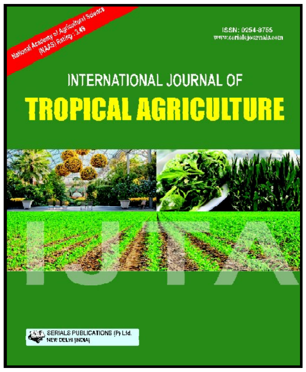

INTERNATIONAL JOURNAL OF TROPICAL AGRICULTURE

ISSN : 0254-8755

available at http: www.serialsjournals.com

Volume 36 • Number 4 • 2018

Periodically Variation in the Quality of a lucerne cultivar and its Relationship with Morphological and Maturity Estimates

H. B. Savaliya and J. R.Ramani

Department of Research and Development, Bombay Super Hybrid Seeds Limited
E-mail: hemangbaxi95@gmail.com

Abstract: To monitor seasonal changes in herbage quality, a lucerne-based pasture (*Medicago sativa*) was sampled in Gujarat every 2 weeks for 28 months. We take our Tinsali variety of the lucern. The pasture was strip-grazed and samples were taken from the regrowth of a previously grazed strip, ready for regrazing, for which herbage mass was estimated with a calibrated rising plate meter. Each sample was sorted into dead and green components, and the latter subsequently separated into grass and lucerne, and then into lamina plus leaflet and stem plus pseudostem fractions. Similarly, at each sampling date, quantitative maturity indexes – mean stage by count and mean stage by weight – were applied to grasses and lucerne. Samples were also analysed for in vitro dry matter digestibility (DMD), crude protein (CP), fibre and non-structural carbohydrates. The dataset was divided into morphological, maturity and nutritional variables. Analyses of variance by season for both groups of variables were carried out using year as a block. Multiple regression analyses were performed for each season between maturity indices and predictors of herbage quality. DMD, and consequently metabolisable energy (ME), was significantly lower in the autumn and CP was lower in the summer compared with overall averages, which were consistently high throughout the year (overall average of 11.5 MJ ME/kg dry matter and 20.6% CP). The sward had a higher proportion of lucerne during summer and autumn, than winter and spring (averages 59.3 and 48.8%, respectively). The highest leaf : stem ratio (2.82) was during winter and the highest green content (97.5%) was during spring. Grasses had a higher mean stage by count and mean stage by weight during spring–summer, whereas lucerne had a higher mean stage by count and mean stage by weight during summer–autumn. Morphological and maturity estimates predicted satisfactorily the changes in the energy and fibre within season, but CP content was not well predicted in summer or winter. These results provide the basis for tactical grazing practices with further calibration.

INTRODUCTION

Herbage nutritional quality at any time is the weighted average of the proportions of plant components and their nutritive value. Sward quality changes seasonally and dynamically when physiological changes take place in the plants, and grazing or harvesting conditions interact with those changes (Nelson and Moser 1994). Matching herbage mass and quality with the nutritional requirements of grazing animals is one of the key challenges facing graziers. Tactical decisions within grazing systems are often based on scant information about herbage quality, in spite of its importance in influencing herbage intake and animal performance (Pearson 1997). For this reason, a systematic characterisation of herbage quality variables on sheep and beef cattle farms in four regions of New Zealand has been undertaken recently (Litherland *et al.* 2002).

