Development and application of an economic ranking index for perennial ryegrass cultivars

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ABSTRACT

Economic values in euros (€) were calculated for traits of economic importance in Irish grass-based systems. The economically important traits selected were spring, midseason, and autumn grass dry matter (DM) yield (€/kg of DM per ha), grass quality (€ per unit DM digestibility), first- and second-cut silage DM yield (€/kg per ha), and sward persistency (€/ % change in persistency per ha per yr). The economic value for each trait was calculated by changing the trait of interest while keeping all other traits constant, using the Moorepark Dairy Systems Model. Herd parameters (including cow numbers and calving pattern), milk production, energy demand, supplementary feeds, and land area were re-adjusted to calculate the economic value for the trait of interest. The base scenario assumed fixed cow numbers with 40 ha of land available, with full costs included. The results for the base scenario show the economic values were: €0.15/kg of DM spring yield, €0.03/kg of midseason yield, €0.10/kg of DM autumn yield, the quality value was €0.001, €0.008, €0.010, €0.009, €0.008, and €0.006 per unit change in DM digestibility/kg of DM yield for the months of April, May, June, July, August, and September, respectively; €0.036/kg of DM first-cut silage; €0.024/kg of DM second-cut silage; and -€4.961 per 1% decrease in persistency/ha per yr. Sensitivity of the economic values to changes in milk price and scenario were tested. The economic values were applied to experimental production data collected over 3 yr for 20 perennial ryegrass cultivars to establish the total economic merit for each cultivar and then to rank each cultivar based on its economic performance. Rank correlations between the base and alternative scenarios ranged from 0.90 to unity. This indicates that the economic values are reliable regardless of system, intensity, or price. The total merit index will identify the cultivars that can make the greatest economic contribution to a grass-based production system.

Key words: economic ranking, yield, quality, persistency

INTRODUCTION

Eighty percent of the world's bovine milk and 70% of the world's beef and veal are produced from temperate grassland cattle (Wilkins and Humphreys, 2003). Perennial ryegrass is considered one of the most important forage grass species used in temperate agriculture for ruminant animal production. In Ireland, 80% of the agricultural area is devoted to pasture, hay, and grass silage (Department of Agriculture, Fisheries and Food, 2009a). Grass growth is seasonal and production is limited in the winter and early spring period, with over 95% of total grass growth occurring between the March to October period (Dillon et al., 2005). Average annual grass DM production ranges from 11 t of DM/ha to 15 t of DM/ha (Brereton, 1995). Grazed grass is the cheapest feed available in Ireland (Finneran et al., 2010) with a relative cost ratio of grazed grass, grass silage, and concentrate (rolled barley) of 1:1.8:2.4. Dairy, beef, and sheep production systems generally target calving and lambing to coincide with the onset of grass growth in the spring (Dillon et al., 1995; Drennan et al., 2005; Keady et al., 2009). During the period of April to August (main grazing season), animal performance is almost entirely achieved through a grass-based diet, with excess forage harvested and conserved as silage, which provides a feed source during periods when fresh herbage availability is inadequate. Current feed budgets for dairy cows consist of 75% of grazed grass, 19% of grass silage, and 6% of concentrates (O'Donovan and Kennedy, 2007), which is similar to 61% of grazed grass, 31% of grass silage, and 8% of concentrates for calf-to-beef production systems (Drennan and McGee, 2009). Sheep production systems incorporate early or late spring lambing with sheep production being dominated by grass-based systems (Keady et al., 2009) and minimal use of supplements.

The economic merit of an individual grass cultivar across a full production year has not been quantified previously. In cattle breeding, the development of a total merit index to assist farmers in identifying the

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most profitable bulls and cows (Veerkamp et al., 2002) has been successfully adopted and accepted in many countries, including New Zealand (Breeding Worth; NZAEL, 2009), United States (AIPL, 2010), Canada (CDN, 2010), and the Republic of Ireland (Economic Breeding Index; ICBF, 2008). The development of a similar approach to rank grass cultivars would be a significant advancement in grass selection to guide grass breeders, research scientists, advisors, and farmers in identifying grass cultivars that would deliver the highest increases in profitability at the farm level. The identification and application of economic values to each trait of economic importance (DM yield, silage yield, quality, and persistency) and the presentation of grass cultivar ranking based on their total economic merit will provide the industry with information on the optimum cultivars for a system.

In developing a total merit index, it was recognized that the traits of importance were those that have the largest effect on the economic performance of a system. The key traits were determined based on those considered most important within the system following a review of several studies (Dillon et al., 1995; Drennan and McGee, 2009; Keady et al., 2009). In addition, a critical consideration in defining specific criteria for selection is the ease with which the traits can be measured (Wilkins and Humphreys, 2003). Improvement in each trait can be achieved through plant breeding. The selected traits have been identified as important by others, including breeders, research scientists, extension officers, and farmers (Casler, 2000).

The objective of this study was to develop an economic index for grass cultivar ranking, which includes all of the variables of economic importance within Irish grass-based production systems and to apply the economic values to measured cultivar performance data to determine the overall economic merit of a grass cultivar. Included as an objective was testing the relative ranking of cultivars across enterprise, production system, and price.

MATERIALS AND METHODS

Moorepark Dairy Systems Model

The Moorepark Dairy Systems Model (MDSM) is a stochastic budgetary simulation model that provides a comprehensive simulation framework integrating biological, physical, and economic processes in a model of a dairy farm (Shalloo et al., 2004). The MDSM was used to simulate herd parameters, nutritional requirements, land use, and total inputs and outputs across the calendar year. A full description of the model is reported by Shalloo et al. (2004). The major revenues in the MDSM

are milk sales and livestock sales. Within the model, simulations of land area was treated as an opportunity cost, with additional land rented when required or leased out when not required for on-farm feeding of animals. Variable costs (fertilizer, concentrate, vet, medicine, artificial insemination, silage, reseedling, and contractor charges), fixed costs (car, electricity, labor, machinery operation and repair, phone, and insurance, among others), and receipts (livestock, milk, and calf) were based on current prices (Teagasc, 2008).

A spring-calving grass-based milk production system, which is similar to the production system of most Irish dairy farms (Dillon et al. 2005), was simulated using the MDSM. Cows were turned out to grass immediately postcalving. Mean calving date was February 24, with a calving interval of 365 d and 70, 20, and 10% of the cows calving in February, March, and April, respectively (Shalloo et al., 2004). To achieve this, breeding started on a fixed calendar date in late April, with every cow detected in estrous served using AI. Regardless of the number of days since calving, the breeding season was confined to a 13-wk period (Shalloo et al., 2004).

