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# Comparison of herbage yield, nutritive value and ensilability traits of three ryegrass species evaluated for the Irish Recommended List

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**Abstract**

**This study examined 169 of the newest varieties of three ryegrass species, perennial (*Lolium perenne* L.), Italian (*Lolium multiflorum* Lam.) and hybrid (*Lolium boucheanum* Kunth), from Recommended List trials in Ireland. The traits examined were yield, dry matter concentration, three nutritive value traits (*in vitro* dry matter digestibility, water-soluble carbohydrate on a dry matter basis and crude protein concentration) and two ensilability traits (buffering capacity and water soluble carbohydrate concentration on an aqueous phase basis). Varietal monocultures of each species underwent a six cut combined simulated grazing and silage management in each of two years following sowing. Perennial ryegrass yielded less than both other species in one-year-old swards, but less than only Italian ryegrass in two-year-old swards, but generally had the higher *in vitro* dry matter digestibility and crude protein values. Italian ryegrass displayed the most favourable ensilability characteristics of the three species with perennial ryegrass less favourable and hybrid ryegrass intermediate. Overall, despite the high yields and favourable nutritive value and ensilability traits recorded, the general differences between the three ryegrass species studied were in line with industry expectations. These findings justify assessing the nutritive value and ensilability of ryegrass species, in addition to yield, to allow farmers select species that match farming enterprise requirements.**

**Keywords**

*Lolium • ryegrass • quality • ensilability • chemical composition*

## Introduction

Recommended List trials for ryegrasses seek to identify varieties that are suited for ruminant grass -based production systems under local climatic and soil conditions. Within the 'Grass and Clover Recommended List Varieties for Ireland' (DAFM, 2013), three ryegrass species are evaluated: perennial ryegrass (*Lolium perenne* L.), Italian ryegrass (*Lolium multiflorum* Lam.) and hybrid ryegrass (*Lolium boucheanum* Kunth). Perennial ryegrass accounts for approximately 0.95 of agricultural grass species seed sold in Ireland (Department of Agriculture, Food and the Marine, personal communication) and for 0.78–0.86 in Northern Ireland (Gilliland *et al.* 2007). Italian and hybrid ryegrasses account for the majority of the remaining seed sold.

Although yield potential remains a priority for breeders, in recent years, breeding and testing objectives have shifted, with an increased emphasis on grass quality traits (Weddell *et al.* 1997 compared to Grogan and Gilliland 2011). In Ireland, grass is the major feed component of ruminant-based production systems and its quality characteristics influence animal productivity (Casler 2000), nitrogen use efficiency (Evans *et al.* 2011) and forage conservation (Burns *et al.* 2013; Buxton and O'Kiely 2003). Therefore, the inclusion of herbage quality traits in Recommended List trials can provide estimates of the nutritive value and ensilability. Burns *et al.* (2013) proposed *in vitro* dry matter digestibility (DMD), water-soluble carbohydrate (WSC) concentration (dry matter (DM) basis; $WSC_{DM}$) and crude protein (CP) concentration as indices of nutritive quality and dry matter (DM), buffering capacity and water soluble carbohydrate concentration (aqueous phase basis; $WSC_{AQ}$) as indices of ensilability.

Although the yield potential hierarchy of 'Italian greater than hybrid greater than perennial ryegrass' is well established (Camlin 1997), much of this information is based on historical trials, including the work of George Stapledon in the early 1930s comparing perennial ryegrass varieties S23 and S24 with the Italian ryegrass variety S22. Modern breeding techniques have enabled the hybridisation of these species, combining the complementary characteristics of early growth of Italian ryegrass with the higher persistence of perennial ryegrass (Thomas & Humphreys 1991) and, in addition,

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further genetic gain has been progressed in each of the parent species (Wilkins and Humphreys 2003). Furthermore, the most recent research comparing the quality traits of ryegrass species have often been limited to a single or small number of varieties (Wilman *et al.* 1996; Gilliland and Mann, 2001; Kemešytė and Lemežienė 2010), and it can sometimes be unclear if the outcomes recorded reflect variety or species effects.

Thus there is a knowledge gap regarding whether the long established differentials in yield and quality between these species has shifted in recent years. In addition, the absence of information on grass ensilability traits is a weakness in Recommend List trails (Conaghan *et al.* 2008).

The study used the Recommended List trials for Ireland as source material. A large numbers of new candidate varieties were assessed, which both minimised the risk of any unique variety-specific trends and also provided an updated comparison of the yield, nutritive quality and ensilability of species based on the most recent breeding achievements in these species. Uniquely, this study compared the three ryegrass species across simulated season-long grazing and silage managements and repeated this comparison over several seasons. Furthermore, it included both nutritive value and ensilability traits as identified by Burns *et al*. (2013), in addition to DM yield.