The need for estimating herbage quality is well recognised by graziers and pastoral researchers. Recently, alternative and faster analytical methods than the traditional laboratory analysis have been used, such as near infrared reflectance spectroscopy (Corson *et al.* 1999). Others have established quantitative relationships between maturity stages and herbage quality in non-defoliated grasses (Berg and Hill 1989; Sanderson and Wedin 1989; Sanderson 1992; Elizalde *et al.* 1999) and legumes (Hintz and Albretcht 1991; Owens *et al.* 1995; Sulc *et al.* 1997) and less frequently in grazed pastures (Smart *et al.* 2001). Similarly, the relationships between maturity and accumulated degree days (Frank and Hofmann 1989; Smart *et al.* 2001) and water stress (Lynk *et al.* 1990) have also been reported. As forage matures, the general trend is for decreasing leaf : stem ratio (Nelson and Moser 1994) both in grasses and legumes. However, maturity is not a clear concept in multispecies pastures, as different maturation patterns have been widely reported for different plant species under similar climatic conditions (Sanderson 1992). The higher contribution of stems and the decrease in their quality with increasing maturity is associated with an increase in neutral detergent fibre content (NDF) and a decline in digestibility within the herbage (Sanderson and Wedin 1989). Argentinean studies of pasture quality have shown that NDF content is a good predictor of dry matter in vitro digestibility (DMD) for lucerne, lucerne–grass pastures and winter and summer fodder crops (Pagella *et al.* 1996). Herbage quality is affected by grazing management (Saul *et al.* 1999; Schlegel *et al.* 2000; Frame *et al.* 2002), and intensive grazing is a key tool to maintain high nutritional value of pastures (Machado *et al.* 2005), keeping the sward immature with a greater leaf : stem ratio (Nelson and Moser 1994; Clark 1995; Smart *et al.* 2001) by preventing excessive development of structural tissue which may lead to a decline of digestible contents (Hodgson and Brookes 1999). Herbage quality is a concept that includes multiple factors in addition to herbage composition, such as nutrient digestion and diet selection (Bush and Burton 1994). However, in this paper, the term herbage quality is restricted to crude protein (CP, %), metabolisable energy (ME) content [ME MJ/kg dry matter (DM)], DMD, NDF (%) and non-structural carbohydrates values (NSC, %).

Lucerne-based pastures are widely used in Argentina (Romero *et al.* 1995; Kloster *et al.* 2000) and Australia (FitzGerald 1979; Reeve and Sharkey 1980), where they are especially noted for their high soil water extraction capability (Dolling *et al.* 2005). Considering the relevance of such pastures, the main objective of this experiment was to study the seasonal variation of pasture quality in a lucerne-based pasture under an intensive beef cattle grazing system in Argentina. Second, the relationship between nutritional variables and potential predictors from morphological and maturity variables was explored quantitatively.

MATERIALS AND METHODS

Herbage samples were taken regularly for analysis from a 3-ha lucerne-based pasture. The pasture was undersown to wheat in 2014, with 3 kg inoculated seed of lucerne (*Medicago sativa*) *var*. Tinsalli, 3 kg seed of Barmasi and 3 kg seed of raaj-3 lucerne. A crop of hay was taken in February 2016. Grazing and herbage sampling started in March 2016 and continued until July 2018.

Throughout the 2 years of sampling, the pasture was rotationally grazed in strips daily by a variable number of Hereford steers. The grazing interval for individual strips was between 21 and 55 days, reflecting seasonal differences in herbage accumulation rate. Representative samples of herbage were taken, every 2 weeks from March 2016 to July 2018, from previously grazed strips which were ready to be regrazed with a target pregrazing herbage mass of 1700 kg DM, (Litherland *et al.* 2002; Machado *et al.* 2005).

At each strip sampling, herbage mass (kg DM/ha) was estimated with a rising plate meter, calibrated against herbage mass (cut 4 cm above ground level) for the same period and experimental site (Machado *et al.* 2003) according to Earle and McGowan (1979) using eight paired samples for plate predictions. Fifty random herbage samples were cut to 4 cm above ground level from the same strip using a knife, bulked in a plastic bag and refrigerated immediately. After thorough mixing in the laboratory, a subsample (0.4 kg) was taken and divided into two parts. The first was sorted into dead (senescent tissues) and green herbage. Subsequently, the green pool was separated into grasses and lucerne, and then divided into grass lamina, lucerne leaf, grass sheath and stem and lucerne stem fractions. The weed component was negligible and was not considered. These fractions were oven-dried (48 h at 60°C), weighed and expressed as dry matter percentage as done by Astigarraga *et al.* (2002). The other fraction was subdivided into two subfractions. One was freeze-dried and analysed for DMD (Tilley and Terry 1962); CP was determined by multiplying the N concentration (Micro Kjeldhal method: AOAC 1960) by 6.25; NDF was determined by the method of Goering and Van Soest (1970); and NSC was determined by the anthrone method (Pichard and Alcalde 1990). The other subfraction was sorted into components as previously described, and samples were then freeze-dried. Five samples per season of each component were randomly selected from the whole set of samples and analysed for DMD and CP.