The base scenario assumed in this study had 40 ha of land with 84 cows. Cow numbers were fixed to isolate the herbage effects from the animal effects in the model. In the base scenario, total annual DM production was assumed to be 13 t of DM/ha, based on measurements at Moorepark (1982 to 2001; Shalloo et al., 2004). The system optimizes the use of grazed grass as a proportion of the total diet of the lactating dairy cow, allowing high cow performance, while minimizing the cost of milk production. The net energy system described by Jarrige (1989) was used to determine the energy requirements of the system. Monthly forage fill values (FV) and feed units for lactation (UFL) values within the model were calculated using average monthly values calculated from the chemical composition of 98 swards sampled from the Moorepark Research Farm between 2001 and 2008 (B. O'Neill, Teagasc, Moorepark, Fermoy, Co. Cork, Ireland, personal communication). The FV and UFL values were used to calculate the energy supplied by the diet. Dry matter intake was calculated based on the FV of the sward, the intake capacity (IC), and the energy requirements of the animal (maintenance, milk production, and pregnancy). The proportions of feed offered (grass, grass silage, and concentrate) were adjusted to meet the NE_L requirements, maintenance, and BW change (Shalloo et al., 2004), while optimizing the proportion of grazed grass in the diet (Dillon et al., 1995). The grass proportion in the diet increased as grass supply in the system increased. The average annual milk production per cow was 6,238 kg, with 37.0 g of fat/kg, 33.4 g of protein/kg, and 46.6 g of lactose/kg. The lactation curves within the MDSM for milk

Table 1. Default parameter values in the Moorepark Dairy Systems Model

Variable	Default value
Farm size (ha)	40
Gross milk price (€/L)	0.27
Fat price (€/kg)	3.13
Protein price (€/kg)	6.27
Price ratio of protein:fat	2:1
Opportunity cost of land (€/ha)	297
Concentrate costs (€/t)	220
Fertilizer costs (€/t)	
Calcium ammonium nitrate	280
Urea	360
N:P:K fertilizer (0:7:30)	340
First-cut grass silage, including contractor charges (€/ha)	284
Second-cut grass silage, including contractor charges (€/ha)	235
Reseeding costs (€/ha)	496

yield and milk composition were based on national milk supply profiles calculated using the standard lactation curve method (Olori and Galesloot, 1999).

The area required for silage within the model was calculated based on the requirement of the herd for silage and the yield per hectare for the 2 silage harvests. This resulted in 37% of the farm closed for first-cut silage and 25% closed for second-cut silage. The total yield for both first and second cut was calculated on the assumption that 80% of the DM harvested was used. The utilizable silage yield per hectare was 4,435 kg (first cut) and 3,558 kg of DM/ha (second cut).

Assumptions

The key assumptions used in the MDSM are shown in Table 1. The base gross milk price received was 27c/L (Binfield et al., 2008). The ratio of fat-to-protein price was 1:2 with a fat price of 3.42 €/kg and a protein price of 6.84 €/kg. An opportunity cost of €297/ha was placed on all land in the system.

Scenario Analysis

Sensitivity analysis was used to determine the effect of a change in the production system efficiencies and price on the economic value of each trait compared with that of the base value. Several scenarios (**S**) were evaluated, which deviated from the base scenario:

- 1) fixed cow numbers, with land area fluctuating (S1),
- 2) fixed land area (40 ha), with cow numbers fluctuating (S2), and
- 3) variations in total DM yield per hectare (S3)
 - a) 15 t of DM/ha
 - b) 11 t of DM/ha.

All scenarios were tested with 3 different milk prices (22c/L, 27c/L, and 30c/L).

Trait Definition and Methodology to Calculate Economic Values

The traits of importance for grass-based systems were identified as 1) DM yield (in spring, midseason, and autumn), 2) quality, 3) silage DM yield (of first and second cut), and 4) sward persistency.

Economic values were derived by simulating a physical change for each trait of interest independently. The difference between the net margin per hectare before (default) and after the change was simulated, and was divided by the change in the trait of interest to calculate the economic value for a unit change in that trait. Thus, the economic value of a trait can be described as follows:

$$\text{Economic value} = \frac{\Delta \text{ net margin per hectare}}{\Delta \text{ in trait of interest}}.$$

Spring. The economic value for an increase in spring DM yield is calculated based on the assumption that each additional 1 kg of DM of grass grown during the spring period will be grazed by an animal. The additional 1 kg of grass will displace grass silage and concentrate on an equal energy basis. Thus,

$$\begin{aligned} &\text{Euro per 1-kg increase in spring DM yield} \\ &= \frac{\Delta \text{ net margin per hectare}}{\Delta \text{ grass intake per hectare}} \times \text{utilization.} \end{aligned}$$

Midseason. Midseason DM yield is calculated on the assumption that each additional 1 kg of DM grass produced across the main grazing season will allow an increase in the carrying capacity of the farm, thereby allowing a higher stocking rate to be maintained in the same area. Therefore,

$$\begin{aligned} &\text{Euro per 1-kg increase in midseason DM yield} \\ &= \frac{\Delta \text{ net margin per hectare}}{\Delta \text{ grass grown per hectare}} \times \text{utilization.} \end{aligned}$$

Autumn. The economic value for an increase in autumn DM yield is calculated based on the assumption that each additional 1 kg of grass grown during the autumn period will be grazed by an animal. The additional 1 kg of grass will displace grass silage and concentrate on equal energy basis. Thus,

$$\begin{aligned} &\text{Euro per 1-kg increase in autumn DM yield} \\ &= \frac{\Delta \text{ net margin per hectare}}{\Delta \text{ grass intake per hectare}} \times \text{utilization.} \end{aligned}$$

The economic values for the spring, midseason, and autumn DM yields were calculated assuming a grass utilization of 90%, 85%, and 80%, respectively (O'Donovan and Kennedy, 2007).

Quality. The voluntary DMI (VDMI) of forages for lactating dairy cows is transformed into FV and expressed as fill units (FU) for lactating dairy cows (LFU; Jarrige, 1989). If the forage is fed ad libitum as the sole feed, the VDMI of the forage is obtained by dividing the feed IC of the animal by the FV expressed in the same FU of the forage (Jarrige, 1989). A negative relationship exists between VDMI and LFU. The IC of a lactating dairy cow is calculated as

$$IC = \left\{ \begin{aligned} &13.9 + [0.015(BW - 600)] + (0.15 \times MY_{Pot}) \\ &+ [1.5 \times (3 - BCS)] \end{aligned} \right\} \times IL \times IP \times IM,$$

where MY_{Pot} = potential milk yield; IL = indices of lactation = $a + (1 - a) \times (1 - e^{-0.16 \times \text{week of lactation}})$, where $a = 0.6$ for primiparous and 0.7 for multiparous cows, e = exponential, and $IL = 1$ for dry cows; IP = indices of pregnancy = $0.8 + 0.2 \times (1 - e^{-0.25 \times (40 - \text{wk of pregnancy})})$; and IM = indices of maturity = $-0.1 + 1.1 \times (1 - e^{-0.08 \times \text{age in mo}})$ (Faverdin et al., 2007).

