Calculation of sheep and beef economic weightings for the seasonal dry matter production trait for use in a forage-cultivar selection decision-support tool

Cameron I. LUDEMANN
Cameron Ludemann Consulting, Arnhem, The Netherlands
cameronludemann@gmail.com

Abstract

Development of an independent forage-cultivar selection decision-support tool (DST) could transfer substantial benefits to sheep and beef (S&B) farmers. This study took a first step toward development of a S&B DST by describing and assessing one method of calculating S&B forage trait economic weightings. The 'change in livestock production' economic weighting method was applied to the Otago/Southland Breeding Finishing Farm Class in this study. The trait economic weightings for the seasonal dry matter (DM) production trait were applied to cultivar performance trial data using the DairyNZ Forage Value Index (FVI) framework. Analysis indicated the rankings of perennial ryegrass cultivars using the DST method varied from those calculated using the DairyNZ FVI when using the same seasonal DM production data. It was concluded the change in livestock production method is an option for calculating the economic value of traits for evaluation of perennial ryegrass cultivars that are more applicable to S&B farmers. However, this method should be applied to a wider range of S&B Farm Classes before a decision is made as to its suitability for the New Zealand S&B industry.

Keywords: FVI, *Lolium perenne*, plant breeding, yield

Introduction

The New Zealand dairy industry has had an independent forage evaluation system (DairyNZ Forage Value Index-FVI) since 2011 (Chapman et al. 2017). This functionality allows the dairy industry to provide farmers with an independent evaluation of cultivars of perennial ryegrass for selection decisions and provide plant breeders a signal to guide their breeding objectives. The value of the DairyNZ FVI has been estimated at about $160 million each year (DairyNZ 2017). Development of a similar forage-cultivar selection decision-support tool (DST) could transfer substantial benefits to sheep and beef (S&B) farmers given the high dependence the New Zealand S&B industry has on home-grown feed.

The seasonal dry matter (DM) production trait was introduced into the DairyNZ FVI in 2011 and, since then, a framework ('DairyNZ framework') has been refined to include new forage traits of metabolisable energy content (Ludemann et al. 2018) and persistence (Ludemann & Chapman 2019). Key components of the performance of cultivars of perennial ryegrass are converted into units farmers are familiar with and that can be applied across traits. This process involves calculating the change in farm operating profit for the unit change in the trait to convert cultivar performance into a common unit (dollars) that is applicable among different traits. Various methods of calculating the economic values of forage traits have been described (McEvoy et al. 2011; Smith & Fennessy 2011; Ludemann & Smith 2016; O'Donovan et al. 2016; Chapman et al. 2017; Leddin et al. 2018; Ludemann & Chapman 2019). Each method has advantages and disadvantages.

Plant breeders and those who want to compare the overall performance of pasture plant cultivars should consider the marginal value of every extra kilogram of DM produced (Lewis et al. 2020). This approach may use the value of feed substitutes – 'replacement cost' method- as approximations for the economic value of pasture DM (Hardin & Johnson 1955; Lewis et al. 2013; Ludemann et al. 2013). While simple to calculate, the replacement cost method (using barley prices) may accurately reflect neither inter-seasonal variations in value of pasture to farmers nor the greater opportunity cost of pasture if it is consumed by livestock and converted into products (Ludemann & Smith 2016). In contrast, Smith and Fennessy (2011) estimated the relative weightings for forage traits through surveys of experts using discrete choice experiments. This involved asking experts which of two options they preferred when some of the options had known economic values, so relative weightings of different traits could be estimated. An advantage of this method is that it may elucidate relative weightings of traits that are difficult to measure the economic value for, however the relative rankings may differ between certain groups of people surveyed in certain traits (Smith & Fennessy 2011).

