

Impacts of Sward Renewal Method with Perennial Ryegrass (*Lolium perenne*) on Dry Matter Yield, Tiller Density and Nitrate Leaching

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Abstract

The objective of this study was to evaluate alternative methods of grassland renewal (reseeding) with perennial ryegrass and quantify their effects on subsequent DM yield, tiller density and nitrate leaching. Two experiments were carried out; the first focused on quantifying the influence of Autumn reseeding (August cultivation), and the second, on Spring reseeding (May cultivation) on sward establishment and grass DM production. The study incorporated six treatments namely: direct drill (DD), disc plus power harrow (DPH), power harrow (PH), conventional-plough, till and sow (PLO), and the chemical application of diquat to suppress the existing sward followed by direct drilling (DIQ), represented a rejuvenation method as opposed to full renewal (Spring trial only). All treatments were compared against a control (old permanent pasture). Reseeded swards produced more seasonal ($P < 0.05$) and total ($P < 0.01$ Autumn only) DM yield than the control sward. All reseeding methods increased the perennial ryegrass tiller density of the sward compared to the old permanent pasture ($P < 0.05$ Autumn trial, $P < 0.001$ Spring trial). All sward renewal methods evaluated were equally as effective as the conventional method of grassland reseeding with the DIQ rejuvenation method intermediate as measured in terms of DM yield and PRG tiller density. The results of the study show no significant difference in the level of nitrate lost in leachate following reseeding regardless of method used or indeed any difference between reseeded swards and old permanent pasture.

Keywords

Grass Planting, Pasture and Grazing

1. Introduction

Grassland in Ireland including rough grazing accounts for over 90% of agricultural land use [1]. While perennial ryegrass (*Lolium perenne* L.) is by far the most widely sown grass species in Ireland accounting for approximately 95% of forage grass seed sold [2], its overall level in national pastures is still thought to be low due to the low levels of sward renewal taking place [3]. As its name suggests, perennial ryegrass has a perennial life-cycle, capable of surviving for many decades in pasture under suitable conditions. Perennial ryegrass dominates in swards of temperate climates as it establishes rapidly from seed; it has a strong tillering ability allowing it to produce a dense sward; it is highly acceptable to stock, capable of withstanding intensive grazing, and responds well to fertile conditions and inputs of nitrogen (N). A grassland survey by Creighton *et al.*, [4] highlighted the low level of grassland reseeding in Ireland. Twenty-three percent of dairy farmers had not reseeded any grassland in the previous three years, with an average of just 6.8% of the land area on specialist dairy farms being reseeded annually.

Intensive grass based production systems require swards with high production potential. Assuming that all environmental and management factors under the farmers control are at their optimum, the botanical composition of the sward can become a limiting factor to production [5]. As there is a high cost associated with the sward renewal process, considerable benefit must be gained to make it a viable undertaking [4] [6]. There are few published data directly comparing existing old permanent pasture to reseeded swards under a grazing system. Lawson and Kelly [7] increased herbage production by an average of 1.1 t DM/ha over 4 years following over-sowing with perennial ryegrass compared to a 15 years old perennial ryegrass pasture. Total sward production in years 2 - 4 after reseeding was similar to the old pasture although it was higher in the winter and spring periods. Conijn [8] and Hopkins *et al.* [9] concluded that the production increase following reseeding is at best more or less equal to the production loss in the year of renewal. Strategies to reduce this loss need to be investigated.

Methods of renewal will depend on whether a partial rejuvenation of the sward or full reseed is necessary or possible. The conventional plough, till, sow method of sward renewal is recognised for its capacity to produce a firm, fine seedbed reducing the physical challenge to seed germination and establishment by surface trash, pests and diseases [10]. While these benefits are important and desirable many areas are unsuitable for ploughing/deep cultivation, e.g. areas that are too steep or wet, or have shallow, stony soils. Other reasons put forward are the loss of soil moisture, the risk of soil erosion or detrimental effects to soil structure [11]. For these reasons alternative methods of sward renewal must be used under such conditions. Alternative methods may include the use of herbicides for full or partial destruction of the old sward followed by minimum cultivation or direct drilling techniques to renew or rejuvenate the sward [12].

It has been reported that the process of sward renewal is associated with a flush of soil organic nitrogen (N) mineralization and an increase in soil mineral N content. Because of the high N content of grassland soils, the process of sward renewal can increase the mineral N content to more than 200 kg N/ha [13] [14]. Reasons for this increase in N content are related to the mineralization of stubble and root residues and the period of little or no crop N uptake during the renewal process while swards are establishing [15]. Although it is generally assumed that deep ploughing causes the greatest increase in the level of N leaching when reseeding, Seidel *et al.* [16] observed higher N losses in direct drilled swards compared to rotary cultivation. Lloyd [17] found similar N losses between shallow cultivation and ploughing of grassland.

The objective of this study was to compare different reseeding methods and quantify effects on subsequent DM production, tiller density and nitrate leaching.

2. Materials and Methods

This study was undertaken at Teagasc, Moorepark, Animal and Grassland Research and Innovation Centre, Fermoy, Co Cork, Ireland (latitude 50°07' North, 8°16' West). The soil type was a free draining, acid brown earth with a sandy loam to loam texture. The study was undertaken over two full production years from autumn 2008 to spring 2011, during which metrological data was recorded on site using an automated weather station.