High FV indicate forages with lower rates of digestibility. In order to calculate the economic value of a unit change in DM digestibility (DMD), it is necessary to determine the effect a reduction in sward quality will have on animal intake and milk yield. In the model, the quantity of feed offered was adjusted to meet the net energy requirement of the system when forage quality changed. If the LFU of a sward was less than the calculated IC of the dairy cow, then quality affected energy intake and the resulting economic value was based on the feed requirement change. If the LFU of the sward was greater than the calculated intake requirement, then the energy intake requirement could not be satisfied and the performance of the animal was decreased, thereby resulting in a negative effect on production. For each month of April to September (inclusive), the economic effect of a 1% change in sward DMD on DMI, corrected for LFU, was calculated as follows:

$$\begin{aligned} &\text{Euro per unit increase in DMD value} \\ &= \frac{(\Delta \text{ net margin per hectare} \times \text{utilization})}{\% \text{ unit } \Delta \text{ DMD}}. \end{aligned}$$

First-Cut Silage. The value of an increase in DM yield above the base DM yield for first-cut silage was calculated based on

$$\begin{aligned} &\text{Euro per 1-kg increase in first-cut silage yield} \\ &= \frac{\Delta \text{ net margin per hectare}}{\Delta \text{ first-cut silage yield per hectare}} \times \text{utilization.} \end{aligned}$$

Second-Cut Silage. The value of an increase in DM yield above the base DM yield for second-cut silage was calculated based on

$$\begin{aligned} &\text{Euro per kg increase second-cut silage yield} \\ &= \frac{\Delta \text{ net margin per hectare}}{\Delta \text{ second-cut silage yield per hectare}} \times \text{utilization.} \end{aligned}$$

Dry matter losses from mowing, wilting, and harvesting of approximately 3% have been reported (Forristal et al., 1995; Rotz, 1995), with 17% of losses occurring during the ensiling and feeding processes (P. O'Kiely, Teagasc, Grange, Co. Meath, Ireland, 2008, personal communication). Thus, total losses of harvestable DM are 20% and, hence, a utilization rate of 0.80 was assumed in the calculation of the economic values for both first- and second-cut silage DM yields.

Persistence. The economic value for persistence was derived by assuming a 10-yr period as the standard sward longevity based on current recommendations. The economic value for persistence was calculated based on a 1% change in the lifetime of the sward relative to the base scenario set at 10 yr and was calculated as follows:

$$\begin{aligned} &\text{Euro per \% change in persistence per hectare} \\ &= \frac{\Delta \text{ net margin per hectare}}{\% \text{ change in persistence relative to a 10-yr base}}. \end{aligned}$$

Cultivar Ranking

The model parameters were investigated through the application of the economic values to production data of 20 perennial ryegrass cultivars sown at Moorepark Dairy Research Centre, on a free-draining, acid brown earth soil with a sandy loam texture. The experimental design was a randomized complete block with 120 plots (1.5×5 m) and a 20×2 factorial arrangement of treatments. Two management systems were applied. Management 1 represented a typical grazing rotation system used at the farm level (simulated grazing) and management 2 represented a 2-cut silage system. Plots

were replicated 3 times within each management. All plots were harvested to 4 cm in November 2006. Dry matter yield was determined over 3 yr (2007 to 2009 inclusive) and sward quality was measured over 2 yr (2007 and 2008). Plots were harvested with an Etesia mechanical mower (Etesia UK Ltd., Warwick, UK) to a height of 4 cm and N fertilizer, in the form of calcium ammonia nitrate, was applied within 3 d of defoliation.

The simulated grazing management incorporated 10 defoliations annually; the first annual cut was taken on March 23, with cuts 2 to 6 taken at intervals of 3 wk and cuts 7, 8, 9, and 10 taken at intervals of 4 to 5 wk, with the final cut taken in the first week of November. Nitrogen was applied at the rate of 365 kg of N/ha with approximately 50 kg of N/ha applied 4 wk before the first cut and thereafter, 35 kg of N/ha was applied after all cuts except the final cut, annually. The 2-cut silage management system was designed to mimic a mixed grazing and conservation system. It incorporated a harvest in early April, followed by 2 silage harvests at regrowth intervals of 7 wk (cut 2; first-cut silage) and 6 wk (cut 3; second-cut silage), followed by 3 backend simulated grazing harvests, taken at regrowth intervals of 4, 5, and 5 wk, for cuts 4, 5, and 6, respectively. In total, 6 defoliations were taken from mid-March to mid-November. Nitrogen was applied at the rate of 350 kg of N/ha. Five weeks before the first cut, 40 kg of N/ha was applied and 100, 90, 50, 40, and 30 kg of N/ha were applied following cut 1, 2, 3, 4 and 5, respectively. No N fertilizer was applied after the final cut. All cuts were taken $\pm$ 3 d of targeted cutting date.

Dry matter yield was measured on each plot at every cutting date for the appropriate protocol. The full length of the plot (5 m) was harvested (mower width was 1.2 m). All mown herbage from each plot was collected. It was weighed and subsampled (0.1 kg), the subsample was dried for 48 h at 40°C in a drying oven to determine the DM content. Subsequently, the dried sample was milled through a 1-mm screen. In 2007 and 2008, the DMD of each sample was estimated using near-infrared spectrometry (NIRS; FOSS 6500 NIR, Hillerød, Denmark). The reference method of Tilley and Terry (1963) was used for the DMD calibrations of the NIRS.

The production values for spring, midseason, and autumn DM yield and quality were generated from the simulated grazing management. Within this protocol, the overall grazing season was divided into spring (February 1 to April 10), midseason (April 11 to August 6), and autumn (August 7 onwards). Data from the first- and second-cut silage harvests in the 2-cut silage management was used to generate the first- and second-cut silage DM yields, respectively; the remainder of the

data from this management was collected but not used in the analysis. Data were analyzed with repeated measures analysis using Proc Mixed in SAS (SAS Institute, 2006). All measurements were subjected to ANOVA using the following model:

$$Y_{ijk} = \mu + Y_i + M_j + C_k + P_l + e_{ijkl}$$

where μ = mean; Y_i = year effect ($i = 1$ to 3); M_j = management effect ($j = 1$ to 2); C_k = cultivar effect ($k = 1$ to 20); P_l = plot effect ($l = 1$ to 120); and e_{ijkl} = residual error term.

The total economic merit of a cultivar was calculated by applying the economic values to the biological data of each cultivar for DM yield (spring, midseason, autumn, and first- and second-cut silage). A similar calculation was used to calculate the economic merit for quality; however, an assumption was made in relation to the total monthly utilizable herbage for grazing (1,200 kg of DM/ha). The calculated values for each trait are then summed to give the total economic merit of the cultivar.

Spearman rank correlations were used to determine the degree of re-ranking of cultivars when the economic values of the different scenarios were applied to their production data. The Spearman rank correlation coefficient (r_s) was calculated using the following equation:

$$r_s = 1 - \left(\frac{6 \sum d^2}{n(n^2 - 1)} \right),$$

where $\sum d^2$ is the difference in rank change in economic performance squared and summed for all 20 cultivars, and n is the number of cultivars. The r_s returns a value between -1 and 1 , with 1 implying the exact same ranking, and 0 implying no correlation between cultivars across scenarios.