An alternative non-survey method of calculating the value of seasonal DM is to model the expected value of the change in livestock production (the 'change in livestock production' method) (Ludemann & Smith

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2016). The 'change in livestock production' method requires more data and a better understanding of the classes of livestock that represent the region under examination than the replacement cost method. The 'change in livestock production' method may provide a more realistic assessment of the inter-annual variability in value of traits without the need for either expensive farm experiments or detailed farm systems models, which provide results that are specific only to one situation. Achieving a balance between the complexity of the system modelled and adequacy of information for decision making is required when developing models (Behrendt et al. 2013). The change in livestock production method was highlighted by Ludemann and Smith (2016) as an alternative to detailed farm system models, on farm experiments and replacement cost methods. The change in livestock production method can provide a good balance between the cost of estimation and its applicability to a wide range of farms, whilst still accounting for the inter-seasonal variability of the economic value of DM production. The purpose of this study is to assess the change in livestock production method in the calculation of perennial ryegrass economic values for seasonal DM production in an approach similar to that developed for the DairyNZ FVI. The method was applied to the Otago/Southland breeding finishing Farm Class (Beef +Lamb NZ 2019) to provide context. The hypothesis tested was whether rankings of cultivars using the S&B DST would vary from those calculated using the DairyNZ FVI using the same seasonal DM performance data.

Materials and Methods

Calculation of the sheep and beef forage-cultivar decision-support tool (DST)

Equation 1 was used to calculate the DST of perennial ryegrass cultivars (i):

$$DST^{i} = \sum\left(PVDM_{a}^{ix} \times EWDM_{a}^{ij}\right) \quad \text{[Equation 1]},$$

where the $PVDM_a^{ix}$ were the same performance values for the seasonal DM production trait as those used in the DairyNZ FVI when it included only this trait (Chapman et al. 2017). The difference between the 2017 DairyNZ FVI equation and DST (Equation 1) was the use of trait economic weights (*EW*) for the seasonal DM production trait ($EWDM_a^{ij}$) for the DST as opposed to the use of trait economic values (*EV*) for the 2017 DairyNZ FVI. The $EWDM_a^{ij}$ equation for the DST still included economic value for DM ($EVDM_a^{ij}$) as shown in Equation 2. However, the economic values were multiplied by industry weighting factors (IWF) ($IWFDM_a^{ij}$) for a given season '*a*' and region '*j*' for each cultivar '*i*':

$$EWDM_{a}^{ij} = EVDM_{a}^{ij} \times IWFDM_{a}^{ij} \quad \text{[Equation 2]}.$$

At a high level, the $EVDM_a^{ij}$ (like the DairyNZ FVI) was calculated as:

$$EVDM_{a}^{ij} = \frac{\text{Change in farm operating profit}}{\text{Unit change in forage trait}} \quad \text{[Equation 3]}.$$

In Equation 3, the change in DM production is presented in units of kg DM grown and the change in farm operating profit is given in units of NZ dollars. Further explanation of how Equation 3 was calculated for a S&B context is included in the next two sections.

Change in livestock production economic value method

The change in livestock production economic value ($\Delta ProdEVDM_t$) for period *t* was calculated based on Equation 4:

$$\Delta ProdEVDM_{t} = \frac{DMME}{\left(^{E}/_{U}\right)} \times MP \quad \text{[Equation 4]}.$$

where *DMME* is the pasture DM metabolisable energy content (in MJME/kg DM), *E* is the energy required for the class of livestock to produce the product (in MJME/unit product calculated using standard CSIRO (2007) equations), *U* is the utilisation of pasture DM by the class of livestock (expressed as a proportion of DM available), and *MP* is the market price of the product produced by that class of livestock. This equation follows principles similar to those employed by Ludemann and Smith (2016). However, instead of applying the change in livestock production economic value method to changes in carcase weight alone - as was the case for Ludemann and Smith (2016) – a generalised equation was developed to include other products such as live weight and body condition score gains. Parameters used to calculate $\Delta ProdEVDM_t$ for each class of livestock are included in Table 1 for sheep and Table 2 for cattle enterprises.