The objective of this research was to compare the yield, DM concentration, three herbage nutritive value traits and two ensilability traits using varieties of the three ryegrass species grown between 2001 and 2008.

## Materials and Methods

Field plots were at the Grass and Clover Variety Evaluation Centre, Backweston, Co. Kildare (53° 26’ N, 06° 30’ W; 50 m above sea level), on a medium loam soil of pH 7.2 and 63 g organic matter kg (Grogan and Gilliland 2011). This research was carried out on herbage taken from plots in the Irish grass and clover Recommended List trials and, as such, were managed under a standard protocol (Grogan and Gilliland 2011).

Monoculture plots (7.0 m × 1.5 m) of an individual variety were sown in late summer in the year prior to first harvest in a randomised complete block ($n$ = 4) design. Seed was sown at a rate of 31.0 and 41.0 kg/ha for diploid and tetraploid perennial ryegrass varieties, respectively, and at 41.0 and 51.0 kg/ha for diploid and tetraploid plots, respectively, in both Italian and hybrid ryegrass trials.

A total of 868 plots were sown across three sowing years (2001, 2005 and 2007; Table 1) with the 2001 and 2005 sowings harvested in two subsequent years and the 2007 sowing harvested for only one subsequent year (Figure 1). There were a total of 169 unique varieties of which 133, 20 and 16 were perennial ryegrass, Italian ryegrass and hybrid ryegrass, respectively. Of the 133 perennial ryegrass varieties, 72 were diploid varieties and 61 were tetraploid varieties. Not all varieties were present in all sowings, dependent on their stage in the Recommended List evaluation cycle.

In the 2001 and 2005 sowings, Italian ryegrass and hybrid ryegrass were managed in the same trials, whilst in the 2007 sowing, they were managed in adjacent trials. Perennial ryegrass plots were managed in separate adjacent trials for the two maturity groups (intermediate and late heading) with between 19 and 31 varieties in intermediate heading trials and 24 and 33 varieties in the late heading trials. Inorganic nitrogen fertilizer was applied at an annual rate of 350 kg N $ha^{-1}$ in all harvest years except 2006 when 400 kg N $ha^{-1}$ was applied. Nitrogen application was applied initially at a rate of 40 kg N/ha in February followed by 100–110, 90–110, 50–60, 35–45 and 25–35 kg N/ha after harvests 1–5, respectively.

Within each harvest year, plots were harvested to a stubble height of 5 cm using a Haldrup harvester (Haldrup, Logstor,

***Table 1. Total number of ryegrass variety units (n) and harvested plots ($n^1$) for species and sowing year in the first (Year 1) and second (Year 2) after harvest.***

| | | Year 1 | | Year 2 | |
|---|---|---|---|---|---|
| | | n | $n^1$ | n | $n^1$ |
| **Species** | Perennial ryegrass | 170 | 3824 | 107 | 2824 |
| | Italian ryegrass | 28 | 644 | 16 | 412 |
| | Hybrid ryegrass | 19 | 440 | 10 | 256 |
| **Sowing year** | 2001 | 58 | 1392 | 58 | 1392 |
| | 2005 | 75 | 1500 | 75 | 2100 |
| | 2007 | 84 | 2016 | - | - |

***n = number of varieties × sowings (some varieties were sown in more than one year).***

| Year | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
| $S^1$ | I Y1 | I Y2 | | | | | |
| $S^1$ | L Y1 | L Y2 | | | | | |
| $S^1$ | It/Hy Y1 | It/Hy Y2 | | | | | |
| | | | | $S^2$ | I Y1 | I Y2 | |
| | | | | $S^2$ | L Y1 | L Y2 | |
| | | | | $S^2$ | It/Hy Y1 | It/Hy Y2 | |
| | | | | | | $S^3$ | I Y1 |
| | | | | | | $S^3$ | L Y1 |
| | | | | | | $S^3$ | It Y1 |
| | | | | | | $S^3$ | Hy Y1 |

***S, year of sowing; I, intermediate-heading perennial ryegrass trial; L, late-heading perennial ryegrass trial; It, Italian ryegrass trial; Hy, hybrid ryegrass trial; Y1, first harvest year; Y2, second harvest year.***

**Figure 1:** ***Schematic outline of sowing and harvest year schedule of all trials present in the study***

Denmark) on five to seven occasions throughout the growing season under a combined simulated grazing and silage management. The initial harvests taken in early April simulated spring grazing and the timing of the initial harvest was dependent on seasonal growing conditions. Italian and hybrid trials had the earliest harvest date, approximately one week earlier than the intermediate heading perennial ryegrass trial, followed by the late heading trial approximately one week later. The following two harvests simulated silage production practices and were taken at six- and seven-week regrowth intervals, respectively. The final three harvests simulated grazing and were then taken after four-, five- and six-week regrowth intervals. Owing to poor growing conditions, the first harvest in 2006 was not sampled, and in 2007, an additional harvest was taken for all trials at the start of the growing season because of the favourable growing conditions.