2.1. Experimental Design and Procedures

Sward renewal experiments were undertaken on two occasions, in autumn 2008 (RA) and in spring 2009 (RS). Both experiments were set up using a randomised block design with each treatment replicated three times, with one half reseeded in autumn 2008 and the other half in spring 2009. Plot size was 30 m × 6 m (180 m²). In the

RA study four methods of sward renewal were compared against old permanent pasture (control) which had not been reseeded in the previous 20 years. The area to be renewed was sprayed off, except for the control plots, with a glyphosate product (Roundup Biactive 360 g/l), 10 days before cultivation. The treatments for the RA experiment were:

- 1) Control—old permanent pasture (C)—no treatments applied.
- 2) Direct drill (DD)—existing sward sprayed with glyphosate followed by seeding using a drill fitted with tines which cut channels 7.5 cm apart into which seed was sown.
- 3) Disc plus rotary power harrow (DPH)—existing sward sprayed with glyphosate followed by cultivation with disc harrow (shallow (10 cm) inversion of the soil), followed by cultivation with rotary power harrow to produce seed bed. Seed sown using air seeder attached to power harrow.
- 4) Power harrow only (PH)—existing sward sprayed with glyphosate followed by shallow surface cultivation with rotary power harrow to produce seed bed. Seed sown using air seeder attached to power harrow.
- 5) Conventional-plough, till, sow (PLO)—existing sward sprayed with glyphosate followed by ploughing (total inversion of soil surface (20 cm depth)), followed by cultivation with rotary power harrow to produce seed bed. Seed sown using air seeder attached to power harrow.

The RS study incorporated the same as above with an additional treatment added; the chemical application of diquat to suppress the existing sward followed by direct drilling without spraying off with a glyphosate product (DIQ), represented a rejuvenation method as opposed to full renewal.

The RA swards were sown on 25th August 2008 and the RS swards on 08th May 2009 at a seeding rate of 37 kg ha⁻¹ with *cv.* Tyrella, a late heading diploid perennial ryegrass. A seed bed fertilizer application of 60 kg N ha⁻¹, 7.5 kg P ha⁻¹ and 32 kg K ha⁻¹ was applied at sowing. All swards received 7.5 kg P ha⁻¹ and 32 kg K ha⁻¹ in January each year. Nitrogen was applied as granulated urea (0.46 N) from January to April, and thereafter as calcium ammonium nitrate (CAN, 0.27 N). All swards received a total of 200 kg N ha⁻¹ yr⁻¹ applied in equal proportions after each defoliation during the grazing season.

Once established the RA plots were defoliated (grazed) once in late October 2008 and then closed until the following spring when they were grazed at 21 to 35 day intervals from February to October in 2009 and 2010 and February to April in 2011. The RS plots were defoliated twice in early 2009 before reseeding and again seven weeks post sowing in early July 2009 and every 21 to 35 days thereafter (from July to October in 2009, February to October in 2010 and February to April 2011). The DIQ swards were grazed once in between sowing and the first grazing for the other treatments in order to reduce competition from existing grasses. The interval between defoliations varied between 21 and 35 days depending on grass growth rates and season, longer intervals were imposed at the beginning and end of the grazing season with more frequent defoliation in midseason mirroring higher growth rates. Plots were grazed by dairy heifers with grazing duration averaging 2 days per grazing event. For analysis purposes the grazing season was broken down into spring (February to April—first two defoliations), summer (May to July—next four defoliations) and autumn (August to October—final three defoliations). Grass DM yield (kg DM ha⁻¹) above 4 cm was estimated before each defoliation by cutting a 6 m strip across the centre of each plot using a reciprocating blade mower. Harvested grass was sub-sampled and 100 g was dried at 80°C for 16 h in a forced air oven to determine dry matter (DM) content. Sward tiller densities were measured at the end of years 2 and 3 by removing three turves (100 mm × 100 mm) from each plot and dissecting to estimate the number of perennial ryegrass (PRG) tillers and to calculate total tiller density m⁻².

The plots established in the RA study were also used to evaluate the effect of sward renewal method on nitrate leaching. Four ceramic cups were installed at 1 m depth in each plot to obtain samples of the soil solution as described by Lord and Shepherd [18]. Samples were collected at 14 day intervals during the main drainage season (September to April). A vacuum of 40 KpA was applied to the cups using a hand pump 24 h before each sampling occasion. Samples were then drawn into a flask using the hand pump and poured into labelled plastic vials. Samples were analysed for total oxidised nitrogen (TON) and nitrite N (NO₂-N); the nitrate (NO₃-N) concentration was calculated by subtracting the NO₂-N from TON. Mean NO₃-N concentration was calculated from the four samples in each plot at each sampling interval with the values for each treatment summed to obtain cumulative NO₃-N leaching levels. Estimated NO₃-N leaching loads were calculated using the following equation as described by Lord and Shepherd [18], with effective rainfall calculated using the soil moisture deficit (SMD) model [19]:

$$\text{Load (kg} \cdot \text{ha}^{-1}) = \text{Median concentration (mg} \cdot \text{L}^{-1}) \times \text{Effective rainfall (mm)} \times 0.01$$

The results are broken down into two periods, period 1 (P1) which recorded NO₃-N leaching levels over the first winter post establishment (September 2008-April 2009) and period two (P2) which recorded the second winter post establishment (September 2009-April 2010).

2.2. Statistical Analysis

All statistical analysis was carried out using SAS [20]. All pasture measurements were investigated using analysis of variance (ANOVA) using the general linear model procedure (Proc GLM). The following model was used:

$$y = B_i + T_j + e_{ij}$$

where B = Block ($i = 1$ to 3), T = Treatment ($j = i$ to vi) and e = residual error term.

Variables investigated included total DM yield, seasonal DM yield, sward tiller density and nitrate leaching concentrations.