Many breeding animals are not sold (such as non-cull, breeding ewes and cows) during the year as shown in Tables 1 & 2. Therefore, the direct benefits of additional DM cannot be calculated based only on changes in carcase weight or liveweight sold. To overcome this limitation, the value in livestock production from non-cull ewes and breeding cows was based on changes in body condition score. The effect of changes in body condition score on reproductive performance was shown to be variable and probably have a curvilinear relationship by Kenyon et al. (2014). This situation complicates calculation of the economic value of pasture DM based on changes in body condition score. Therefore, the opportunity cost of feed for otherwise gaining body condition was used to estimate the value

Table 1 Parameters used for each class of sheep livestock in the calculation of the economic value of dry matter (DM) using the 'change in livestock production' method where ES means early-season, MS means mid-season and LS means late-season lambs.

Abbreviation	Parameter	Units	Class of livestock							
			Weaned lamb[1]	ES prime lamb[2]	MS prime lamb[3]	LS prime lamb[4]	Replace-ment ewe	Prime hogget	Cull ewes	Mixed age ewe lamb
	Product (name and units)	Name and units	Live weight (kg)	Carcase weight (kg)	Carcase weight (kg)	Carcase weight (kg)	Live weight (kg)	Carcase weight (kg)	Carcase weight (kg)	1 body condition score (BCS)
-	Baseline units of product	Units	28.0	17.3	17.3	17.3	65.5	19.3	26.2	3.0
E	Energy requirement per unit of product[5]	MJME/unit product	35.4	101.7	105.1	112.1	73.0	145.4	246.3	427.8
MP	Market price of product[6]	$/unit product	2.98	6.79	6.46	6.26	2.70	6.50	3.40	15.82
U	Utilisation of pasture DM	Proportion of offered feed consumed	0.60	0.60	0.60	0.60	0.65	0.65	0.70	0.70
DMME	Annual average pasture energy content[7]	MJME/kg DM	10.60	10.60	10.60	10.60	10.60	10.60	10.60	10.60

[1] Value of weaned lamb based on weaned lamb sale price off-ewe.
[2] These lambs received ES lamb prices related to the months of August and end of September, with 5% of lambs sold in this season.
[3] These lambs received MS lamb prices related to the months of October through to the end of January, with 35% of lambs sold in this season.
[4] These lambs received LS lamb prices related to the months of February through to the end of July, with 60% of lambs sold in this season.
[5] Used CSIRO (2007) equations.
[6] Market prices of products came from the Beef +Lamb NZ Economics Team and were 5-year rolling average values (inflation adjusted) except for the market price of liveweight of replacement lambs and the market price of change in body condition score in ewes. The cost of the these were calculated as the total energy required per unit product multiplied by the barley replacement cost of feed per unit energy utilised.
[7] Based on data from sheep and beef farms from Upsdell et al. (2017).

of a change in body condition score. The cost of gaining condition was based on the equivalent energy cost of feed barley (*Feed\$*$_t$). The *Feed\$*$_t$ (in \$/MJME utilised) was calculated as:

$$Feed\$_t = \frac{MPF_t + AFE_t}{1000kg\_tonne \times FProp_{DM} \times FProp_U \times FE_t}$$

[Equation 5].

As shown in Table 3, the MPF_t is the real 5-year rolling average market price of feed at point *t* in time, AFE_t is the real 5-year rolling average additional feed expenses (such as repairs and maintenance and transport costs of feeding equipment or additional labour to feed it out) (in dollars per tonne fresh weight for the purchased feed), the *1000kg_tonne* represents the conversion factor for tonnes to kilograms, $FProp_{DM}$ is the barley feed DM as a proportion of fresh weight, $FProp_U$ is the proportion of purchased barley feed DM utilised by livestock, and FE_t is the barley feed energy content in megajoules of metabolisable energy per kilogram of DM.

