: $P < 0.01$; ***: $P < 0.001$.

CP: crude protein; NDF: neutral detergent fibre; OMD: organic matter digestibility.

authors that variation between grass cultivars exists within both heading dates and ploidy categories. Therefore it is possible that other grass cultivars within these groups may have other beneficial chemical or morphological traits (i.e. increased water soluble content, organic matter digestibility, green leaf mass, bulk density, herbage mass, etc.) for higher milk production than the cultivars used in this study. It would be misleading to interpret the results of the study as representative of all cultivars in both classification categories.

4.1. Milk yield and composition

In this study cows grazing late heading grass cultivars recorded a larger milk yield and milk composition than cows grazing intermediate heading cultivars. In both years of the study there was an interaction between

heading date and rotation. In Year 1, the milk yield difference between cows grazing late and intermediate heading cultivars was 1.2 (rotation 2), 1.9 (rotation 3) and 1.3 kg·cow⁻¹·day⁻¹ (rotation 4). In Year 2, such differences were 1.0 (rotation 2), 1.8 (rotation 3), 1.2 (rotation 4), 1.3 (rotation 5), 1.8 (rotation 6) and 1.7 kg·cow⁻¹·day⁻¹ (rotation 7). The occurrence of a moisture deficit in mid July of Year 1 reduced the milk yield differences between cultivars. In both years of the study, there was a pronounced milk yield decrease during late May/early June. This period corresponds to the respective heading date of intermediate heading cultivars. In fact the observed timing of heading of both intermediate and late heading cultivars was in accordance to that reported by the Irish recommended list [8]. The lower milk yield of cows grazing intermediate heading cultivars at this time corresponds clearly with a low proportion of leaf and a high

proportion of stem in the sward [16]. The large milk yield decrease recorded is more apparent in this study than that of Gately [15] because peak milk yield occurred at the same time as the heading date of the intermediate heading cultivars.

Grass ploidy had no significant effect on milk yield in both years of this study. This finding disagrees with the work of Castle and Watson [4] and Lantinga and Groot [22], where tetraploid cultivars had a milk production advantage compared to diploid cultivars. One reason for a non-significant response to tetraploid cultivars in this study was due to the poor performance of the intermediate tetraploid cultivar particularly in Year 1. The cows grazing this cultivar had consistently lower milk yield than the other three cultivars. On an individual cultivar basis the late tetraploid cultivar recorded the highest milk yield.

The concept of LMY is used to explain apparent differences in milk yield between the cows grazing the cultivars with different

heading dates. The observed or experimental milk yield can be viewed as a direct function of pre-experimental milk yield and the achieved level of DMI during the experiment [10]. The relationships between EMY and LMY for cows grazing intermediate and late heading cultivars in both years is shown in Figure 1. The difference between LMY and EMY for cows grazing intermediate heading cultivars was (- 2.1 kg) in Year 1 and significantly higher in Year 2 (- 4.1 kg). For cows grazing late heading cultivars this difference was not as large but differed between years, -1.3 and -2.6 kg in Year 1 and 2, respectively. Peyraud and Gonzalez-Rodriquez [32] reported that beyond 15 kg of milk, cows are able to produce two thirds of their likely milk yield. However, in this experiment the shortfall is much smaller than that reported by Kolver and Muller [21]; Peyraud and Gonzalez-Rodriquez [32] and Delaby et al. [10] but higher than that reported by Butler et al. [2]. The difference between EMY and LMY was higher for cows grazing intermediate

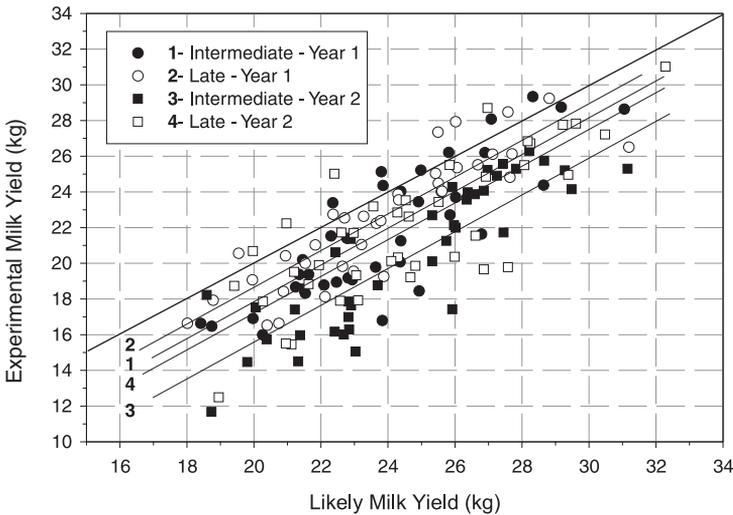


Figure 1. The relationship of experimental milk yield to likely milk yield for cows grazing intermediate and late heading grass cultivars in both years.

heading cultivars in both years. A likely explanation for this is the inadequacy of the intermediate heading cultivars used, to consistently supply high quality herbage during the main grazing season. The relationships between EMY and LMY for cows grazing diploid and tetraploid cultivars were similar and almost equal.