3. Results

3.1. Climatic Conditions

The mean daily temperature and monthly rainfall amounts at Moorepark over the years 2008, 2009, 2010 and spring 2011 are presented in **Table 1**. Overall, daily rainfall amounts were similar to the 15 year average in 2008 (+1%), higher in 2009 (+24%) but below average in 2010 (−17%). Mean daily temperature was below average in 2008 (−0.2°C), 2009 (−0.4°C) and 2010 (−1.3°C). Rainfall amounts for spring 2011 (February to April) were 62% below normal with average daily temperature 0.5°C above normal.

3.2. Autumn Reseed

There was no significant effect of renewal method on the total DM yield of the autumn sown swards in 2009 (first full year's production, **Table 2**). Total DM yield in 2010 (second full years production) was affected ($P < 0.01$) by establishment method with all reseeded swards yielding ($P < 0.01$) more compared to the control. The DD treatment produced a similar grass DM yield when compared to DPH (13,352 kg DM/ha) but yielded more ($P < 0.01$) than all other treatments. The DPH, PH and PLO treatments had a similar DM yield (12,476 kg DM/ha) but were higher than the control (10,339 kg DM/ha). There was a significant effect ($P < 0.01$) of establishment method on spring DM yield in 2009 with the DD and PLO treatments having lower yields (−457 and

Table 1. Average daily temperature (°C) and monthly rainfall (mm) at the Moorepark site for the years 2008, 2009, 2010 and 2011 compared to the 15 year average.

	Month											
	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Total Monthly rainfall (mm)												
2008	145	42	111	38	51	94	135	118	90	113	65	50
2009	194	16	56	107	89	52	154	117	41	127	260	83
2010	107	39	88	59	38	53	143	23	102	83	98	37
2011	57	92	28	26	na	na	na	na	na	na	na	na
15 yr Avg.	111	67	80	69	67	68	73	95	83	119	119	95
Mean daily temp. (°C)												
2008	6.8	6.0	6.1	7.9	12.8	13.6	15.1	15.4	12.4	9.2	8.0	5.3
2009	4.5	5.1	7.1	8.9	11.0	14.6	14.8	14.9	12.9	11.8	7.8	3.2
2010	2.2	3.0	5.4	8.5	10.9	15.4	15.8	14.3	13.6	9.9	5.4	0.6
2011	3.4	7.1	6.4	10.7	na	na	na	na	na	na	na	na
15 yr Avg.	5.5	5.7	7.1	8.8	11.4	13.9	15.5	15.5	13.7	10.7	7.6	5.6

15 yr Avg. = fifteen year average 1996-2010, na = not applicable.

Table 2. Effect of reseeding method on swards sown in Autumn 2008 on DM yield (kg DM/ha) and tiller density/m² in 2009, 2010 and 2011.

Treatment	Control (C)	Direct Drill (DD)	Disc (DPH)	P. Harrow (PH)	Plough (PLO)	SED	Sig
Total DM yield '09	10,368	11,134	12,144	11,820	10,205	1103.1	NS
Total DM yield '10	10,339 ^a	13,568 ^b	13,135 ^{bc}	12,082 ^c	12,211 ^c	552.8	P < 0.01
Spr. DM yield '09	1881 ^a	1424 ^b	1808 ^a	1743 ^a	1313 ^b	103.7	P < 0.01
Spr. DM yield '10	1336	2204	1924	2038	2004	349.1	NS
Spr. DM yield '11	1640 ^a	1679 ^a	1608 ^a	1919 ^b	1821 ^{ab}	96.8	P = 0.05
Sum. DM yield '09	5236	6012	6481	6141	5901	630.0	NS
Sum. DM yield '10	5597 ^a	6960 ^b	6849 ^b	6060 ^a	6390 ^{ab}	397.1	P < 0.05
Aut. DM yield '08	1902 ^a	242 ^b	393 ^b	486 ^b	358 ^b	229.2	P < 0.001
Aut. DM yield '09	3251	3699	3855	3935	2990	487.5	NS
Aut. DM yield '10	3407	4404	4362	3984	3816	361.2	NS
PRG tillers/m ² '09	2667 ^a	5492 ^b	4892 ^b	5267 ^b	5275 ^b	547.7	P < 0.01
PRG tillers/m ² '10	3650 ^a	5575 ^b	5150 ^b	5850 ^b	5925 ^b	518.1	P < 0.05
Total tillers/m ² '09	6650	6542	5517	5975	5742	673.9	NS
Total tillers/m ² '10	5425 ^a	6075 ^a	6025 ^a	7400 ^b	6525 ^a	356.5	P < 0.01

SED = Standard error of the difference; PRG = Perennial ryegrass; Spr. = Spring; Sum. = Summer; Aut. = Autumn; ^{abc} values not sharing a common superscript are significantly different from each other.

–568 kg DM ha⁻¹, respectively) than the control (1881 kg DM ha⁻¹) which was not different to DPH or PH (1776 kg DM ha⁻¹). There was no effect of reseeding method on spring DM yield in 2010, however the PH treatment was higher yielding in spring 2011 (+277 kg DM ha⁻¹) relative to C, DD, and DPH (1642 kg DM ha⁻¹). Summer DM yield was not significantly different between treatments in 2009 but was affected by establishment method in 2010 with the DD (+1363 kg DM ha⁻¹) and DPH (+1252 kg DM ha⁻¹) treatments having higher (P < 0.05) yields compared to the control (5597 kg DM ha⁻¹) while the PLO treatment produced a similar quantity of grass to DD and DPH. Sward DM production following establishment in autumn 2008 was affected (P < 0.001) as all reseeded swards were lower yielding than the control. There was no effect of establishment method on autumn DM yield in 2009 or 2010.