Industry weighting factors

Industry weighting factors are used in animal genetic-selection indices to weight the economic value of a trait by a factor that reflects the region being modelled (Byrne et al. 2012). Similarly for the present study, IWF were included in the EW calculation to weight the EV (calculated for each class of livestock using the 'change in livestock production' method) in order to reflect the Farm Class under investigation. To illustrate the rationale for IWF, consider the following scenario. If there were an increase in pasture production of 100kg DM across a sheep and beef farm that had improved cultivars in every paddock, then not all the extra DM may be consumed by one class of livestock. In a dairy farm system with fewer classes of livestock, it may mean use of IWF is of less concern when estimating the economic value of forage traits (therefore the EW is equal to the EV). However, for a sheep and beef farm system with more classes of livestock we must account for the economic value of extra DM grown and consumed by those classes of livestock.

The IWF were, therefore, calculated as the

Table 2 Parameters used for each class of cattle livestock in the calculation of the economic value of dry matter (DM) using the 'change in livestock production' method.

Abbreviation	Parameter	Units	Class of livestock						
			Weaner calf sold store	Replacement heifers change in live weight	Store cattle sold 1-1.5 years	Prime cattle-P grade-heifer/steer	Prime cattle-M grade-bull	Mature cow body condition score (BCS)	Cull cow sold prime
	Product (name and units)	Name and units	Live weight (kg)	Live weight (kg)	Carcase weight (kg)	Carcase weight (kg)	Live weight (kg)	BCS	Carcase weight (kg)
-	Baseline units of product	Units	210.0	310.0	310.0	194.4	194.4	5.0	276.6
E	Energy requirement per unit of product[1]	MJME/unit product	42.7	49.6	64.1	122.8	122.0	1748.6	130.9
MP	Market price of product[2]	$/unit product	3.49	1.83	3.49	5.49	5.35	64.68	4.11
U	Utilisation of pasture DM	Proportion of offered feed consumed	0.60	0.70	0.70	0.70	0.70	0.70	0.70
DMME	Annual mean pasture energy content[3]	MJME/kg DM	10.60	10.60	10.60	10.60	10.60	10.60	10.60

[1] Used CSIRO (2007) equations.
[2] Market prices of products came from the Beef +Lamb NZ Economics Team using 5-year rolling average values (inflation adjusted) except for the market price of liveweight of replacement heifers and the change in body condition score in cows. The cost of these were calculated as the total energy required per unit product multiplied by the barley replacement cost of feed per unit energy utilised.
[3] Based on data from sheep and beef farms from Upsdell et al. (2017).

Table 3 Assumptions used in the calculation of Feed$t for the barley replacement cost method.

Abbreviation	Description	Units	Value	Reference
MPF_t	5-year (Sept 2014 to Aug 2019) mean real market price of barley feed for t years.	$/tonne	386	DairyNZ economics team
AFE_t	Additional barley feeding expenses (on top of market price) for *t* years[1].	$/tonne present day value	25	
$FProp_{DM}$	Barley dry matter as a proportion of fresh weight.	kg DM/kg fresh weight	0.90	Rayner (2007)
$FProp_U$	Proportion of barley utilised by livestock.	kg consumed/kg offered	0.95	Rayner (2007)
FE_t	Mean barley metabolisable energy content.	MJME/kg DM	13	Rayner (2007)
Feed$t	Mean replacement cost of feed per unit of energy utilised.	$/MJME utilised	0.04	
$PProp_U$	Proportion of pasture utilised by livestock.	kg consumed/kg offered	0.70	Byrne et al. (2012)

[1] Includes costs such as transporting, handling and feeding out barley.

proportions of total pasture DM energy consumed in each month and season by each class of livestock. The breeding ram/bull and minor classes of livestock did not have EW calculated because in total they made up less than 2% of pasture DM energy consumed and would, therefore, have an insignificant effect on overall trait EW. The IWF were calculated using CSIRO (2007) livestock energy requirement equations and the mean number of livestock and livestock productivity factors that represented the region of interest. For this study, data from the 'Otago/Southland Finishing Breeding Farm Class' were used (Beef +Lamb NZ 2019). While in this study, the IWF were calculated based on proportion of extra dry matter consumed by each class of livestock, there is flexibility to apply more weighting on certain classes of livestock if deemed appropriate.