Fifty tillers per grass species and fifty lucerne shoots were collected at random at each sampling date. Descriptions of morphological stages of development were used for lucerne (Fick and Mueller 1989) and grasses (Simon and Park 1981). Values for each tiller and shoot were recorded and a mean arithmetic stage by count (MSC) per species was estimated. Additionally, tillers and shoots were oven-dried (48 h at 60°C) for each stage of development to estimate a mean stage corrected by weight (MSW). A regression analysis was performed between MSC and MSW for each species.

The dataset was grouped into morphological and maturity variables (herbage mass, dry matter content, green content, leaf : stem ratio, MSC or MSW, for each of the three species) and nutritional variables (DMD, CP, NDF and NSC) for the whole sward. Analyses of variance by season for individual variables were carried out using year as a block, with normally 5–6 values per season within years. Seasons were assumed to be: autumn = March–May, winter = June–August, spring = September– November and summer = December–February. Multiple regression analyses (‘stepwise’ model selection, alpha = 0.15) were performed for each season, using MSC or MSW as the maturity predictor alternatively. CP and ME of plant components were analysed with a completely random design within seasons. Following a significant F-test ($P < 0.05$), least- squares means were separated using least significant differences (Steel and Torrie 1980). All analyses used the SAS statistical analysis system (SAS/STAT 2001).

Additionally, a Bayesian smoothing analysis was applied to the complete dataset of herbage ME and CP using Flexi 3.1 (Wheeler and Upsdell 2003) to reveal possible underlying seasonal trends. This smoothing technique employs a variance components model to fit a constant term describing the general level of the variable and a correlated random term to describe departures of the curve from this constant. A cycle of 365 days with fluctuating covariance (the cycle is not forced to repeat exactly) and integral equal to 0 were used to model the data as: total fit of ME or CP = seasonal component + long-term component + error. Graphs are presented with confidence intervals (83% as default for Flexi) for the fitted curves (Wheeler and Upsdell 2003).

RESULTS

Seasonal change in nutritional quality

Between-year differences in whole-sward quality parameters were usually significant, so seasonal variations (Table 1) were corrected for between-year contrasts. DMD (and consequently ME) was lowest ($P < 0.05$) during autumn (Table 1), and for the rest of the year had a fairly stable value of ~11 MJ ME/kg DM (Table 1). CP was lowest ($P < 0.05$) during summer (Table 1), although variability for the rest of the seasons was greater than for ME content, with two peaks occurring at the start of winter and during spring. NSC was lowest during autumn, whereas NDF content was constant across seasons (Table 1).

Seasonal variations in contents of ME and CP in lucerne components are presented in Table 2. The ME of grass parts was lower ($P < 0.05$) in summer than other seasons, although ME of sheath and stem started to decrease during spring. Lucerne leaf ME decreased during autumn and lucerne stem ME during summer. Dead material had the lowest ME value during autumn. The ME content in leaf fractions (computed mean between lucerne and grasses) had a trend to lower coefficients of variation (CV) than stem fractions (9.4 and 13.3% CV, respectively). Lucerne fractions tended to be more stable in ME than grass fractions, while the ME of dead components had the highest seasonal variability. CP was lower ($P < 0.05$) in summer in most of the sward components, but in lucerne leaflets it was similar between seasons, and in grass stem it was also lower during autumn. CP content was highly variable between seasons in all sward components, with an average CV of 20.6%. However, CP in the lucerne leaf was the least variable component (10.6%).

Seasonal change of morphological and maturity variables

Seasonal variations in morphological and maturity variables in pasture, and in the alternative maturity indices for individual species, are shown in Table 3. Pregrazing herbage mass was similar through the seasons ($P > 0.05$) with an overall average of 1586 kg DM/ha (>4 cm above ground level). The pasture was dominated by lucerne throughout the year (62% of the green material). During summer and autumn, the sward had a higher proportion of lucerne and dry matter, with lower leaf : stem ratio and green content. This last variable also declined during autumn ($P < 0.05$).

Barmasi and Raaj-3 had a higher maturity status during spring and summer than in autumn and winter, using both MSC and MSW. Tinsaali was more mature during summer–autumn using MSC. A similar pattern was obtained for MSW but with spring also differing from winter.