Perennial ryegrass tiller density was affected by treatment at the end of 2009 (P < 0.01) and 2010 (P < 0.05) with all reseeded swards having a higher PRG tiller density. Total tiller density was unaffected by treatment in 2009 but was affected in 2010 with the PH treatment having a higher total tiller density (P < 0.01, +1975 tillers m⁻²) than all other treatments.

3.3. Spring Reseed

For the spring sown swards, total DM yield in 2009 (year of establishment) was not significantly affected by treatment (**Table 3**). Total DM yield in 2010 (first full years production) approached significance (P = 0.08) with proportionate increases of 0.13, 0.26, 0.20, 0.27 and 0.16 for the DD, DPH, PH, PLO and DIQ treatments respectively, compared to the control. Spring DM yield in 2010 was not affected by treatment. Spring DM yield in 2011 was affected by treatment with all reseeding treatments having a higher (P < 0.01) DM yield compared to the control.

Summer DM yield in 2009 did not differ between the C, DPH, PH and DIQ treatments. The DD and PLO treatments had significantly (P < 0.05) lower DM yields than the C and DPH treatments (6299 kg DM/ha) but were similar to PH and DIQ (5692 kg DM/ha). Neither autumn DM yield in 2009 nor summer DM yield in 2010 were affected by treatment. Autumn DM yield in 2010 was different with DPH (+903 kg DM ha⁻¹), PH (+868 kg DM ha⁻¹) and PLO (+991 kg DM ha⁻¹) treatments having greater (P < 0.05) yields than the control (3281 kg DM ha⁻¹).

Perennial ryegrass tiller density was affected by treatment in 2009 and 2010 (P < 0.001). In 2009, the PLO and DD treatments had the highest PRG tiller densities, averaging 0.87 of the total tiller density, followed by the

Table 3. Effect of reseeding method on swards sown in Spring 2009 on DM yield (kg DM/ha) and tiller density/m² in 2009, 2010 and 2011.

Treatment	Control (C)	Direct Drill (DD)	Disc (DPH)	P. Harrow (PH)	Plough (PLO)	Diquat (DIQ)	SED	Sig
Total DM yield '09	9781	9233	10,395	10,191	8949	9567	512.7	NS
Total DM yield '10	10,001	11,308	12,586	12,040	12,674	11,564	844.2	P = 0.08
Spr. DM yield '10	1740	1945	2299	2278	2444	1613	305.4	NS
Spr. DM yield '11	1328 ^a	2166 ^b	2016 ^b	1990 ^b	1949 ^b	1908 ^b	155.0	P < 0.01
Sum. DM yield '09	6286 ^a	5211 ^b	6311 ^a	5875 ^{ab}	5186 ^b	5509 ^{ab}	382.8	P < 0.05
Sum. DM yield '10	4980	5631	6103	5613	5958	6118	415.3	NS
Aut. DM yield '09	1616	2142	2205	2437	1883	2179	340.1	NS
Aut. DM yield '10	3281 ^a	3733 ^{ab}	4184 ^b	4149 ^b	4272 ^b	3833 ^a	283.1	P < 0.05
PRG tillers/m ² '09	1450 ^a	5150 ^b	3550 ^c	3600 ^c	5250 ^b	2300 ^a	412.8	P < 0.001
PRG tillers/m ² '10	1050 ^a	4700 ^b	5500 ^c	5550 ^c	4700 ^b	3950 ^d	269.3	P < 0.001
Total tillers/m ² '09	6400 ^a	6350 ^a	5250 ^b	6800 ^a	5700 ^b	6700 ^a	287.5	P < 0.001
Total tillers/m ² '10	8300	6000	6850	7550	6650	6900	880.4	NS

SED = Standard error of the difference; PRG = Perennial ryegrass; Spr. = Spring; Sum. = Summer; Aut. = Autumn; ^{abc}values not sharing a common superscript are significantly different from each other.

DPH and PH treatments at 0.61, which were all higher than the control (0.23). There was no difference between the control and the DIQ treatment (0.34). In 2010, the PH and DPH treatments had the highest PRG tiller densities at 0.77 of the sward, followed by the DD and PLO treatments (0.75) with the DIQ treatment having the lowest PRG tiller density (0.57) of the renewed swards although still higher ($P < 0.001$) than the control (0.13). Total tiller density in 2009 was lower for the DPH (-1150 tillers m^{-2}) and PLO (-700 tillers m^{-2}) treatments ($P < 0.001$) relative to the control however, there was no significant difference in total tiller number in 2010.

3.4. Nitrate Leaching

On average all reseeded swards had lower quantities of NO₃-N leached (53.7 kg N leached ha⁻¹) compared to the control (75.7 kg N leached ha⁻¹) in P1, although differences failed to reach significance (**Figure 1**). In P2, the effect of treatment approached significance ($P = 0.09$) with the PH treatment leaching 0.43 more NO₃-N per hectare on a proportionate basis compared to the average of the other treatments including the control (46.6 kg N leached ha⁻¹). With the exception of the DD treatment all reseeded swards had a higher NO₃-N leaching than the control in P2.

4. Discussion

Currently, regardless of system or enterprise, grazed grass is the largest proportional constituent of the ruminant feed budget [21]-[23]. Increasing the period of time during which grass can be harvested by the grazing animal (*i.e.* extending the grazing season) has been shown in a number of studies to reduce costs of production while at the same time increasing output per hectare [24]. The financial impact of grass DM yield fluctuates across the season and is influenced by feed supply and herd demand [25]. Feed demand generally exceeds supply for Irish grass-based ruminant production systems in spring and autumn, whereas grass supply generally exceeds feed demand during the main grazing season, but the extent depends on stocking rate. Each additional kilogram of herbage produced in spring and autumn has a greater economic impact on a grazing system than a similar increase during the mid-season [26].