For instance, in late spring, an IWF of 1 could be applied to the lamb classes of livestock if the decision maker deemed it appropriate for their farm system.

Statistical analysis

Perennial ryegrass cultivars eligible for the 2020 DairyNZ FVI lists were included in analysis of the DST calculation. The absolute DST and DST rankings of cultivars were compared with the absolute FVI and FVI rankings of the 35 cultivars in the 2020 DairyNZ FVI for the Lower South Island. Comparisons were made using correlation coefficients of all cultivars, and mean values for three functional groups were calculated. The functional groups included mid-heading diploids, late-heading diploids and tetraploids (Wims et al. 2017). Three scenarios for the change in livestock production DST were simulated to test sensitivity of cultivar rankings to key assumptions. Scenario 1 assumed the body condition score component of the calculation for economic value of seasonal DM was unchanged. In Scenario 2, the opportunity cost of otherwise gaining body condition score in breeding ewes and cattle was set to zero (as opposed to the $0.04/MJME utilised values used in Scenario 1) because pasture DM in late spring was in much greater supply than livestock demand. Scenario 3 was the same as Scenario 2 except that a 30-day delay in ewe mating date (from the 20 April date used for Scenarios 1 and 2) was made. This change was included to assess how applicable DST cultivar rankings at a regional level may be to famers with different lambing dates to those assumed in the model.

Results

The IWF for the sheep (Table 4) and cattle (Table 5) classes of livestock indicated that the 'breeding' classes of livestock such as replacement-ewe lambs, mixed-age ewes and breeding cows consumed most of the energy

Table 4 Industry weighting factors* for the sheep livestock classes in the calculation of the sheep and beef forage-cultivar decision-support tool for Scenario 1.

Season[1]	Class of livestock							
	Weaned lambs	Prime lamb (Early-season)	Prime lamb (Mid-season)	Prime lamb (Late-season)	Replacement-ewe lamb	Prime hogget	Cull ewe	Mixed-age ewe
Winter	0.00	0.00	0.00	0.00	0.22	0.01	0.13	0.54
E Spring	0.26	0.00	0.00	0.00	0.17	0.00	0.09	0.35
L Spring	0.36	0.00	0.01	0.02	0.15	0.00	0.06	0.25
Summer	0.00	0.01	0.07	0.15	0.24	0.01	0.07	0.29
Autumn	0.00	0.00	0.00	0.02	0.23	0.02	0.12	0.48
Annual	0.12	0.00	0.02	0.05	0.20	0.01	0.09	0.37

* Industry weighting factors (IWF) do not include breeding rams/bulls and minor classes of livestock in this table, hence annual IWF of sheep and cattle do not sum to 1.
[1] As defined by Chapman et al. (2017), where E=Early and L=Late.

Table 5 Industry weighting factors* for the cattle livestock classes in the calculation of the sheep and beef forage-cultivar decision-support tool values for Scenario 1.