A 300 g sample of herbage from each harvested plot was oven dried at 80°C for 16 hours to determine DM concentration, then milled (1-mm pore sieve) and the absorbance spectra (log 1/reflectance) was measured from 400 to 2500 nm at 2 nm intervals using an NIRsystems 6500 or a standardised NIRsystems XDS (Foss UK Ltd., Warrington, UK). The calibration model of Burns *et al.* (2013) was used to assess *in vitro* DMD, $WSC_{DM}$, CP concentration and buffering capacity. $WSC_{AQ}$ (g/L) was calculated as

$$WSC_{DM}/((1000 - DM)/DM))$$

### *Statistical analysis*

The results from the harvests within a year were grouped into the following seasonal periods: Spring – harvests taken up to 17 April; Silage 1 – harvest taken on approximately 22 May; Silage 2 – harvest taken on approximately 10 July; Rest of Year (ROY) – combines three harvests taken on approximately 7 August, 11 September and 23 October. Quality trait values that encompassed several harvests were the average of the individual harvest values each weighted for its individual herbage DM yield.

A restricted maximum likelihood (REML) analysis was used at each seasonal period for DM yield and each nutritive quality trait (Tables 2–6) and at 'Silage 1' and 'Silage 2' for ensilability traits (Tables 7 and 8). There were fixed-effect terms for harvest year, species, maturity and ploidy and random-effect terms for trial, variety within trial and variety within block within trial. Individual terms were added to the full fixed model and then species dropped from the full mixed model to assess the significance. The REML analyses were carried out independently for one-year-old and two-year-old swards. Where a significant effect of species occurred, a student t-test was applied to each paired species combination to assess the significance between paired species combinations.

The ensilability of grass was assessed based on the combination of grass $WSC_{AQ}$ concentration, expressed on an aqueous-phase basis to account for the dilution of fermentable substrate by water, and buffering capacity.

*Table 2. Comparison of three ryegrass species of one-year-old and two-year-old swards for herbage yield (t DM/ha)*

| | Spring | Silage 1 | Silage 2 | ROY | Annual |
|---|---|---|---|---|---|
| **One-year-old sward** | | | | | |
| Perennial ryegrass | 1.63[a] | 5.66[a] | 3.63[a] | 5.67 | 15.94[a] |
| Italian ryegrass | 2.82[b] | 6.70[b] | 5.11[b] | 6.39 | 20.31[b] |
| Hybrid ryegrass | 2.48[b] | 6.72[b] | 5.13[b] | 6.29 | 20.03[b] |
| SED | 0.250 | 0.306 | 0.202 | 0.256 | 0.460 |
| Significance on 2, 9.2 d.f. | P<0.01 | P<0.05 | P<0.001 | N.S. | P<0.001 |
| **Two-year-old sward** | | | | | |
| Perennial ryegrass | 0.57[a] | 5.17 | 3.41 | 3.38 | 12.36[a] |
| Italian ryegrass | 0.93[b] | 5.82 | 3.89 | 4.07 | 15.10[b] |
| Hybrid ryegrass | 0.70[a] | 5.99 | 3.86 | 4.06 | 14.99[b] |
| SED | 0.056 | 0.280 | 0.271 | 0.258 | 0.573 |
| Significance on 2, 12.2 d.f. | P<0.001 | N.S. | N.S. | N.S. | P<0.01 |

***ROY, Rest of Year; S.E.D., mean standard error of difference between paired species comparisons; N.S., not significant. Superscript letters within columns and age of sward indicate significant difference of means.***

*Table 3. Comparison of three ryegrass species of one-year-old and two-year-old swards for dry matter concentration (g/kg)*

| | Spring | Silage 1 | Silage 2 | ROY | Annual |
|---|---|---|---|---|---|
| **One-year-old sward** | | | | | |
| Perennial ryegrass | 218[a] | 162[a] | 189[a] | 198[a] | 184 |
| Italian ryegrass | 180[b] | 200[b] | 215[b] | 218[b] | 211 |
| Hybrid ryegrass | 177[b] | 195[b] | 227[b] | 223[b] | 214 |
| S.E.D.[1] | 12.1 | 10.2 | 8.8 | 7.9 | 7.7 |
| S.E.D.[2] | 12.2 | 10.5 | 9.1 | 8.2 | 7.9 |
| S.E.D.[3] | 4.9 | 4.9 | 5.5 | 5.0 | 4.2 |
| Significance on 2, 9.3 d.f. | P<0.05 | P<0.001 | P<0.001 | P<0.05 | N.S. |
| **Two-year-old sward** | | | | | |
| Perennial ryegrass | 267[a] | 227[a] | 199[ab] | 236[ab] | 223[a] |
| Italian ryegrass | 237[b] | 271[b] | 215[b] | 252[b] | 244[b] |
| Hybrid ryegrass | 244[ab] | 264[b] | 192[a] | 229[a] | 230[ab] |
| S.E.D.[1] | 11.2 | 10.7 | 14.8 | 14.1 | 11.9 |
| S.E.D.[2] | 11.5 | 11.1 | 15.1 | 14.5 | 12.2 |
| S.E.D.[3] | 4.7 | 5.5 | 5.9 | 5.9 | 5.0 |
| Significance on 2, 34.0 d.f. | P<0.05 | P<0.001 | P<0.001 | P<0.001 | P<0.01 |