4.1. Timing of Reseeding

A survey by Creighton *et al.* [4] found that up to 70% of Irish grassland dairy farmers choose to reseed pastures in autumn. This makes sense from a feed budget perspective but it does have some negative consequences. Variable weather conditions can have a negative effect on sward establishment, resulting in reseeded swards not

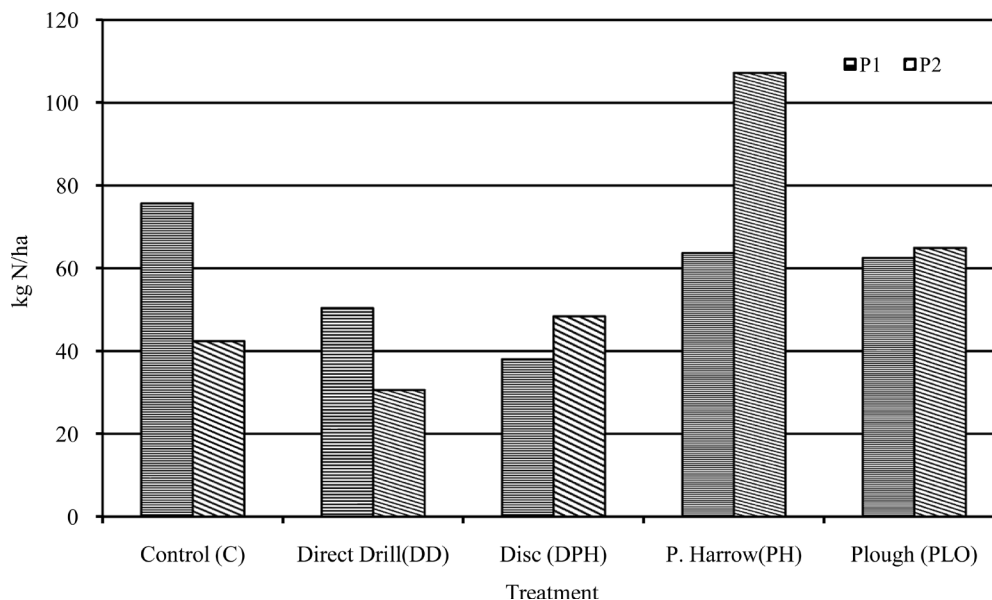


Figure 1. Effect of reseeding method for swards sown in Autumn 2008 on N loads lost to a depth of 1 m (kg N/ha) during the first (P1) and second (P2) Winter post establishment. P1 = September 2008–April 2009; P2 = September 2009–April 2010.

being as productive as they potentially could be. In the current study mean autumn DM yield of the RA plots on a proportionate basis was 0.81 lower than the control. It is clear from the recorded met data that both rainfall and temperature can deviate dramatically from the norm during the autumn/winter months which are critical for sward establishment with an autumn reseeded pasture. The effect of late autumn sowing on subsequent sward establishment and DM production was investigated by Culleton *et al.* [27]. The results suggested that tiller number and DM production of late-autumn sown swards were significantly reduced compared to earlier-sown swards. The authors found that by delaying autumn reseeding by a month from early September to early October, reduced spring DM yield by 50%. Reseeding in the spring has advantages over the autumn due to better growth conditions compared to the autumn [15]. The results of this study concur with that theory as the DM yields observed in the spring trial show that there was no loss of production in the establishment year. Timing of reseeding is a management based decision; Blackmore [28] and Thom *et al.* [29] made a case for spring sowing in colder regions or when slow seedling growth species such as tall fescue and white clover are part of the sward.

4.2. DM Yield (Seasonal and Overall)

Shalloo *et al.* [30] demonstrated that increasing the level of reseeding had a positive effect on farm profitability through an increase in total and seasonal herbage production and, when accompanied with an increased stocking rate, increased herbage utilisation. The greatest gain in terms of DM yield will be achieved when the new sward is replacing a sward with low perennial ryegrass content and a high proportion of weeds and hence poor production potential. This study shows that the old permanent pasture control swards had a far lesser proportion of perennial ryegrass tillers than the newly reseeded swards which impacted on seasonal and total DM production. Nationally reseeding levels on farms in Ireland are low (2% annually). The Food Harvest 2020 Report [31] developed by the Irish government sets out ambitious targets for increasing animal production, especially in the dairy sector with much of this increase driven by utilising more grazed grass. It is clear that reseeded swards will allow higher grass production to be realised as after the initial year of establishment both the autumn and spring reseeded pastures had a higher grass DM production than the control plots.

A recurring issue with reseeding and the assessment of DM yield benefits associated with it is the level of production lost in the year of renewal. Conijn [8] and Hopkins *et al.* [9] concluded that the production increase following reseeding is at best more or less equal to the production loss in the year of renewal. This was not totally obvious in this study. Irrespective of timing of reseeding, the swards required time allow perennial ryegrass hierarchy to establish and then the advantage to reseeding became apparent. Charles [32] showed that competi-

tion between grass plants can result in as little as 0.20 seedling survival two months after sowing and as few as 0.10 after twelve months, and that the competition for space was likely to be completed in two years.