Season[1]	Class of livestock						
	Weaner calves sold store live weight	Replacement heifers change in live weight	Store cattle sold 1-1.5 years	Prime cattle-P grade-heifers /steers	Prime cattle-M grade-bulls	Mature cow body condition score	Cull cows sold prime
Winter	0.00	0.02	0.02	0.00	0.01	0.04	0.00
E Spring	0.01	0.01	0.01	0.00	0.01	0.07	0.01
L Spring	0.02	0.01	0.01	0.00	0.01	0.08	0.01
Summer	0.03	0.01	0.01	0.00	0.01	0.08	0.01
Autumn	0.01	0.01	0.02	0.00	0.01	0.06	0.01
Annual	0.01	0.01	0.01	0.00	0.01	0.07	0.01

* Industry weighting factors (IWF) do not include breeding rams/bulls and minor classes of livestock in this table, hence annual IWF of sheep and cattle do not sum to 1.
[1] As defined by Chapman et al. (2017), where E=Early and L=Late.

throughout the year. For instance, 20% of total energy consumed was by replacement ewe lambs, and 46% was consumed by mixed age ewes and cull ewes. In total, lambs sold store or prime consumed 18% of the energy. Breeding cows consumed the most energy of the cattle class of livestock, with consumption of 7% of the total energy consumed on the farm.

The trait economic weightings for the seasonal DM production trait (Table 6) varied by calculation method. Of the S&B calculations, Scenario 3 showed the least inter-seasonal variability with a range of \$0.07/kg DM grown, compared with \$0.08/kg DM grown for Scenario 2 and \$0.11/kg DM grown for Scenario 1. All three scenarios assessing changes in production showed less inter-seasonal variation than the 2020 DairyNZ DM economic values, which had a seasonal range of \$0.41/kg DM grown.

The greatest overall mean DST was calculated for the late-heading diploid cultivars using Scenario 1 (\$273/ha/year) (Table 7). In contrast, the tetraploid functional group had a mean value of \$112/ha/year when calculated using the DairyNZ FVI method giving it the least valuable DST of any method or functional group (Table 7). The functional group that consistently had the greatest DST across methods was the late-heading diploid group followed by the tetraploid group (Table 7).

Regression coefficients of results in Table 8 indicate there were differences in the absolute values, order and star ratings of cultivars among the scenarios and methods tested. The greatest differences were seen between the cultivar star ratings using the DairyNZ FVI method and Scenario 1 using the DST (R^2=0.92). To put this R^2 value into perspective, the DairyNZ FVI scenario had five cultivars in the 5-star rated category of which two of these cultivars were not categorised as 5-star rated using the Scenario 1 DST method. Furthermore, the DairyNZ FVI had nine cultivars in the

Table 6 Seasonal dry matter trait economic weights or economic values using the forage-cultivar decision-support tool (DST) and DairyNZ FVI methods of calculation for the Otago/Southland Breeding Finishing Farm Class.

Season[1] (where E=Early and L=Late)	Length of season (months)	Trait economic weights (in \$/kg DM grown) for various calculation methods			Trait economic value (\$/kg DM grown) DairyNZ FVI Lower South Island for 2020
		DST change in livestock production-Scenario 1	DST change in livestock production-Scenario 2	DST change in livestock production-Scenario 3	
Winter	2	0.25	0.25	0.25	0.42
E Spring	2	0.33	0.33	0.28	0.48
L Spring	2	0.36	0.27	0.27	0.19
Summer	3	0.29	0.29	0.32	0.07
Autumn	3	0.25	0.25	0.26	0.24

[1] As defined by Chapman et al. (2017)

Table 7 Absolute sheep and beef forage-cultivar decision-support tool (DST) values of different functional groups of perennial ryegrass with three scenarios for calculating trait economic weightings as compared with the 2020 DairyNZ Forage Value Index (where only the seasonal DM production trait performance data were included).

Functional group*	Number of cultivars	Mean absolute value (in \$/ha/year)			
		DST change in livestock production-scenario 1	DST change in livestock production-scenario 2	DST change in livestock production-scenario 3	2020 DairyNZ FVI for Lower South Island
Mid-heading diploid	13	170	162	170	113
Late-heading diploid	17	273	252	270	136
Tetraploid	5	186	177	190	112
All cultivars	35	222	208	222	124

[1] As defined by Wims et al. (2017).