***ROY, Rest of Year; S.E.D.[1], standard error of difference between perennial ryegrass and Italian ryegrass; S.E.D.[2], standard error of difference between perennial ryegrass and hybrid ryegrass; S.E.D.[3], standard error of difference between Italian ryegrass and hybrid ryegrass; N.S., not significant. Superscript letters within columns and age of sward indicate significant difference of means.***

***Table 4. Comparison of three ryegrass species on the in vitro dry matter digestibility (g/kg) of one-year-old and two-year-old swards***

| | Spring | Silage 1 | Silage 2 | ROY | Annual |
|---|---|---|---|---|---|
| **One-year-old sward** | | | | | |
| Perennial ryegrass | 834[a] | 798 | 776[a] | 804[a] | 797[a] |
| Italian ryegrass | 823[b] | 782 | 730[b] | 726[b] | 754[b] |
| Hybrid ryegrass | 831[ab] | 787 | 734[b] | 729[b] | 758[b] |
| S.E.D.[1] | 3.2 | 7.1 | 7.1 | 6.6 | 4.5 |
| S.E.D.[2] | 3.4 | 7.4 | 7.4 | 6.9 | 4.7 |
| S.E.D.[3] | 3.1 | 4.6 | 4.6 | 4.7 | 3.6 |
| Significance on 2, 9.2 d.f. | P<0.05 | N.S. | P<0.001 | P<0.001 | P<0.001 |
| **Two-year-old sward** | | | | | |
| Perennial ryegrass | 843 | 776 | 796[a] | 793[a] | 789[a] |
| Italian ryegrass | 843 | 776 | 723[b] | 724[b] | 754[b] |
| Hybrid ryegrass | 853 | 782 | 744[c] | 760[c] | 771[a] |
| S.E.D.[1] | 7.9 | 12.3 | 11.5 | 6.9 | 8.2 |
| S.E.D.[2] | 8.2 | 12.8 | 11.9 | 7.5 | 8.6 |
| S.E.D.[3] | 4.4 | 6.7 | 6.1 | 5.8 | 5.2 |
| Significance on 2, 25.9 d.f. | N.S. | N.S. | P<0.001 | P<0.001 | P<0.001 |

***ROY, Rest of Year; S.E.D.[1], standard error of difference between perennial ryegrass and Italian ryegrass; S.E.D.[2], standard error of difference between perennial ryegrass and hybrid ryegrass; S.E.D.[3], standard error of difference between Italian ryegrass and hybrid ryegrass; N.S., not significant. Superscript letters within columns and age of sward indicate significant difference of means.***

***Table 5. Comparison of three ryegrass species on the water soluble carbohydrates concentration (g/kg DM) of one-year-old and two-year-old swards***

| | Spring | Silage 1 | Silage 2 | ROY | Annual |
|---|---|---|---|---|---|
| **One-year-old sward** | | | | | |
| Perennial ryegrass | 200 | 159[a] | 145[a] | 188[a] | 168 |
| Italian ryegrass | 183 | 196[b] | 183[b] | 166[b] | 182 |
| Hybrid ryegrass | 179 | 185[b] | 195[b] | 170[b] | 184 |
| S.E.D.[1] | 21.5 | 10.0 | 7.5 | 8.0 | 6.1 |
| S.E.D.[2] | 21.7 | 10.4 | 7.9 | 8.4 | 6.4 |
| S.E.D.[3] | 8.9 | 7.0 | 6.6 | 5.8 | 4.9 |
| Significance on 2, 9.3 d.f. | N.S. | P<0.01 | P<0.001 | P<0.05 | P=0.054 |
| **Two-year-old sward** | | | | | |
| Perennial ryegrass | 244 | 208[a] | 190[a] | 175 | 199 |
| Italian ryegrass | 223 | 265[b] | 149[b] | 143 | 199 |
| Hybrid ryegrass | 235 | 249[b] | 135[b] | 154 | 191 |
| S.E.D.[1] | 12.7 | 16.3 | 20.6 | 15.7 | 14.3 |
| S.E.D.[2] | 13.2 | 16.7 | 21.1 | 16.1 | 14.7 |
| S.E.D.[3] | 7.2 | 7.4 | 8.6 | 7.1 | 6.1 |
| Significance on 2, 24.6 d.f. | N.S. | P<0.001 | P<0.05 | N.S. | N.S. |