The current study shows the benefits of reseeding with improved spring and autumn (spring trial only) growth relative to the controls (old permanent pasture). In the autumn sown swards spring DM yield was increased by 0.52 in the second spring post establishment, with a difference of 0.07 the following spring; however this was a historically cold spring for grass production. For the spring reseed, spring DM yield for the reseeded swards was 0.22 and 0.52 higher in year one and two, post cultivation. The increase in perennial ryegrass content and spring DM yield demonstrates that reseeding can increase grass production at the shoulders of the year, which has been shown to have a positive contribution to farm profits by reducing the requirement for conserved and concentrate feeds. McCarthy [33] reported that reseeded swards generally out yielded old permanent pasture in silage swards by 0.21 (1180 kg DM ha⁻¹) but the DM yield differential disappeared at the second cut. In general this author found reseeded swards to yield 0.12 more grass DM for conservation systems. The harvested yield from the control plots in this study was greater than that reported by Shalloo *et al.*, [30]. The DM yield from the reseeded plots is similar to that on plots intensively grazed in a study by Wims *et al.*, [34]. If plots had been subjected to a conservation management strategy, greater DM yield would have been expected [35].

4.3. Reseeding Method

The objectives of traditional cultivation and tillage methods (ploughing, discing, and levelling) are to obtain a fine, firm competition free seedbed [29] [36] [37]. The conventional plough, till and sow method of grassland reseeding is generally accepted as the most consistent and reliable method of seedbed preparation and sowing but it does have its disadvantages including loss of soil moisture, and the risk of damage to soil structure [11]. The main aim of this study was to evaluate alternative grassland reseeding methods in terms of their effect on DM production potential and perennial ryegrass tiller density. While all having different modes of action, each of the full sward renewal methods evaluated performed satisfactorily. While the DD and PLO treatments were slower to establish in both the autumn (lower spring 2009 DM yields) and spring sown trials (lower summer 2009 DM yields) both increased their contribution to established swards. The DD treatment was the highest yielding of the autumn sown treatments in 2010 with the PLO swards showing the highest proportional increase in total DM yield in 2010 compared to the control in the spring sown trial.

Bartholomew *et al.* [38] concluded from a comparison of cultivation methods for the establishment of perennial ryegrass, that there was no significant difference in DM yield due to establishment method over the 2.5 year trial.

All reseeding methods significantly increased the perennial ryegrass tiller density of the sward compared to the old permanent pasture. It can be concluded that all sward renewal methods evaluated are equally as effective as the conventional method of grassland reseeding. The DIQ rejuvenation method evaluated in the spring trial demonstrated encouraging results in terms of DM yield and sward PRG tiller density. Where DD is used to complement rather than replace an existing crop, there is usually a gain in annual forage output and an improvement in seasonal distribution of production [12]. The perennial ryegrass content of the sward increased from 0.23 in 2009 to 0.57 in 2010 compared to the control which is similar to a study by Stafford *et al.*, [39], where over-sowing old permanent pasture with perennial ryegrass following the application of the herbicide paraquat (*N,N'*-dimethyl-4,4'-bipyridinium dichloride, Syngenta) to suppress the existing sward increased the sward perennial ryegrass content to 0.55 from 0.33. Further investigation of this partial rejuvenation alternative in terms of persistence and economic impact would seem warranted based on these results.

4.4. Nitrate Leaching

The results of this study show no significant differences in the level of NO₃-N lost in leachate following reseeding regardless of method used or indeed any difference between reseeded swards and old permanent pasture. This finding is similar to that of Lloyd [17] who found similar N losses from shallow cultivation and ploughing of grassland. Although not significantly different, the higher levels of leaching observed in 2010 in the PH treatment do contradict the common view that deep ploughing causes the greatest increase in the level of N leaching when reseeding. Seidel *et al.* [16] however observed similar results to the current study having higher N losses in direct drilled swards compared to rotary cultivation. The level of NO₃-N leaching that occurred in the current study is similar to that in a study carried out by Scholefield *et al.* [40], where they observed NO₃-N

leaching levels of 38 kg N ha⁻¹ as NO₃-N from old permanent pastures receiving 200 kg N ha⁻¹. While there was no significant difference in the level of NO₃-N being leached from the different swards there was a significant difference in the total DM yield potential of the swards. This would support the view that reseeded swards are more nutrient efficient. Previous studies have reported a high level of NO₃-N losses from autumn reseeded swards compared to non-reseeded (control) swards during the first winter of establishment [15]. In general, this effect was only significant in the first winter and not the second winter after reseeding according to Shepherd *et al.* [14]. They concluded that the effect of ploughing grassland for reseeding is relatively short term in contrast to the effect of repeated cultivation in arable rotations. The results observed in the current study are somewhat different in that the level of NO₃-N leaching did not significantly decrease in the second winter (Figure 1). A possible reason for this may be the exceptionally wet conditions observed in winter 2009. As a whole rainfall amounts at this site were 24% above the 15 year average in 2009. The risks of increased NO₃-N leaching from the soil are highest when the increase of soil mineral N contents occurs during periods of wet conditions [14]-[16] [41].

5. Conclusion

Reseeding old permanent pasture increased sward DM production, both seasonally and annually compared to old permanent pasture. There was no total annual DM production loss observed in the year of establishment in the spring trial; in contrast to the autumn trial. Spring reseeding offers advantages in terms of minimising the production losses associated with reseeding swards. Irrespective of reseeding timing, DM yield in the first full year of production for autumn reseeds and the year of establishment for spring reseeds, is similar to that of the existing sward with the real advantages of reseeding in terms of sward DM yield becoming evident during the second full year's production. There was no effect of reseeding method on NO₃-N leaching, and no significant difference in the NO₃-N leaching between reseeded swards and old permanent pasture. Based on the fact that the reseeded swards were significantly more productive compared to the old sward post establishment it is possible that they were also more nutrient efficient.