Table 8 Regression coefficients of cultivars for the sheep and beef forage-cultivar decision-support tool (DST) under three scenarios compared with the 2020 DairyNZ Forage Value Index (where only the seasonal DM production trait performance data were included)

Cultivar parameter	The R^2 value for each calculation method[1]			
	DST change in livestock production-scenario 1	DST change in livestock production-scenario 2	DST change in livestock production-scenario 3	2020 DairyNZ FVI for Lower South Island
Absolute value	1.00	1.00	1.00	0.94
Order rankings	1.00	1.00	1.00	0.93
Star ratings[2]	1.00	0.99	0.99	0.92

[1] Regression coefficient of the values for perennial ryegrass cultivars compared with the change in forage-cultivar DST livestock production-scenario 1.
[2] Based on star rating system described by DairyNZ (2020).

4-star rated category of which four of these cultivars were not categorised as 4-star rated using the Scenario 1 DST method.

Discussion

Results of this study support the hypothesis that use of S&B economic weightings for the seasonal DM trait would result in different forage evaluation rankings of cultivars compared with using dairy economic weightings. This highlights the importance of having a forage evaluation system developed specifically for the S&B industry. The differences were typified by the differences in cultivars in each star rating group, and the regression coefficient of rankings of cultivars calculated using the lower South Island DairyNZ FVI being 0.93 when compared with the DST cultivar rankings using Scenario 1. Differences in cultivar rankings can be attributed to the differences in economic weighting for the seasonal DM trait, in the late spring and summer period. For instance, the DairyNZ FVI had economic values of $0.19/kg DM and $0.07/kg DM in late spring and summer respectively for the lower South Island seasonal DM trait. In contrast, the DST-Scenario 1 had economic weightings of $0.36 and $0.29/kg DM for late spring and summer, respectively. The main difference in relative seasonal weighting was because the economic values were calculated for a broader range of classes of livestock. Greater diversity in classes of livestock meant there were different economic values for the additional pasture DM at different times of year. A further contributor to this difference in relative weighting of seasonal DM traits in the DST was the use of barley energy costs as an estimate of the opportunity cost of gains in body condition score of the breeding classes of livestock. These classes of livestock were estimated to consume the majority of pasture DM throughout the year. Therefore, the greatest IWF were assigned to the economic values associated with the breeding classes of livestock.

There are advantages to using the equivalent barley energy cost to assess the value of additional DM (through increased body condition score of breeding classes of livestock). One advantage is that it is relatable to farmers, given many farmers know the value of barley supplements. Another advantage is that it overcomes the complexity of assessing the value of body condition score when the flow-on effects (on productivity) from changes in body condition score of breeding livestock may occur in another season or year. This is because the effects on productivity from a change in body condition score can be variable and are likely to be curvilinear (Kenyon et al. 2014). One drawback to the use of equivalent barley energy cost method is that it may not sufficiently account for variation in value of the seasonal DM trait (Ludemann & Smith 2016). Scenario 2 was, therefore, modelled to assess the effects of reducing the economic weighting of seasonal DM (from changes in the breeding livestock body condition scores) in late spring. This is a time when farmers are unlikely to use barley as a source of feed and late spring pasture supply is generally in excess of demand by livestock. It was, therefore, assumed in Scenario 2 that excess pasture supply in late spring could be used to improve body condition score of breeding livestock classes at a reduced (zero) cost. A comparison between Scenarios 1 and 2 revealed that similar rankings of cultivars (based on the DST Scenario 2) would be maintained even if the contribution of value from extra pasture DM was set to zero from the breeding classes of livestock. Indeed, the relative rankings of the three functional groups of cultivars were similar across scenarios with late-heading diploids generally having greater mean DST values than tetraploids and tetraploids having greater DST than mid-heading diploid cultivars. It must be acknowledged that these results are for a single trait, and inclusion of other traits such as metabolisable energy and persistence may alter these rankings (Ludemann & Chapman 2019). Consideration should also be given to the greater soil moisture and soil fertility requirements of tetraploid cultivars (Sugiyama 2006), especially in a hill-country environment. However, for the seasonal DM production trait, there appears to be stability of the rankings of cultivars to changes in economic weightings of the seasonal DM trait when using the DST method. This is an advantage when generalising results to a broader region in a forage evaluation system.