***ROY, Rest of Year; S.E.D.[1], standard error of difference between perennial ryegrass and Italian ryegrass; S.E.D.[2], standard error of difference between perennial ryegrass and hybrid ryegrass; S.E.D.[3], standard error of difference between Italian ryegrass and hybrid ryegrass; N.S. not significant. Superscript letters within columns and age of sward indicate significant difference of means.***

***Table 6. Comparison of three ryegrass species on the crude protein (g/kg DM) of one-year-old and two-year-old swards***

| | Spring | Silage 1 | Silage 2 | ROY | Annual |
|---|---|---|---|---|---|
| **One-year-old sward** | | | | | |
| Perennial ryegrass | 178 | 122 | 145[a] | 141[a] | 137[a] |
| Italian ryegrass | 175 | 120 | 121[b] | 120[b] | 124[b] |
| Hybrid ryegrass | 184 | 120 | 118[b] | 121[b] | 123[b] |
| S.E.D.[1] | 8.8 | 4.6 | 5.7 | 3.1 | 2.8 |
| S.E.D.[2] | 8.9 | 4.7 | 5.9 | 3.2 | 3.0 |
| S.E.D.[3] | 4.9 | 3.0 | 3.6 | 2.0 | 2.0 |
| Significance on 2, 9.0 d.f. | N.S. | N.S. | P<0.001 | P<0.001 | P<0.01 |
| **Two-year-old sward** | | | | | |
| Perennial ryegrass | 178[a] | 115[a] | 129 | 156 | 131[a] |
| Italian ryegrass | 164[b] | 104[b] | 129 | 150 | 120[b] |
| Hybrid ryegrass | 169[ab] | 107[b] | 136 | 153 | 124[b] |
| S.E.D.[1] | 6.6 | 2.7 | 9.1 | 6.0 | 3.6 |
| S.E.D.[2] | 6.8 | 3.0 | 9.3 | 6.2 | 3.7 |
| S.E.D.[3] | 2.7 | 2.3 | 3.9 | 2.4 | 2.0 |
| Significance on 2, 11.1 d.f. | P<0.05 | P<0.001 | N.S. | N.S. | P<0.05 |

***ROY, Rest of Year; S.E.D.[1], standard error of difference between perennial ryegrass and Italian ryegrass; S.E.D.[2], standard error of difference between perennial ryegrass and hybrid ryegrass; S.E.D.[3], standard error of difference between Italian ryegrass and hybrid ryegrass; N.S., not significant. Superscript letters within columns and age of sward indicate significant difference of means.***

***Table 7. Comparison of three ryegrass species on the buffering capacity (mEq/kg DM) of one-year-old and two-year-old swards***

| | Silage 1 | Silage 2 |
|---|---|---|
| **One-year-old sward** | | |
| Perennial ryegrass | 446[a] | 359[a] |
| Italian ryegrass | 375[b] | 293[b] |
| Hybrid ryegrass | 401[b] | 281[b] |
| S.E.D.[1] | 15.1 | 10.4 |
| S.E.D.[2] | 15.7 | 10.9 |
| S.E.D.[3] | 10.5 | 8.1 |
| Significance on 2, 8.5 d.f. | P<0.001 | P<0.001 |
| **Two-year-old sward** | | |
| Perennial ryegrass | 360[a] | 383[a] |
| Italian ryegrass | 321[b] | 331[b] |
| Hybrid ryegrass | 335[b] | 377[a] |
| S.E.D.[1] | 9.7 | 13.9 |
| S.E.D.[2] | 10.3 | 14.4 |
| S.E.D.[3] | 7.3 | 7.4 |
| Significance on 2, 14.7 d.f. | P<0.01 | P<0.001 |

***ROY, Rest of Year; S.E.D.[1], standard error of difference between perennial ryegrass and Italian ryegrass; S.E.D.[2], standard error of difference between perennial ryegrass and hybrid ryegrass; S.E.D.[3], standard error of difference between Italian ryegrass and hybrid ryegrass; N.S., not significant. Superscript letters within columns and age of sward indicate significant difference of means.***

***Table 8. Comparison of three ryegrass species on the water-soluble carbohydrate concentration (g/ L) of one-year-old and two-year-old swards***

| | Silage 1 | Silage 2 |
|---|---|---|
| **One-year-old sward** | | |
| Perennial ryegrass | 30.6[a] | 33.6[a] |
| Italian ryegrass | 50.7[b] | 51.8[b] |
| Hybrid ryegrass | 48.1[b] | 58.7[c] |
| S.E.D.[1] | 4.94 | 4.18 |
| S.E.D.[2] | 5.07 | 4.33 |
| S.E.D.[3] | 2.59 | 2.71 |
| Significance on 2, 48.7 d.f. | P<0.001 | P<0.001 |
| **Two-year-old sward** | | |
| Perennial ryegrass | 62.7[a] | 51.4[a] |
| Italian ryegrass | 100.1[c] | 49.4[a] |
| Hybrid ryegrass | 90.0[b] | 31.7[b] |
| S.E.D.[1] | 7.41 | 9.21 |
| S.E.D.[2] | 7.90 | 9.41 |
| S.E.D.[3] | 3.44 | 3.68 |
| Significance on 2, 72.1 d.f. | P<0.001 | P<0.001 |