Relationships between variables

DMD was significantly correlated with NDF, NSC and CP (overall correlation coefficients of –0.62, 0.41 and 0.36, respectively), and NDF content with NSC (–0.32) ($n = 56$). Best-fit equations from step-wise regression analysis within each season relating herbage quality variables and morphological and maturity variables of the pasture are presented in Table 4. During summer and autumn, nutritional variables were mostly predicted from morphological variables. CP could not be predicted either in summer or winter, and autumn presented a lower regression coefficient (R2 = 0.54) than spring. The content of NSC was only predicted significantly in spring. In the cases when MSW was selected, this could be replaced acceptably by the corresponding MSC without much loss of prediction capability, except for the case of DMD in winter.

A multivariate canonical correlation analysis (Matthew *et al.* 1994) was carried out to assess the overall relationship between nutritional and morphological-maturity variables. Table 5 shows the results based on maturity stage estimated by weight (MSW); results for maturity stage by count (MSC) were similar (data not shown). The first canonical factor based on MSW explained 27% of the raw variance of the nutritional variables and 77% of the multiple dispersion ($P < 0.01$). Tinsaali's maturity was substantially more important than other's maturity in the first canonical factor (Table 5), but the reverse was the case in the second canonical factor (data not shown).

DISCUSSION

Seasonal change in nutritional quality

The lucerne's quality of bulk harvests was maintained to a high standard throughout the experiment and was consistent between years, although CP content was lower in summer and ME and NSC in autumn. This general pattern is likely to be a consequence of at least two main factors. First, there were no obvious adverse climatic conditions during the study, with conditions being consistent between years (results not shown). Second, the grazing management carried out during this study ensured intensive use of the pasture area at animal production levels of 264 kg beef /ha.year, well above values for the region for cow–calf and fattening mixed systems (Di Nezio *et al.* 2003). Intensive use of pastures is a key tool to keep the sward immature by moderating the development of structural tissue (Nelson and Moser 1994; Clark 1995; Hodgson and Brookes 1999). The results are also in agreement with the seasonal nutritional observations in a New Zealand beef cattle finishing pasture (ryegrass and white clover) managed intensively over 3 years (Machado *et al.* 2005).

The observed CP levels throughout the seasons were similar to those obtained in pastures of similar characteristics managed under intensive rotational systems over 2 years in Argentina (Kloster *et al.* 2000), where the authors observed CP values by season of 23.7, 26.0, 25.8 and 23.4% CP for autumn, winter, spring and summer, respectively. The CP values of the present study clearly exceeded (except for the summer) the recommended CP content of herbage required for very young growing animals, i.e. 15–18% CP (Hodgson and Brookes 1999). Patterns of variation in the nutritive value of the bulk samples (Table 1) and of plant parts (Table 2) must be treated with caution, as sample numbers within seasons were not the same. However, they show that ME content of grasses fractions and lucerne stem declined during summer. In the case of grass stem there was some decrease during spring, in agreement with the changes in DMD observed by Mowat *et al.* (1965) in M. sativa and Berg and Hill (1989) in D. glomerata. Leaf components had a lower CV in ME content and less marked variation in CP, in comparison with that observed in stems. In a study carried out over two spring periods on lucerne (Christian *et al.* 1970), leaf had 4 and 19% CV values, and stem 23.0 and 40.5% CV values of DMD and CP, respectively.

Seasonal change of morphological and maturity variables

The higher proportion of lucerne during summer–autumn (75%) than winter–spring (48%) in this experiment is in agreement with the results of Kloster *et al.* (2000) in pasture of a similar composition (80 and 59% of lucerne in canopy DM for spring–summer and autumn–winter, respectively). This seasonal pattern is likely to be associated with the different growth patterns of the species and with the different factors for which grasses and lucerne in mixtures compete (McKenzie *et al.* 1999). Spring showed the highest level of green percentage, similar to that observed by Kloster *et al.* (2000) in a lucerne–grass pasture under grazing. These authors reported averages of 87.5 and 99.0% of green material for autumn–winter and spring–summer, respectively, for the 2 years of measurement. Pasture DM increased significantly during spring–summer, which is in agreement with results reported by Christian *et al.* (1970).