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References

- [1] Rath, M. and Peel, S. (2005) Grassland in Ireland and the UK. In: McGilloy, D.A., Ed., *Grassland: A Global Resource, XX International Grassland Congress*, Wageningen Academic Publishers, Dublin, 13-27.
- [2] DAFF—Department of Agriculture Fisheries and Food (2011) Grass and Clover, Recommended List Varieties for Ireland 2011. Department of Agriculture Fisheries and Food, Maynooth.
- [3] Humphreys, J. and Casey, I.A. (2002) Grassland Renovation in Ireland. In: Conijn, J.G., Velthof, G.L. and Taube, F., Eds., *Grassland Resowing and Grass-Arable Rotations, Proceedings of European Grassland Federation International Workshop Agricultural and Environmental Issues*, Wageningen, 18-19 April 2002, 79-91.
- [4] Creighton, P., Kennedy, E., Shalloo, L., Boland, T.M. and O' Donovan, M. (2011) A Survey Analysis of Grassland Dairy Farming in Ireland, Investigating Grassland Management, Technology Adoption and Sward Renewal. *Grass and Forage Science*, **66**, 251-264. <http://dx.doi.org/10.1111/j.1365-2494.2011.00784.x>
- [5] Sheldrick, R.D., Lavender, R.H. and Martyn, T.M. (1990) Dry Matter Yield and Response to Nitrogen of an *Agrostis-stolonifera*-Dominant Sward. *Grass and Forage Science*, **45**, 203-213. <http://dx.doi.org/10.1111/j.1365-2494.1990.tb02200.x>
- [6] Doyle, C.J. and Wilkins, R.J. (1984) Grassland Yield: Realising the Potential. In: Corral, A.J., Ed., *Money from Grass, Occasional Symposium 15*, British Grassland Society, Hurley.
- [7] Lawson, A.R. and Kelly, K.B. (2007) Responses to the Renovation of an Irrigated Perennial Pasture in Northern Victoria. 1. Pasture Consumption and Nutritive Characteristics. *Australian Journal of Experimental Agriculture*, **47**, 149-158. <http://dx.doi.org/10.1071/EA05258>
- [8] Conijn, J.G. (2004) Crop and Animal Performance In: Conijn, J.G. and Taube, F., Eds., *Grassland Resowing and*

Grass-Arable Crop Rotations Consequences for Performance and Environment, Plant Research International, Wageningen, Report 80, 48-65.

- [9] Hopkins, A., Gilbey, J., Dibb, C., Bowling, P.J. and Murray, P.J. (1990) Response of Permanent and Reseeded Grassland to Fertilizer Nitrogen. 1. Herbage Production and Herbage Quality. *Grass and Forage Science*, **45**, 43-55. <http://dx.doi.org/10.1111/j.1365-2494.1990.tb02181.x>
- [10] Thom, E.R., Fraser, T.J. and Hume, D.E. (2011) Sowing Methods for Successful Pasture Establishment—A Review. *Pasture Persistence-Grassland Research and Practice Series*, **15**, 31-38.
- [11] Naylor, R.E.L., Marshall, A.H. and Matthews, S. (1983) Seed Establishment in Directly Drilled Sowings. *Herbage Abstracts*, **53**, 73-91.
- [12] Bartholomew, P.W. (2005) Comparison of Conventional and Minimal Tillage for Low-Inputpasture Improvement. <http://www.plantmanagementnetwork.org/pub/fg/review/2005/minimal/>
- [13] Davies, M.G., Smith, K.A. and Vinten, A.J.A. (2001) The Mineralisation and Fate of Nitrogen Following Ploughing of Grass and Grass-Clover Swards. *Biology and Fertility of Soils*, **33**, 423-434. <http://dx.doi.org/10.1007/s003740100348>
- [14] Shepherd, M.A., Hatch, D.A., Jarvis, S.C. and Bhogal, A. (2001) Nitrate Leaching from Reseeded Pasture. *Soil Use Management*, **17**, 97-105. <http://dx.doi.org/10.1111/j.1475-2743.2001.tb00014.x>
- [15] Velthof, G., Hoving, I.E. and Dolfin J. (2009) Method and Timing of Grassland Renovation Affects Herbage Yield, Nitrate Leaching, and Nitrous Oxide Emission in Intensively Managed Grasslands. *Nutrient Cycling in Agroecosystems*, **86**, 401-412. <http://dx.doi.org/10.1007/s10705-009-9302-7>
- [16] Seidel, K., Kayser, M. and Muller, J. (2009) The Effect of Grassland Renovation on Soil Mineral Nitrogen and on Nitrate Leaching during Winter. *Journal of Plant Nutrition and Soil Science*, **172**, 512-519. <http://dx.doi.org/10.1002/jpln.200800217>
- [17] Lloyd, A. (1992) Nitrate Leaching under Arable Land Ploughed out from Grass. *Proceedings Fertiliser Society*, **330**, 32.
- [18] Lord, E.I. and Shepherd, M.A. (1993) Developments in the Use of Porous Ceramic Cups for Measuring Nitrate Leaching. *Journal of Soil Science*, **44**, 435-449. <http://dx.doi.org/10.1111/j.1365-2389.1993.tb00466.x>
- [19] Schulte, R.P.O., Diamond, J., Finkle, K., Holden, N.M. and Brereton, A.J. (2005) Predicting the Soil Moisture Conditions of Irish Grasslands. *Irish Journal of Agricultural and Food Research*, **44**, 95-110.
- [20] SAS Institute (2002) Users Guide: Statistics. SAS Inst., Cary.
- [21] Kennedy, E., O'Donovan, M., Murphy, J.P., O'Mara, F. and Delaby, L. (2007) The Effect of Initial Spring Grazing Date and Subsequent Stocking Rate on the Grazing Management, Grass Dry Matter Intake and Milk Production of Dairy Cows in Summer. *Grass and Forage Science*, **61**, 375-384. <http://dx.doi.org/10.1111/j.1365-2494.2006.00544.x>
- [22] Drennan, M.J. and McGee, M. (2009) Performance of Spring-Calving Beef Suckler Cows and Their Progeny to Slaughter on Intensive and Extensive Grassland Management Systems. *Livestock Science*, **120**, 1-12. <http://dx.doi.org/10.1016/j.livsci.2008.04.013>
- [23] Keady, T., Hanrahan, J.P. and Flanagan, S. (2009) An Evaluation of Two Grassland Based Systems of Mid Season Prime Lamb Production Using Prolific Ewes of Two Genotypes. *Irish Journal of Agricultural and Food Research*, **48**, 87-101.
- [24] O'Donovan, M., Lewis, E., Boland, T. and O'Kiely, P. (2010) Requirements of Future Grass Based Ruminant Yield Systems in Ireland. *Proceedings of Grasses for the Future International Conference*, Teagasc IE, Cork, 11-41.
- [25] Doyle, C.J. and Elliot, J.G. (1983) Putting an Economic Value on Increases in Grass Yield. *Grass and Forage Science*, **38**, 169-177. <http://dx.doi.org/10.1111/j.1365-2494.1983.tb01635.x>
- [26] McEvoy, M., O'Donovan, M. and Shalloo, L. (2011) The Development and Application of an Economic Ranking Index for Grass Varieties. *Journal of Dairy Science*, **94**, 1627-1639. <http://dx.doi.org/10.3168/jds.2010-3322>
- [27] Culleton, N., Murphy, W.E. and McGilloway, D. (1992) A Note on the Effects of Date of Autumn Sowing on Establishment of *Lolium perenne* L. *Irish Journal of Agricultural and Food Research*, **31**, 185-187.
- [28] Blackmore, L.W. (1955) The Overdrilling of Pastures. *Proceedings of the New Zealand Grassland Association*, **17**, 139-148.
- [29] Thom, E.R. Thomson, N.A. and Clayton, D.G. (1985) Establishment and Management of Suitable Species in Dairy Pastures. *Grassland Research and Practice Series*, **3**, 71-75.
- [30] Shalloo, L., Creighton, P. and O'Donovan, M. (2010) Reseeding. A Cost or an Opportunity. *Proceedings of Grasses for the Future International Conference*, Teagasc IE, Cork, 139-151.
- [31] DAFF. Department of Agriculture Fisheries and Food (2010) Food Harvest 2020—A Vision for IRISH Agri-Food and Fisheries. Department of Agriculture, Fisheries and Food, Dublin.