***ROY, Rest of Year; S.E.D.[1], standard error of difference between perennial ryegrass and Italian ryegrass; S.E.D.[2], standard error of difference between perennial ryegrass and hybrid ryegrass; S.E.D.[3], standard error of difference between Italian ryegrass and hybrid ryegrass; N.S., not significant. Superscript letters within columns and age of sward indicate significant difference of means.***

## Results

### One-year-old swards

In the first harvest year, yielding of perennial ryegrass was lower than that of both Italian and hybrid ryegrass ($P<0.001$), and this was also evident at all seasonal periods except for the 'ROY' period where differences were non-significant (Table 2). No significant annual difference existed in DM concentration (Table 3); however, species did differ significantly in each seasonal period with perennial ryegrass having a higher concentration of DM at 'Spring' ($P<0.05$) than both Italian or hybrid ryegrass swards. This relationship was reversed at 'Silage 1' and 'Silage 2' ($P<0.001$) and in the 'ROY' ($P<0.05$). The *in vitro* DMD of perennial ryegrass was higher than that of both other species at 'Silage 2' ($P<0.001$), 'ROY' ($P<0.001$) and 'Annual' ($P<0.001$), but only significantly higher than Italian ryegrass in 'Spring' ($P<0.05$), with no significant effect at 'Silage 1' (Table 4). Similarly, the differences between species for $WSC_{DM}$ concentration (g/kg DM) was approaching significance ($P = 0.054$) for the annual values (Table 5) and significant at 'Silage 1' ($P<0.01$) and 'Silage 2' ($P<0.001$) where both Italian and hybrid ryegrasses had significantly higher $WSC_{DM}$ concentration than perennial ryegrass. A significant difference was also present at 'ROY' ($P<0.05$) when perennial ryegrass had a higher $WSC_{DM}$ concentration than both Italian and hybrid swards. Perennial ryegrass had a significantly higher CP concentration (Table 6) at 'Silage 2', ($P<0.001$), 'ROY' ($P<0.001$) and 'Annual' ($P<0.01$) periods. At both 'Silage 1' and 'Silage 2', there was also a significant difference between species ($P<0.001$) for buffering capacity (Table 7) whereby perennial ryegrass had higher buffering capacity than Italian or hybrid ryegrass. Perennial ryegrass had significantly lower $WSC_{AQ}$ concentration than Italian and hybrid ryegrass at 'Silage 1' and 'Silage 2', and for 'Silage 2', hybrid ryegrass had a significantly higher $WSC_{AQ}$ than Italian ryegrass.

### Two-year-old swards

In their second year, perennial ryegrass was yielding lower than that of both Italian and hybrid ryegrass. No significant differences were detected between species at 'Silage 1', 'Silage 2' or 'ROY' periods but species had an effect at the 'Spring' period ($P<0.01$) when Italian ryegrass swards had a higher herbage yield than both perennial or hybrid ryegrasses (Table 2). At the 'Annual' ($P<0.01$) period, perennial ryegrass had a significantly lower concentration of DM than that of Italian ryegrass, with hybrid ryegrasses not significantly different from either species (Table 3). At the 'Spring' period, perennial ryegrass had significantly higher concentration of DM ($P<0.05$) than Italian ryegrass, and at 'Silage 1', significantly lower concentration of DM ($P<0.001$) than both species. At the 'Silage 2' ($P<0.001$) and 'ROY' ($P<0.001$) periods, Italian ryegrass had a significantly higher concentration of DM than hybrid ryegrasses, with perennial ryegrass intermediate but not significantly different from either species. No significant difference existed between species for *in vitro* DMD at the 'Spring' or 'Silage 1'periods (Table 4). At both the 'Silage 2' ($P<0.001$) and 'ROY' ($P<0.001$) periods, all three species were significantly different, with perennial ryegrass having the highest and Italian ryegrass the lowest *in vitro* DMD values. At the 'Annual' period, Italian ryegrass had a significantly lower *in vitro* DMD than both other species. The $WSC_{DM}$ concentration of perennial ryegrass swards was lower than that of both other species at the 'Silage 1' period ($P<0.001$); however, this order was reversed at the 'Silage 2' ($P<0.05$) period with perennial ryegrass plots having a higher $WSC_{DM}$ concentration. There was no significant difference in $WSC_{DM}$ concentration because of species at any other seasonal period or annually (Table 5). Perennial ryegrass had a higher CP concentration than Italian ryegrass at 'Spring' ($P<0.05$) and both other species at the 'Silage 1' ($P<0.001$) and 'Annual' ($P<0.05$) periods, but with no significant effect at either 'Silage 2' or 'ROY' (Table 6). At 'Silage 1', perennial ryegrass had a higher buffering capacity ($P<0.01$) than both other species, whilst at 'Silage 2', it was higher ($P<0.001$) than Italian but not hybrid ryegrass (Table 7). All three species had a significantly different $WSC_{AQ}$ concentration ($P<0.001$) at 'Silage 1' in the order Italian ryegrass > hybrid ryegrass > perennial ryegrass, and at 'Silage 2', hybrid ryegrass was significantly lower than both perennial and Italian ryegrass (Table 8).