Analysis of Scenario 3 provides further rationale for the change in livestock production method being deployed at the regional level in a DST. The only difference in assumptions between Scenario 2 and 3 was that the mating date in Scenario 3 was 30-days later. The same rankings of cultivars (R^2 of 1.0 for cultivar order rankings) were estimated when Scenarios 2 and 3 were analysed. This result has important implications for the applicability of FVI results to farm systems with different average mating dates if a S&B farmer were to select their ryegrass cultivars based on a regional-level calculation of DST. Even if a farmer had a different mating date than assumed in the regional DST calculation, the relative rankings of cultivars would remain applicable to that farmer's situation.

The relative stability of forage evaluation systems to changes in trait economic weightings is not surprising. To the author's knowledge no published studies have compared rankings of cultivars when trait economic weightings have been calculated using assumptions for different farming enterprises (e.g. dairy versus S&B). However, each year when economic values are updated in the DairyNZ FVI, the rankings of cultivars tend to remain similar (although this effect is confounded by a concomitant inclusion of new trait performance data and new cultivars) (Ludemann 2019; DairyNZ 2020). Furthermore, studies that have assessed the effect of including new traits in the DairyNZ forage evaluation system indicated the rankings of cultivars were generally inelastic to the addition of traits, albeit with some variation by functional groups (Ludemann et al. 2018; Ludemann & Chapman 2019).

Considering the generalisability of the change in livestock production method described in this study and how relatable it can be to farmers to understand, the method lends itself well to use in calculation of the relative rankings cultivars of perennial ryegrass for the New Zealand S&B industry at a regional level. Although Scenario 1 exhibited some of the disadvantages expected when part of the economic weighting is based on equivalent barley costs (i.e. lack of inter-annual variability in economic values), Scenario 2 provided a method that overcame this drawback. Scenario 2, therefore, offers a feasible method for calculating the relative economic value of cultivars of perennial ryegrass based on the seasonal DM trait alone. However, before a decision is made as to what method of calculating the EV of seasonal DM traits is best for the S&B industry, it is important to first apply the method developed in this study to a wider range of Farm Classes. It is also advisable to compare these results with results calculated using alternative methods of calculation. Alternatives could include the use of the simpler replacement cost method (Lewis et al. 2013; Ludemann & Smith 2016) and/or the use of surveys of experts through discrete choice surveys (Smith & Fennessy 2014). The latter of these methods could also provide a framework for building consensus over the relative weightings of forage traits that are difficult to measure, or that are weighted by non-economic values (eg. environmental values).

Conclusions

Development of an independent S&B forage-cultivar DST could provide substantial benefits to New Zealand S&B farmers. This would come through improved cultivar selection at the farm level and better guidance for plant breeders as to which traits to focus on to provide the best on-farm return. This study took a first step toward development of a S&B forage value index in that it assessed one method of calculating forage trait economic weightings and applied them to the DairyNZ FVI system. The change in livestock production method was applied to the Otago/Southland Breeding Finishing Farm Class in this study for analysis and showed differences in rankings of cultivars when compared with the DairyNZ FVI. The change in livestock production method, therefore, offers an option for calculating the economic value of traits for evaluation of perennial ryegrass cultivars that are more applicable to S&B farmers. However, before a decision is made as to the suitability of this method for the New Zealand S&B industry, it should be applied to a wider range of S&B Farm Classes. While far from complete as a system, the present study shows the potential for a forage evaluation system to be developed for a range of S&B farms similar to the DairyNZ FVI.

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