The intensive use of the pasture in this study meant that it was maintained in a relatively immature state, and the relationship between this condition in lucerne-based pastures and bloat incidence has been established (Thompson *et al.* 2000). However, on the beef cattle unit where the present study was developed, bloat was controlled effectively (Majak *et al.* 2001), and no cases were reported during the trial.

Leaf : stem ratio was lowest in summer. High temperature in this season promotes plant maturation leading to proportionally more stem growth (Buxton and Fales 1994) and a marked decline in the quality of the stems and increased senescence of green material (Christian *et al.* 1970; Nelson and Moser 1994). Clearly, the combination of species in the mixture used in this experiment resulted in a spread of pasture maturity. Although the three species were most mature during summer, grasses increased in maturity index during the spring, and lucerne extended its maturity through the autumn (Table 3). Increased temperature in summer associates positively with plant maturity, but maturity integrates multiple environmental factors and represents the physiological and ecological status of the plant stand (Sanderson 1992).

There was a very high correlation between MSC and MSW, with an overall correlation between species of r = 0.94 (n = 56), which is in agreement with that reported by others using lucerne pasture (Mueller and Fick 1989). MSW has been shown to be the best maturity predictor (Fick *et al.* 1994), but measurement of MSC is less time consuming, and is simply the arithmetic average of the quantitative maturity stages of individual tillers and stems. As MSC does not take into account the change in size of the stems and tillers, this could be an important bias when substantial morphological plant changes are occurring. One study under grazing conditions (Smart *et al.* 2001) reported that MSC became an increasingly poor predictor of leaf: stem ratio as grazing progressed in the growing season of a big bluestem pasture. The prevention of maturity by intensive grazing in the present study is likely to have contributed to the high association between the two methods used for obtaining maturity estimates.

Prediction of nutritive value

The overall correlation between NDF and DMD is in agreement with the observation of Pagella *et al.* (1996). As expected from the seasonal changes in nutritional variables (Table 1) and morphological and maturity variables (Table 3), nutritional predictors changed seasonally (Table 4). For this reason, no significant predictor could be identified when the overall dataset was used without grouping by season (result not shown). Changes in grasses became important during spring, due to earlier maturity than lucerne (Table 3), when the grass stem and sheath components started to decrease in ME and CP content (Table 2). Stems decrease in quality faster than leaves in most forage plants, especially when plants approach maturity (Nelson and Moser 1994), and a close inverse association between MSW and DMD of lucerne stem has been demonstrated (Sanderson and Wedin 1989; Sanderson *et al.* 1989).

Table 1
Seasonal variation of nutritional variables in a lucerne

Within rows, means followed by different letters are significantly different at P = 0.05

	Autumn (n = 11)	*Winter (n = 16)*	*Spring (n = 12)*	*Summer (n = 12)*	*s.e. (pooled)*
In vitro digestibility (% of DM)	71.7a	76.8b	78.8b	75.7ab	1.83
Metabolisable energy (MJ ME/kg DM)	10.8a	11.6b	11.9b	11.4ab	0.27
Neutral detergent fibre (% DM)	34.5	33.7	33.3	32.2	1.60
Crude protein (% DM)	21.5b	22.2b	22.0b	17.3a	1.00
Non-structural carbohydrates (% of DM)	6.3a	8.8b	10.0b	8.6b	0.58

Table 2
Seasonal variation in contents of metabolisable energy and crude protein in different sward components

Component of sward	*Autumn (n = 11)*	*Winter (n = 16)*	*Spring (n = 12)*	*Summer (n = 12)*	*s.e. (pooled)*	*CV*[A]
			Metabolisable energy (MJ ME/kg DM)			
Grass lamina	10.2ab	12.1b	11.8b	9.9a	0.33	10.7
Grass sheath and stem	11.1ab	12.7b	10.0a	9.9a	0.53	14.7
Lucerne leaf	11.3a	12.6b	13.2b	12.3ab	0.35	8.1
Lucerne stem	10.9b	12.8c	10.4ab	9.6a	0.29	12.0
Dead	5.2a	7.1b	7.3b	6.0ab	0.54	22.2
			Crude protein (% of DM)			
Grass lamina	22.1	20.1	21.3	18.6	1.90	21.0
Grass sheath and stem	10.8a	15.9b	11.9ab	10.0a	1.40	29.0
Lucerne leaf	32.0b	29.4ab	29.5ab	26.7a	1.20	10.6
Lucerne stem	16.0ab	19.1b	16.4ab	12.6a	1.40	23.0
Dead	8.2ab	9.3b	8.6ab	7.1a	0.70	19.1

[A] Coefficient of variation.