## Discussion

Previous research has shown that the management strategy applied in variety evaluation trials can influence grass quality and productivity (Gilliland *et al.* 1995) and this could impact on the relative merits of species or varieties being compared. However, the management currently applied is reflective of on-farm management whereby the initial harvest of Italian and hybrid ryegrass was taken approximately a week earlier than perennial ryegrass, reflecting the earlier seed-head emergence during the inflorescence development of Italian and hybrid ryegrasses. As there were fixed regrowth periods between harvests, this resulted in all subsequent harvests for Italian and hybrid ryegrass being taken a week prior to perennial ryegrass. Comparisons are, therefore, reflective of optimal management of each species and provide a more reliable indication of on-farm results.

**Herbage yield**

In the current study, Italian and hybrid ryegrasses had 21% more herbage yield than perennial ryegrass in the first year after sowing, and this is in line with previous results (Gilliland and Mann 2001; Gilliland and Meehan 2013). This supports the recommendation of Italian and hybrid ryegrass varieties for increased silage yield for short-term and medium-term swards (Camlin 1997). Wilman and Gao (1996) found hybrid ryegrass swards to be the lowest yielding in their first harvest year with Italian ryegrass swards the highest yielding, although this may reflect a varietal effect as only one variety was used to represent each species in their study. In the second harvest year of the current study, Italian and hybrid ryegrass swards maintained their higher herbage yield than perennial ryegrass but with a slightly reduced advantage of 18%. This is in agreement with Gilliland and Mann (2001) and Recommended List trials in Northern Ireland (Gilliland and Meehan 2013) and England and Wales (NIAB 2013). Although not measured in the current study, the persistence of perennial ryegrass is generally greater than both Italian and hybrid ryegrass swards (Camlin 1997), and Wilman and Gao (1996) demonstrated the increased tiller density of perennial ryegrass swards over Italian ryegrass swards during the course of three years. Gilliland and Mann (2001) found a similar rate of decline in productivity for all three species over five harvest years. As is widely accepted, the evaluation of these ryegrass species also needs to provide some estimation of their productivity over the expected lifetime of the sward, which could be 5–10 years, or longer for perennial ryegrass, depending on management.

It is evident from the market dominance of perennial ryegrass, and the larger number of perennial ryegrass varieties in these Irish Recommended List trials, that considerably more breeding effort has been invested in perennial ryegrass than in either of the Italian or hybrid ryegrasses, for use in the mild-maritime climates, such as Ireland. The differential between species for yield is largely unchanged from what has been reported in the past and appears to have remained despite many years of plant breeding effort. This does not infer that there has been no genetic gain in ryegrasses through plant breeding, as Wilkins and Humphreys (2003) summarised that there have been considerable variations in gains achieved from forage grass breeding throughout different regions of the world. In temperate north-western Europe, there have been gains of between 4% and 5% per decade in dry matter yield since the 1970s (Wilkins and Humphreys 2003). In contrast, United States has seen only a 0–1% gain per decade (Wilkins and Humphreys 2003). Furthermore, Woodfield (1999) reported a faster rate of genetic gain in Italian ryegrass versus perennial ryegrass (1.18 vs. 0.25–0.73, respectively) in an evaluation of genetic improvement in New Zealand. Even given the background of genetic gain reported by Wilkins and Humphreys (2003), the classical performance differences between these species appears to remain.

**Nutritive value traits**

Wilman *et al.* (1996) reported perennial ryegrass to have the highest digestibility of eight grass species that included Italian and hybrid ryegrasses, over two harvest years, and similar findings have been reported on Recommended List trials (Gilliland and Meehan 2013). The results of the current study supplement these results, with perennial ryegrass swards having the highest *in vitro* DMD in the first harvest year and higher than Italian ryegrass in the second harvest year. However, these findings are in contrast to Kemešytė and Lemežienė (2010) who found that both Italian and hybrid ryegrass swards had a significantly higher *in vitro* DMD in the early spring of their first harvest year.