- [32] Charles, A.H. (1961) Differential Survival of Cultivars of *Lolium*, *Dactylis* and *Phleum*. *Journal of the British Grassland Society*, **16**, 69-75. <http://dx.doi.org/10.1111/j.1365-2494.1961.tb00214.x>
- [33] McCarthy, D. (1984) Milk Production from Grassland. In: *Moorepark 25th Anniversary Publication. Part 1, Milk Production*, AFT Publication, 11-66.
- [34] Wims, C., McEvoy, M., Boland, T.M and O'Donovan, M. (2010) A Comparison between Cut and Intensively Grazed Swards on Dry Matter Yield of Perennial Ryegrass. EGF, Kiel, Germany. *Grassland Science in Europe*, **15**, 578-580.
- [35] Wilkins, P.W. and Lovatt, J.A. (2010) Gains in Dry Matter Yield and Herbage Quality from Breeding Perennial Ryegrass. *Proceedings of Grasses for the Future International Conference*, Teagasc IE, Cork, 43-50.
- [36] Tripplett, G.B. and VanDoren, D.M. (1977) Agriculture without Tillage. *Scientific American*, **236**, 28-35. <http://dx.doi.org/10.1038/scientificamerican0177-28>
- [37] Hume, D.E. and Fraser, T.J. (1985) Establishing and Managing Recent Cultivars in Arable Dryland Pastures. *Grassland research and Practice Series*, **3**, 45-50.
- [38] Bartholomew, P.W. Easson, D.L. and Chesnut, D.M.B. (1981) A Comparison of Methods of Establishing Perennial and Italian Ryegrasses. *Grass and Forage Science*, **36**, 75-80. <http://dx.doi.org/10.1111/j.1365-2494.1981.tb01542.x>
- [39] Stafford, L.T., O'Donovan, S.F. and Raferty, T.F. (1978) The "Stitching in" Technique for Pasture Renovation. *Irish Journal of Agricultural Research*, **17**, 283-294.
- [40] Scholefield, D., Tyson, K.C., Garwood, E.A., Armstrong, A.C., Hawkins, J. and Stone, A. C. (1993) Nitrate Leaching from Grazed Grassland Lysimeters: Effects of Fertilizer Input, Field Drainage, Age of Sward and Patterns of Weather. *Journal of Soil Science*, **44**, 601-613. <http://dx.doi.org/10.1111/j.1365-2389.1993.tb02325.x>
- [41] Djurhuus, J. and Olsen, P. (1997) Nitrate Leaching after Cut Grass/Clover Leys as Affected by Time of Ploughing. *Soil Use and Management*, **13**, 61-67. <http://dx.doi.org/10.1111/j.1475-2743.1997.tb00558.x>