It is generally accepted that marked changes occur throughout lactation in the concentration of all major milk constituents [34]. In both years of this study there was a significant heading date by rotation interaction for daily SCM yield, protein yield and lactose yield, the fat yield difference was significant only in Year 2. The reduction in SCM from rotation 1 to rotation 3 was 8.2 and 6.4 kg·cow⁻¹·day⁻¹ for cows grazing intermediate heading and late heading cultivars, respectively. Rotation 3 corresponded in both years to the largest SCM decrease for intermediate heading cultivars. Therefore, similar to milk yield, the onset of inflorescence had a negative effect on milk solids production. There was also a significant heading date by rotation interaction for milk fat, protein and lactose (both years) concentration. Grass ploidy had no significant effect on milk solids production. However, its interactions, particularly with rotation had significant effects on protein yield (in both years), lactose yield and concentration (Year 2). Castle and Watson [4] and Lantinga and Groot [22] observed higher (fat and protein corrected milk) production with tetraploid cultivars.

4.2. Body weight and condition score

In both years of the study, rotation had significant effects on animal body weight and condition score. Changes in body weight took place at different periods during the grazing season especially during the heading period. Cows grazing intermediate heading cultivars lost body weight during this period. Castle and Watson [4]; McCallum and Thomson [25] and Emile

et al. [14] all found no significant effect of grass cultivar on animal body weight. Gately [15] reported that the cows grazing late heading cultivars gained more body weight at the higher stocking rate than the animals grazing the early heading cultivars. However, the animals used in that study were of much lower genetic merit than the animals used in the current study and it is conceivable that they partitioned more energy into body weight gain than into milk production.

4.3. Dry matter intake

The estimation of DMI under grazing has been subject to much research and many factors influencing intake have been identified. Such factors include both animal characteristics and sward (chemical and physical) characteristics. The multiple regression analysis used in this experiment attempts to combine the effects of both the animal and the sward to explain DMI. Milk yield and body weight were used as representatives for the effect of animal characteristics on DMI, while nutritional and sward characteristics are enclosed under the effects of heading date and grass ploidy. This is emphasized by the considerable fluctuation of the intercepts for the individual cultivars with regression analysis. The partial coefficients for PMY ranged from 0.21 to 0.33 which is in agreement with those of Peyraud et al. [33], Greenhalgh et al. [17], Curran and Holmes [7] and Caird and Holmes [3]. DMI increased by 2.0 to 2.4 kg per 100 kg body weight but did not differ if using experimental or pre-experimental data. Similarly, in a review of prediction equations for DMI, Vazquez and Smith [41] reported DMI increases ranging from 1.8 to 2.5 kg per 100 kg body weight.

There are no direct DMI comparisons between grasses with differing heading date within the literature. Most research work has centred on comparisons between diploid and tetraploid grass cultivars.

Furthermore, most comparisons involve experiments which were completed over short periods, i.e. whole grazing season effects are absent unlike the present study. In two of the three intake measurements cows grazing tetraploid cultivars had higher DMI than diploid cultivars. Hageman et al. [18], Lantinga and Groot [22] both previously found higher grass DMI with tetraploid cultivars. In two of the three intake measurements cows grazing late heading grass cultivars had superior grass DMI relative to the intermediate cultivars. However, cows grazing the intermediate heading cultivars had a higher DMI during the autumn intake period. The reduced DMI of intermediate heading cultivars early in the grazing season would suggest that the inflorescence period is antagonistic to achieving high DMI [17]. High sward surface height, low leaf to stem ratio limits grass intake [26]. Hodgson [19] concluded that tall swards were more prehensible, but conceded that the presence of leaf sheath in the grazed horizon may contribute to, or cause a decline in herbage intake that was found with declining sward surface height.

The positive relationship between high leaf content and high DMI of late heading cultivars is amplified by the position of leaf lower in the grazing canopy. O'Donovan (unpublished) suggested that the pseudostem height and lowest ligule height of intermediate heading cultivars is higher than in late heading cultivars. This indicates that as the cow grazes into the sward canopy there is a higher proportion of leaf material deeper in the sward. To quantify the height and proportion of free leaf lamina within the sward profile, as well as the pseudostem and lowest ligule height could lead to a better understanding of apparent DM intake differences between grass cultivars. The benefit of this has been shown by Parga [31] to limit the reduction in intake even when herbage allowance is restricted.

It is concluded from the results of the study that the later heading grass cultivars

used have beneficial effects on the milk production performance of dairy cows at pasture.

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