RESULTS

Bio-Economic Model

Table 2 presents the default herd parameters for a 365-d period (Jan to Dec), including the number of animals present, feed requirements, and land use for the base scenario. The total annual DMI (kg per cow) was 3,947, 1,114, and 366 kg of DM of grazed grass, grass silage, and concentrate, respectively; on a proportional basis, these correspond to 0.71, 0.21, and 0.08 of the total diet, respectively. Total milk sales were 510,776 kg with total fat and protein sales of 18,907 and 17,114 kg, respectively.

The feed budget in the model was influenced by the calving date (Table 2). Cows were turned out to grass immediately postcalving. Calving began in February with 59, 17, and 8 cows calving in February, March, and April, respectively. The corresponding proportion of grass in the feed budget of the total herd for these months was 0.2, 0.5, and 0.8, respectively, with silage decreasing from February (0.6) to March (0.2) and being removed from the diet thereafter until November (0.1).

Economic Values

Table 3 presents the key herd parameters with the effect of a change in each trait relative to the default system on feed and land requirements, milk sales, silage yields, and profit/ha. In the default scenario, the stocking rate is 1.9 cows/ha. Table 4 presents the calculated economic value for each trait.

Spring DM Yield. Simulating an increase in spring DM yield resulted in an additional 43 kg of DM/ha grass in the system (Table 3); when corrected for energy, this displaced 26 kg of DM silage and 24 kg of concentrate DM from the diet during the spring period. Total costs were decreased compared with the base scenario costs and the resultant farm profit increased by €13.80/ha. The economic value for an increase in spring DM yield is calculated at €0.15 per kg of DM at 90% utilization (Table 4).

Midseason DM Yield. Simulating an increase in midseason herbage production resulted in an increase of 1.3 t of DM/ha of herbage grown, of which 1.1 t of DM/ha is utilized. The resultant increase in farm profit was €46.60/ha, which corresponded to €0.03 per kg of DM at 85% utilization.

Autumn DM Yield. Simulating an increase in autumn DM yield resulted in an additional 47 kg of DM/ha grass available; when corrected for energy, 27 and 23 kg of DM silage and concentrate, respectively, were displaced from the diet. The resultant increase in farm profit was €11.60/ha, which corresponds to €0.10 per kg of DM at 80% utilization.

Quality. Simulating a 1 unit decrease in sward DMD resulted in a negative effect on milk production in the months of May to September (inclusive). The economic value for quality expressed as € per unit decrease in DMD per 1 kg of DM was –€0.001 for the month of April. Fill value did not affect animal intake during April; hence, no effect of grass quality on animal performance was present. During the months of May to September, the FV of the grass restricted the DMI of the animal. As a result of this restriction on intake, milk yield decreased. The resulting economic values for these months expressed as € per unit decrease in

DMD per 1 kg of DM were as follows: –€0.008 (May), –€0.010 (June), –€0.009 (July), –€0.008 (August), and –€0.006 (September).

First-Cut Silage DM Yield. Simulating an increase in silage DM yield required less total area to be used for silage harvesting. Increased DM yield of first-cut silage resulted in an additional 445 kg of DM/ha conserved. This resulted in a total of 4,880 kg of DM/ha harvested as first-cut silage. The resulting total farm profit increased by €19.70/ha. The economic value for each additional 1 kg of DM of first-cut silage conserved was €0.036 per ha.

Second-Cut Silage DM Yield. Simulating an increase in the DM yield of the second-cut silage resulted in an increase in 356 kg of DM/ha conserved, therefore, reducing the total area required for silage by 0.8 ha compared with the base value. The resulting farm profit achieved from an increase in harvest yield of second-cut silage was €10.90/ha. The economic value for each additional 1 kg of DM of second-cut silage was €0.024 per ha.

Persistency. Simulating a 1% decrease in persistency per year will result in a decrease in net margin of €4.96/ha per yr. The cost of reseedling is incorporated into the calculation of the economic value at €496.00/ha.

Scenario Analysis

The sensitivity of the economic values to each scenario are presented in Table 5 (these values were not statistically tested). The economic values for each trait are dependant on the scenario selected as well as the relevant milk price, except for persistency, which was –€4.96/% decrease in persistency per ha per yr, regardless of the scenario examined. As the scenario changes, the net margin per hectare is adjusted and this affects the economic value for each trait. Table 5 presents the adjusted economic values for each scenario at each milk price.

In the base scenario, at a milk price of 22c/L, the economic value, expressed as €/unit change in DMD, increased slightly for the months of May to September compared with the corresponding values at a milk price of 27c/L. At a milk price of 30c/L, the economic values decreased compared with that of the base at a milk price of 27c/L (Table 5).

In S1 (fixed cow numbers with land area fluctuating), at a milk price of 30c/L and 27c/L, the economic value of spring and autumn DM yield decreased compared with the that of the base, whereas the economic values for midseason and silage DM yields increased (Table 5). The economic values of the traits at 22c/L were similar to the base value for spring, midseason, autumn, and

Table 2. Default herd parameters for 12 mo of a year

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Animals present													
Total cows (n)	71	80	82	82	81	79	78	77	77	76	75	74	—
Cows milking (n)	22	66	75	82	81	79	78	77	77	76	75	74	—
Cows dry (n)	49	14	7	—	—	—	—	—	—	—	—	—	—
Cows calving (n)	—	59	17	8	—	—	—	—	—	—	—	—	84
Replacements calving (n)	—	12	3	2	—	—	—	—	—	—	—	—	—
Milk (%)	0.99	3.59	10.86	13.08	13.84	12.11	11.13	9.90	8.38	6.99	5.69	3.44	—
Fat concentration (%)	4.43	3.96	3.68	3.50	3.44	3.47	3.56	3.69	3.88	4.09	4.26	4.39	—
Protein concentration (%)	3.73	3.15	3.12	3.18	3.24	3.27	3.29	3.37	3.53	3.67	3.74	3.78	—
Feed requirements													
Grass demand (kg of DM/cow per d)	0.0	2.3	7.6	11.9	16.3	17.3	17.3	16.4	15.6	13.7	10.7	0.1	—
Silage demand (kg of DM/cow per d)	10.9	7.4	3.6	0.5	—	—	—	—	—	—	1.4	13.0	—
Concentrate demand (kg of DM/cow per d)	0.3	2.1	4.2	2.9	0.2	—	—	—	—	1.0	1.0	0.5	—
Total demand (kg of DM/cow per d)	11.1	11.7	15.4	15.3	16.6	17.3	17.3	16.4	15.6	14.7	13.1	13.5	—
Proportion of different feeds in diet													
Grazed grass	—	0.2	0.5	0.8	1.0	1.0	1.0	1.0	1.0	0.9	0.8	—	—
Grass silage	1.0	0.6	0.2	—	—	—	—	—	—	—	0.1	1.0	—
Concentrate	—	0.2	0.3	0.2	—	—	—	—	—	0.1	0.1	—	—
Land use													
Area closed for silage (ha)	—	0.0	14.7	14.7	14.7	9.8	9.8	9.8	0.0	0.0	0.0	0.0	—
Area available for grazing (ha)	40.0	40.0	25.3	25.3	25.3	30.2	30.2	30.2	40.0	40.0	40.0	40.0	—
Area cut for silage (ha)	—	—	—	—	14.7	—	—	9.8	—	—	—	—	—
Grass growth utilized (kg of DM/ha)	—	48.3	481.0	1,393.3	1,990.3	1,741.6	1,876.5	1,587.0	1,166.3	644.2	127.1	0.0	11,056