Similar to the current study, Wilman *et al.* (1996) also found Italian ryegrass to have a higher $WSC_{DM}$ concentration than perennial ryegrass, although their study showed hybrid ryegrass to have the lowest $WSC_{DM}$ concentration. Both Wilman *et al.* (1996) and Kemešytė and Lemežienė (2010) examined only a single variety, so it is unclear as to whether this difference was a characteristic of the individual species or a varietal effect.

The CP concentration for all three species remained above the 80 g/kg DM threshold required for successful rumen function (Coleman and Moore 2003). This may at least partially reflect the high rate of N fertiliser application in the current study (350–400 kg/annum), which has previously been shown to influence CP concentration of grass (Binnie *et al.* 2001; Peyraud and Astigarraga 1998). An optimal $WSC_{DM}$:CP ratio of forage in the rumen may result in a greater conversion of forage protein to ruminant product through increased nitrogen use efficiency by the ruminant (Evans *et al.*, 2011; Miller *et al.* 2001; Parsons *et al.* 2011). The $WSC_{DM}$:CP ratio of the current study was 1.23, 1.47 and 1.50 for perennial, Italian and hybrid ryegrasses, respectively, in their first harvest year and 1.51, 1.65 and 1.54 in the second harvest year. A review on the $WSC_{DM}$:CP ratio carried out by Parson *et al.* (2011) indicated that perennial ryegrass normally has $WSC_{DM}$:CP ratio between 0.5 – 2.5. The current high nitrogen application rate potentially increased the CP concentration of the samples; therefore, maintaining the same $WSC_{DM}$:CP ratio would require a similar increase in the concentration of $WSC_{DM}$ in the forage.

**Ensilability quality traits**

When averaged across both simulated silage harvests and the three ryegrass species, herbages in their first year after sowing had poorer ensilability characteristics (46 g WSC/L;

359 mEq/kg DM) than was recorded in the following year (64 g WSC/L; 351 mEq/kg DM). This effect of lower $WSC_{AQ}$ concentration (g/L) may reflect conditions that also stimulated the higher growth rate of herbage in the first year after sowing. Although, on an average, herbage harvested for 'Silage 1' had better ensilability characteristics than herbage for 'Silage 2' (64 vs 46 g WSC/L, despite 373 vs 337 mEq/kg DM), this masked considerable variability amongst species and age of sward. This is as expected because prevailing weather conditions have such a marked effect on both $WSC_{DM}$ and DM (g/kg) values (Roche *et al*. 2009) and thus on $WSC_{AQ}$. When averaged across age of sward and both simulated silage harvests, perennial ryegrass had poorer ensilability characteristics (45 g WSC/L, 387 mEq/kg DM) than Italian (63 g/L, 330 mEq/kg DM) ryegrass, with hybrid ryegrass being intermediate (57 g/L, 349 mEq/kg DM) but more similar to Italian ryegrass. This advantage for Italian ryegrass agrees with Wilson and Collins (1980) who reported that when ensiled under standardised conditions, Italian ryegrass underwent a satisfactory lactic-acid-dominant fermentation more frequently than perennial ryegrass.

Although post-harvest practices will greatly influence the subsequent efficiency of conservation as silage (Conaghan *et al.* 2008; Keady *et al.* 2000), the more favourable ensilability characteristics of Italian and hybrid ryegrass provides supplementary evidence for the current recommendation for their inclusion in some grass seed mixtures sown for silage production (DAFM 2013).

## Conclusions

In both one-year-old and two-year-old swards, perennial ryegrass had a lower DM yield than both Italian and hybrid ryegrasses, with the extent of difference lower in the second year. The seasonal differences in productivity values between perennial ryegrass, Italian ryegrass and hybrid ryegrass justify the current practise of reporting yield on a seasonal basis in the Irish Recommended List, and this facilitates species evaluation information being matched to farm enterprise requirements.

Perennial ryegrass was found to have a more beneficial nutritive composition than Italian and hybrid ryegrasses, possessing a greater *in vitro* DMD than both Italian and hybrid ryegrasses for one-year-old swards and greater than Italian ryegrass in two-year-old swards. Perennial ryegrass swards also exhibited a greater CP concentration than both other species for both one-year-old and two-year-old swards. Nutritive quality is reported in the Irish Recommended List as annualised values for *in vitro* DMD and WSC concentration. Using an annual mean has the potential to mask important seasonal differences in nutritive quality, and seasonal differences in nutritive quality were observed between species in the current study.

Italian ryegrass displayed the most favourable ensilability characteristics, with perennial ryegrass displaying the least favourable characteristics and hybrid ryegrass intermediate but closer to Italian ryegrass. Currently, ensilability traits are not published from in Irish Recommended List trials. In the current study, differences were observed in ensilability traits at silage harvest time between these three species. This provides justification for reporting ensilability traits to ensure that farmers can select the species (and varieties) that best suit their requirements.

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