Table 3. Key herd parameters when a unit change in trait of interest is incurred relative to the default scenario at a milk price of 27c/L

Herd parameter	DM yield				Quality						Silage		
	Default	Spring	Midseason	Autumn	Apr	May	Jun	Jul	Aug	Sept	Persistency	First cut	Second cut
Change in trait ¹		(+)	(+)	(+)	(−)	(−)	(−)	(−)	(−)	(−)	(−)	(+)	(+)
Herbage grown (t/ha)	13.0	13.0	14.3	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
Herbage used (t/ha)	11.1	11.1	12.2	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1
Grass (kg of DM/cow)	3,947	3,990	3,947	3,994	3,977	3,956	3,949	3,955	3,957	3,967	3,947	3,947	3,947
Silage (kg of DM/cow)	1,114	1,088	1,114	1,087	1,114	1,114	1,114	1,114	1,114	1,114	1,114	1,114	1,114
Concentrate (kg of DM/cow)	366	342	366	344	366	366	366	366	366	366	366	366	366
Farm size (ha)	40.0	40.1	37.2	40.1	40.2	40.0	40.0	40.0	40.1	40.1	40.0	39.4	39.7
Area used for silage (ha)	24.5	24.0	24.5	24.0	24.5	24.5	24.5	24.5	24.5	24.5	24.5	23.0	23.7
Farm stocking rate (livestock units/ha)	2.3	2.3	2.5	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.4	2.4
Cows (n/ha)	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Milk sales (kg)	510,776	510,776	510,776	510,776	510,776	504,220	502,492	503,746	504,522	506,809	510,776	510,776	510,776
Fat sales (kg)	18,907	18,907	18,907	18,907	18,907	18,682	18,620	18,657	18,676	18,753	18,907	18,907	18,907
Protein sales (kg)	17,114	17,114	17,114	17,114	17,114	16,902	16,843	16,882	16,903	16,974	17,114	17,114	17,114
Silage yield first cut (kg/ha)	4,435	4,435	4,435	4,435	4,435	4,435	4,435	4,435	4,435	4,435	4,435	4,880	4,435
Silage yield second cut (kg/ha)	3,558	3,558	3,558	3,558	3,558	3,558	3,558	3,558	3,558	3,558	3,558	3,558	3,914
Milk returns (€)	142,847	142,847	142,847	142,847	142,847	141,120	140,641	140,941	141,090	141,667	142,847	142,847	142,847
Livestock sales (€)	36,978	36,978	36,978	36,978	36,978	36,978	36,978	36,978	36,978	36,978	36,978	36,978	36,978
Total costs (€)	152,692	152,136	150,828	152,226	152,843	152,729	152,690	152,719	152,727	152,778	152,912	151,902	152,257
Total profit (€)	27,134	27,690	28,998	27,600	26,982	25,369	24,929	25,201	25,342	25,868	26,914	27,924	27,569
Profit per hectare (€/ha)	678	692	725	690	674	634	623	630	633	646	673	698	689

¹Indicates direction of the simulated change: unit increase = (+) or decrease = (−) in each trait.

Table 4. Economic values (€/ha per yr) for DM yield, quality, persistency, and silage yield performance

	Production (per kg of DM/ha)			Quality (per unit decrease in DMD ¹)							Silage	
	Spring	Midseason	Autumn	April	May	June	July	August	September	Persistency	First cut	Second cut
Base scenario												
Milk price 27c/L	0.152	0.030	0.103	−0.001	−0.008	−0.010	−0.009	−0.008	−0.006	−4.961	0.036	0.024

¹DMD = DM digestibility.

silage DM yield. In S1, the economic values for quality were similar to the corresponding economic values in the base scenario.

Scenario 2 had a lower economic value for spring and autumn DM yield than the base scenario at each milk price. The economic value of midseason and silage DM yield was higher in this scenario compared with the base economic value across all milk prices (Table 5).

In Scenario 3, across all milk prices and at both 15 and 11 t of DM/ha, the economic value for spring and autumn was lower compared with that of the base (Table 5), whereas the economic value for midseason and silage DM yield was higher for this scenario compared with that of the base. The economic values for quality differed from that of the base scenario during several of the months (Table 5).

Cultivar Ranking

Data collected in the plot experiment were used in the generation of biological values for the spring, midseason, and autumn DM yields, sward quality, and silage yields. Table 6 presents the DM yield and DMD values for the 20 cultivars. The average spring DM yield was 1,625 kg of DM/ha. The average midseason and autumn DM yield was 6,498 kg of DM/ha and 4,047 kg of DM/ha, respectively. The lowest average DMD value was measured in September (802 g/kg of DM) compared with the highest in April (846 g/kg of DM). The average first- and second-cut silage yields were 5,370 kg of DM/ha and 3,232 kg of DM/ha, respectively.

Table 7 presents the breakdown of the economic merit for each trait for the cultivars through combining the biological and economic data. The economic merit of each cultivar is dependant on its performance relative to the average performance of all cultivars evaluated. The range in total economic merit between cultivars for each trait was as follows: −€72 to €86 (spring); −€9 to €14 (midseason); −€34 to €41 (autumn); −€77 to €72 (quality); and −€36 to €28 (silage). The cultivars that result in a positive or negative monetary value for a particular trait can be identified and a cultivar can be selected based on its ability to contribute to the economic performance of the production system.

The total economic merit of the 20 cultivars range from −€198 (cultivar 6) to €128 (cultivar 5).

Based on the economic merit, each cultivar was ranked within scenario and price was assessed, and the r_s of each index was established (Table 8). Compared with those of the base scenario, the r_s ranged from 0.90 to unity, with a mean r_s of 0.96.

DISCUSSION

Reform of the Common Agricultural Policy will continue to increase market pressures on ruminant-based production systems within the EU. Grass-based ruminant production systems will have a competitive advantage over high-input systems due to the ability to produce milk or meat almost entirely from a low-cost grass-based diet. Production systems based around maximizing the proportion of grazed grass in the diet will be insulated against the expected increased levels of price volatility (Shalloo et al., 2007). In the future, grass selection will be based on identifying the cultivars that will give the highest economic return within the production systems from which they are used. Economic ranking of grass cultivars, taking cognizance of the most important variables within the production system, will ensure that the optimum cultivars are identified.

Production System

Recent and expected increases in farm stocking rate are being driven by a requirement to generate more product at low cost. This will intensify the demand for grass cultivars, which will provide increased seasonal and total DM production, higher sward quality, and higher silage yields, while maintaining sward longevity. Dillon et al. (2005) showed that a 10% increase in the proportion of grazed grass in the feeding system will reduce the cost of milk produced by €0.025/L. Currently, regardless of system or enterprise, on a proportional basis, grazed grass is the largest constituent of the ruminant feed budget (O'Donovan and Kennedy, 2007; Drennan and McGee, 2009; Keady et al., 2009), whereas grass silage is the principal winter feed for livestock in Ireland (Drennan et al., 2005). The eco-

Table 5. Sensitivity of economic values from the base to 4 assumptions: fixed cows (S1), fixed land (S2), fixed cows growing 15 t of DM/ha (S3) and 11 t of DM/ha at 3 milk prices (30, 27, and 22c/L)

Item	Base			S1			S2			S3			S3		
	30c/L	27c/L	22c/L	30c/L	27c/L	22c/L	30c/L	27c/L	22c/L	30c/L	27c/L	22c/L	30c/L	27c/L	22c/L
€/kg of DM yield															
Spring	0.15	0.15	0.15	0.12	0.13	0.15	0.10	0.10	0.12	0.06	0.08	0.11	0.11	0.12	0.14
Midseason	0.03	0.03	0.03	0.08	0.07	0.03	0.11	0.11	0.08	0.14	0.12	0.08	0.15	0.13	0.10
Autumn	0.10	0.10	0.10	0.07	0.08	0.10	0.06	0.06	0.08	0.02	0.04	0.06	0.06	0.07	0.09
€/unit change in DMD ¹															
April	-0.001	-0.001	-0.001	-0.002	-0.001	-0.001	-0.002	-0.002	-0.002	-0.002	-0.002	-0.001	-0.003	-0.002	-0.002
May	-0.009	-0.008	-0.007	-0.009	-0.008	-0.007	-0.008	-0.008	-0.007	-0.008	-0.007	-0.006	-0.010	-0.009	-0.008
June	-0.011	-0.010	-0.008	-0.011	-0.010	-0.008	-0.010	-0.010	-0.008	-0.010	-0.009	-0.007	-0.013	-0.011	-0.009
July	-0.010	-0.009	-0.007	-0.010	-0.009	-0.007	-0.009	-0.009	-0.007	-0.009	-0.008	-0.006	-0.011	-0.010	-0.008
August	-0.009	-0.008	-0.007	-0.009	-0.008	-0.007	-0.009	-0.009	-0.007	-0.008	-0.008	-0.006	-0.011	-0.010	-0.008
September	-0.007	-0.006	-0.005	-0.007	-0.006	-0.005	-0.007	-0.007	-0.005	-0.007	-0.006	-0.005	-0.008	-0.007	-0.006
€/ % change per yr															
Persistence	-4.96	-4.96	-4.96	-4.96	-4.96	-4.96	-4.96	-4.96	-4.96	-4.96	-4.96	-4.96	-4.96	-4.96	-4.96
€/kg of DM silage yield															
First cut	0.04	0.04	0.04	0.06	0.05	0.03	0.08	0.08	0.06	0.07	0.06	0.05	0.11	0.09	0.07
Second cut	0.02	0.02	0.02	0.04	0.03	0.02	0.05	0.05	0.04	0.05	0.04	0.03	0.07	0.06	0.05

¹DMD = DM digestibility.

conomic influence of grass DM yield fluctuates across the season and is influenced by feed supply and herd demand, which agrees with Doyle and Elliott (1983). In spring and autumn, feed demand generally exceeds supply for grass-based ruminant production systems. In the main grazing season, grass supply generally exceeds herd feed demand, the extent of which is dependant on stocking rate. Each additional 1 kg of herbage produced in spring and autumn has a greater economic value to a grazing system than a similar increase in the midseason DM yield due to a deficit of grass in the system in the spring and autumn.

Economic Traits

The seasonal nature of ruminant production in Ireland influences the traits of importance for grass-based systems and, hence, the traits for which economic values were calculated. The key traits were determined based on those considered most valuable to the system following a review of several studies (Dillon et al., 1995; Drennan and McGee, 2009; Keady et al., 2009) and are similar to those reported by others (Casler, 2000; Wilkins and Humphreys, 2003; Department of Agriculture, Fisheries and Food, 2009b). Cultivars that provide higher DM yields in spring and autumn support the extension of the grazing season and, hence, costs of production are decreased (Moseley et al., 2001). Differences in morphological and nutritive composition between cultivars can have a significant effect on animal production performance (Vipond et al., 1997; Gowen et al., 2003; O'Donovan and Delaby, 2005). The nutritive value of perennial ryegrass varies throughout the growing season (Walsh and Birrell, 1987; Johnston, et al., 1993), as observed with the biological data of the current study. The decline in plant digestibility (May to June period) is largely associated with increases in stem content as the plant changes from vegetative to reproductive growth. Genetic improvements in DMD have resulted in measurable improvements in animal performance by increasing both diet energy content and its voluntary intake (Wilkins and Humphreys, 2003). The effect of a unit change in DMD on a monthly basis resulted in a large effect on the total merit of a cultivar. Table 7 presents the economic values applied to the production data. The range in the total value for quality is -€77.33 (cultivar 6) to €71.96 (cultivar 7). This equates to a difference of €149.29/ha per yr between the worst and best cultivars out of the 20 cultivars assessed on quality alone. This could have substantial effects on the overall profitability of a system. Within many cultivar evaluation trials worldwide, quality is not routinely assessed, or may only be assessed at one or 2 points across the season. This study demonstrates the need for repeated

Table 6. Biological data of individual variety performance including the average of the 20 perennial ryegrass cultivars for yield, quality, persistency, and silage production

Variety	DM yield (kg of DM/ha)			Silage DM yield (kg of DM/ha)		Quality DMD ¹ (g/kg)					
	Spring	Summer	Autumn	First cut	Second cut	April	May	June	July	August	September
Mean	1,625	6,498	4,047	5,370	3,232	845.9	819.3	802.7	822.7	810.4	801.9
Cultivar 1	1,347 ^{efgh}	6,962 ^a	4,449 ^a	5,323 ^{abc}	2,960 ^{defg}	840 ^{ab}	816 ^{abcd}	796 ^{abcd}	829	816 ^{ab}	807 ^{ab}
Cultivar 2	1,587 ^{defg}	6,664 ^{abc}	4,298 ^{ab}	5,349 ^{abc}	2,701 ^{fg}	833 ^{ab}	802 ^{dc}	803 ^{abcd}	834	809 ^{ab}	790 ^{ab}
Cultivar 3	2,048 ^{ab}	6,242 ^c	3,948 ^{abc}	5,365 ^{abc}	3,264 ^{abcdef}	850 ^{ab}	817 ^{abcd}	798 ^{abcd}	816	802 ^{ab}	788 ^b
Cultivar 4	2,193 ^a	6,471 ^{abc}	3,843 ^{bc}	5,434 ^{ab}	3,503 ^{abcde}	844 ^{ab}	821 ^{abcd}	800 ^{abcd}	810	811 ^{ab}	796 ^{ab}
Cultivar 5	2,075 ^{ab}	6,763 ^{abc}	4,174 ^{abc}	5,042 ^{ac}	3,203 ^{bcd}	864 ^a	830 ^{abcd}	815 ^{abc}	831	822 ^{ab}	809 ^{ab}
Cultivar 6	1,148 ^h	6,178 ^c	3,875 ^{bc}	4,944 ^{ac}	3,004 ^{cdefg}	836 ^{ab}	799 ^d	790 ^d	812	797 ^{ab}	780 ^b
Cultivar 7	1,590 ^{cdef}	6,396 ^{abc}	4,171 ^{abc}	5,015 ^{ac}	3,480 ^{abcde}	857 ^{ab}	838 ^a	811 ^{abcd}	834	828 ^a	818 ^{ab}
Cultivar 8	1,812 ^{bcd}	6,657 ^{abc}	3,895 ^{bc}	5,644 ^{ab}	3,825 ^a	855 ^{ab}	839 ^a	815 ^{ab}	821	825 ^{ab}	820 ^{ab}
Cultivar 9	1,472 ^{defgh}	6,494 ^{abc}	4,137 ^{abc}	5,964 ^a	2,470 ^g	837 ^{ab}	805 ^{bcd}	794 ^{bcd}	818	808 ^{ab}	798 ^{ab}
Cultivar 10	1,301 ^{gh}	6,639 ^{abc}	4,234 ^{abc}	5,606 ^{ab}	3,240 ^{bcd}	832 ^b	806 ^{bcd}	801 ^{abcd}	819	803 ^{ab}	806 ^{ab}
Cultivar 11	1,718 ^{bcd}	6,459 ^{abc}	3,853 ^{bc}	5,393 ^{abc}	3,691 ^{ab}	861 ^{ab}	829 ^{abcd}	808 ^{abcd}	823	823 ^{ab}	809 ^{ab}
Cultivar 12	1,741 ^{bcd}	6,325 ^{abc}	3,918 ^{bc}	5,626 ^{ab}	3,719 ^{ab}	860 ^{ab}	828 ^{abcd}	817 ^a	827	813 ^{ab}	808 ^{ab}
Cultivar 13	1,616 ^{cdefg}	6,468 ^{abc}	3,712 ^c	6,045 ^a	3,428 ^{abcde}	847 ^{ab}	832 ^{abc}	803 ^{abcd}	826	818 ^{ab}	810 ^{ab}
Cultivar 14	1,766 ^{bcd}	6,282 ^c	3,869 ^{bc}	5,730 ^{ab}	3,203 ^{bcd}	849 ^{ab}	825 ^{abcd}	805 ^{abcd}	826	812 ^{ab}	804 ^{ab}
Cultivar 15	1,319 ^{gh}	6,228 ^c	4,210 ^{abc}	5,181 ^{abc}	3,017 ^{cdefg}	831 ^b	806 ^{bcd}	791 ^d	817	797 ^{ab}	790 ^{ab}
Cultivar 16	1,376 ^{efgh}	6,920 ^{ab}	4,268 ^{ab}	4,521 ^c	2,873 ^{efg}	837 ^{ab}	804 ^{bcd}	793 ^{dc}	814	797 ^{ab}	789 ^b
Cultivar 17	1,610 ^{cdefg}	6,384 ^{abc}	3,942 ^{abc}	5,339 ^{abc}	3,532 ^{abc}	851 ^{ab}	834 ^{ab}	811 ^{abcd}	833	824 ^{ab}	839 ^a
Cultivar 18	1,592 ^{cdefg}	6,302 ^{abc}	3,825 ^{bc}	5,160 ^{abc}	3,371 ^{abcde}	848 ^{ab}	825 ^{abcd}	806 ^{abcd}	826	794 ^b	805 ^{ab}
Cultivar 19	1,300 ^{gh}	6,399 ^{abc}	4,144 ^{abc}	5,235 ^{abc}	2,942 ^{defg}	832 ^b	799 ^d	794 ^{bcd}	813	797 ^{ab}	786 ^b
Cultivar 20	1,886 ^{abc}	6,735 ^{abc}	4,183 ^{abc}	5,484 ^{abc}	3,209 ^{bcd}	853 ^{ab}	832 ^{abc}	802 ^{abcd}	824	811 ^{ab}	786 ^b
SEM	39.4	69.3	47.9	67.2	63.4	1.6	1.7	2.9	2.0	2.0	2.5
P-value	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.01	0.001	0.01

^{a-h}Values in the same column not sharing a common superscript are significantly different.

¹DMD = DM digestibility.

sampling of cultivars for quality across the months of April to September (inclusive) to accurately capture the potential of a cultivar. The development and adoption of plot harvesters equipped with NIRS, will have a

major effect on the potential to achieve this. The NIRS technique provides the opportunity to estimate large numbers of samples more rapidly than do conventional laboratory analytical methods; however, its reliability

Table 7. Application of the base economic value to the biological data

Variety	Spring € value	Midseason € value	Autumn € value	Quality € value ¹	Silage € value ²	Total economic merit (€/ha per yr)
Cultivar 1	-42.13	14.12	41.33	4.37	-8.28	9.41
Cultivar 2	-5.79	5.03	25.82	-15.64	-13.71	-4.30
Cultivar 3	64.17	-7.82	-10.21	-33.91	0.59	12.82
Cultivar 4	86.18	-0.83	-21.08	-19.95	8.91	53.22
Cultivar 5	68.21	8.07	13.05	51.58	-12.38	128.54
Cultivar 6	-72.37	-9.77	-17.76	-77.33	-20.71	-197.95
Cultivar 7	-5.26	-3.11	12.71	71.96	-6.57	69.74
Cultivar 8	28.31	4.83	-15.71	62.43	24.26	104.12
Cultivar 9	-23.24	-0.15	9.27	-35.95	2.53	-47.52
Cultivar 10	-49.07	4.29	19.16	-25.16	8.58	-42.19
Cultivar 11	14.17	-1.21	-20.05	36.70	12.03	41.64
Cultivar 12	17.58	-5.28	-13.35	39.07	21.01	59.02
Cultivar 13	-1.35	-0.92	-34.50	30.12	28.79	22.14
Cultivar 14	21.47	-6.58	-18.30	16.89	12.10	25.58
Cultivar 15	-46.32	-8.25	16.74	-56.65	-11.98	-106.46
Cultivar 16	-37.71	12.84	22.65	-60.76	-38.98	-101.95
Cultivar 17	-2.24	-3.47	-10.81	78.07	6.25	67.80
Cultivar 18	-5.00	-5.99	-22.89	-1.28	-4.07	-39.22
Cultivar 19	-49.25	-3.03	9.95	-66.27	-11.89	-120.49
Cultivar 20	39.63	7.22	13.98	1.71	3.51	66.05

¹Quality value is the sum of the quality value for the months of April to September (inclusive).

²Silage value is the sum of first- and second-cut silage values.

is dependant on calibrations that are well distributed and represent the range of expected variation in the constituent (e.g., DMD, CP, or water-soluble carbohydrate content) of interest (Stuth et al., 2003).

High persistency is desirable, as full cultivation and reseeding of pasture is expensive (Wilkins and Humphreys, 2003). Additionally, this may have an environmental cost, as less persistent cultivars must be replaced more frequently. Ground cover score is used as a guide to the density of a sward. A low ground score indicates an open sward, which may be more susceptible to poaching, trafficability problems, or ingress by weed grass, thus, comprising the longevity of the sward. This, however, is a subjective point in-time measurement. A requirement exists to measure the lifetime performance of cultivars under animal grazing and relate this to ground score or DM yield stability. Further research in this area would be beneficial to develop a concise and rapid estimate of persistency.

Overall Merit

In animal selection, Beard (1987) reported that genetic progress could be maximized in economic terms if selection were based on the method of index selection. Such a method of selection should be directed toward a breeding objective comprising the sum of the breeding values for traits of economic importance, weighed according to their relative economic values (Beard, 1987). The total merit index for grass selection will highlight the key areas of improvement, allowing breeders to further improve grass cultivars with a strong scientific basis for the emphasis that should be placed on each trait. The higher value of an additional 1 kg of DM in the spring and autumn compared with that of the midseason period (€0.15, €0.10, and €0.03/ha per yr, respectively) will result in the breeders selecting cultivars that provide a greater proportion of their total DM yield in the spring and autumn periods. The change in economic value for DMD across the months of April to September reflects the effect of a change in UFL and FV on the intake potential of grass as the season advances. Through the combination of the biological and economic data, the total merit index can provide the industry with clear guidance on economically optimum cultivars.

Spearman rank correlations tested the level of re-ranking between cultivars across scenarios. The ranking of the cultivars within each index and subsequent comparison to the base scenario showed that cultivar rank remained relatively stable across all scenarios. Rank correlation coefficients between the base (27c/L) and the 3 scenarios at a milk price of 22, 27, or 30c/L, ranged from 0.91 to unity (Table 8). This has impor-

Table 8. Rank correlation (above diagonal) between a cultivar performance for scenarios with fixed cows, fixed land, and varying DM yields at 3 milk prices

Scenario	Trait	Price	S1			S2			S3		
			Base			Fixed cows			Fixed land		
			30c/L	22c/L	27c/L	30c/L	27c/L	22c/L	30c/L	27c/L	22c/L
S1	Base	27c/L	1.0	0.98	0.97	0.98	0.93	0.97	0.90	0.92	0.97
		30c/L		0.97	0.97	0.99	0.93	0.97	0.91	0.93	0.94
	Fixed cows	22c/L			0.94	0.97	0.90	0.98	0.86	0.90	0.92
		30c/L			0.99	0.98	0.98	0.98	0.97	0.98	0.95
S2	Land fixed	27c/L				0.97	0.97	0.99	0.95	0.97	0.98
		22c/L				0.90	0.90	0.98	0.87	0.90	0.92
	11 t of DM	30c/L				1.00	1.00	0.96	0.99	0.99	0.97
		27c/L						0.96	0.99	0.97	0.99
S3	11 t of DM	22c/L						0.94	0.94	0.96	0.99
		30c/L						0.99	0.99	0.99	0.95
	15 t of DM	27c/L						0.95	0.99	0.99	0.97
		22c/L						0.97	0.95	0.98	0.97
		30c/L							0.95	0.99	0.98
		27c/L								0.98	0.98

tant implications for the use of a single economic index. As little or no re-ranking is occurring between indices, the developed economic values are robust. As a result, the total merit index is a reliable method to identify the cultivars that will make the greatest economic contribution to a grass-based milk production system, regardless of system, intensity, or price.

Ruminant meat systems, including beef and lamb, are highly dependant on grass-based production. A nondairy scenario was simulated to establish the overall cultivar ranking for each trait and, hence, the total merit of a cultivar. The r_s of this scenario relative to the base scenario was high ($r_s = 0.89$). Within the nondairy scenario, the economic values for DM yield (spring, midseason, autumn, first- and second-cut silage) and persistency, were similar to those of the base values. It was assumed that quality had no effect on animal performance; therefore, the economic values for quality differed from the base values. In reality, this is unlikely to be the case; however, due to limited availability of data in the literature on the effect of quality on liveweight gain, the effect on performance could not be quantified. Further research needs to be conducted to investigate the effect of sward quality on animal growth and performance for beef and lamb production systems.

Gilliland and Mann (2000) and McEvoy et al., (2009) have shown that perennial ryegrass cultivars will perform differently under different management regimens. This occurs mainly due to a high degree of genetic independence between DM yield of reproductive growth (which is a major determinant of silage DM yield) and DM yield of vegetative growth (Wilkins and Humphreys, 2003). When selecting for silage yield alone, a separate index is necessary to identify the optimum cultivars in a silage-only system. The economic values calculated for a silage-only system resulted in an increase in the economic value of silage compared with the base values, but only the silage economic value will be considered when selecting cultivars for this type of system. The resulting economic value for first- and second-cut silage yield in a silage-only system were €0.099 and €0.102, respectively, per additional 1 kg of silage DM yield/ha.

Implications

In order to assist the farmer in optimizing production from a sward, many countries conduct independent grass cultivar evaluation trials. These trials identify cultivars that are useful, or otherwise, to conditions within that particular country (Laidlaw and Reed, 1993). Grass breeders tend to select and breed cultivars that exhibit traits that will achieve a Recommended List rating. The development of an evaluation protocol that captures

the traits of interest in the economic index would allow cultivars to be ranked based on their total economic merit within the evaluation trials and, subsequently, selected based on their potential to increase the overall profitability of a grazing system.

The total merit index, in conjunction with a recommended list that captures the required traits, will present the farmer with concise economic information for cultivars that are most suitable to national conditions. Based on the individual system requirements, a farmer can then select the cultivar that will provide the greatest economic advantage to the system. In addition, the total merit index will provide breeders with information on the relative importance of one trait relative to another and, thus, allow resources to be used in the best possible manner to allow the greatest economic gains for future breeding progress.

CONCLUSIONS

The contribution of each trait to the overall economic merit of a cultivar and the resulting contribution of that cultivar to a grass-based production system can now be concisely defined. Based on the total economic merit, cultivars that provide the highest economic contribution to a system can be identified. This will enable cultivars to be ranked on their total economic merit within a grass-based production system. The total merit index will allow the advantages and shortcomings of each recommended grass cultivar to be quantified in economic terms. This will provide clear direction to grass breeders, industry stakeholders, research scientists, and farmers. Ultimately, it allows one single index to be used with confidence across grass-based systems, with changes in intensity and price.

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