Table 3
Seasonal variation in morphological and maturity variables in a lucerne

Within rows, means followed by different letters are significantly different at P = 0.05

	Autumn (n = 11)	*Winter (n = 16)*	*Spring (n = 12)*	*Summer (n = 12)*	*s.e. (pooled)*
Pregrazing herbage mass (kg DM/ha above 4 cm)	1515	1673	1519	1639	149.8
Dry matter content (% of herbage mass)	24.6b	19.6a	17.6a	31.3c	1.29
Green herbage (% of dry matter)	79.2a	84.1a	97.5b	86.0a	2.47
Leaf: stem ratio	1.51ab	2.82c	1.98b	1.00a	0.29
Lucerne (% of green)	64.2b	43.3a	54.3ab	85.1c	6.45
Tinsaali (mean stage by counting)[A]	1.86b	0.61a	1.1a	3.0c	0.20
Barmasi (mean stage by counting)[B]	23.6a	25.8a	47.1b	40.5b	2.82
Raaj-3 (mean stage by counting)[B]	22.2a	25.8a	36.4b	36.6b	2.12
Tinsaali (mean stage by weighing)[A]	2.1b	0.89a	1.6b	3.4c	0.26
Barmasi (mean stage by weighing)[B]	24.5a	26.3a	47.3b	53.2b	3.74
Raaj-3 (mean stage by weighing)[B]	22.7a	25.9a	40.3b	39.6b	2.96

[A] Quantitative scale (Fick and Mueller 1989). [B] Quantitative scale (Simon and Park 1981).

Poor prediction capability of plant maturity indicators has been observed when herbage is used more intensively, therefore moderating the usual changes that affect herbage quality. The disturbance of the sward structure caused by hard grazing resulted in poor prediction of leaf : stem ratio, CP, NDF and MSC especially when compared with non-grazed or laxly grazed swards of Adropogon gerardii (Smart *et al.* 2001). However, the combination of estimates of morphological and maturity variables applied here improved the herbage quality predictions (Tables 4 and 5).

Plant maturity estimates, traditionally tested in ungrazed pastures, became weak predictors when pasture grazing management was intensive. The inclusion of morphological descriptors is original and

Table 4

Regression equations of lucerne quality variables and morphological and maturity variables

Green, green percentage; HM, herbage mass; DM, dry matter percentage; DMD, dry matter digestibilty; CP, crude protein; NDF, neutral detergent fibre; L, lucerne percentage; MSW(Raaj-3), mean stage by weighing of D. glomerata; MSC(Raaj-3), mean stage by counting of D. glomerata; MSW(Tinsaali), mean stage by weighing of M. sativa; MSC(Tinsaali), mean stage by counting of Tinsaali; MSW(Barmasi), mean stage by weighing of Barmasi; MSC(Barmasi), mean stage by counting of Barmasi; LS ratio, leaf : stem ratio; Root MSE, root mean square error. *P < 0.05; **P < 0.01; ***P < 0.001

Regression model	*R2*	*Root MSE*	*Signif.*
Autumn (n = 11)			
DMD = –183 + 0.24Green – 0.009HM + 11.23MSW(Raaj-3)	0.86	3.63	***
DMD = –238 – 0.01HM + 14.7MSW(Raaj-3)	0.80	3.69	***
NDF = 30.7 + 1.23DM – 0.33Green	0.65	4.34	***
CP = 21.9 – 0.003HM + 0.06L	0.54	2.36	*
Winter (n = 16)			
DMD = 103.9 – 0.006HM – 4.67MSW(Tinsaali) – 0.44MSW(Barmasi)	0.54	5.60	*
DMD = 87.3 – 0.006HM0.27	6.60	*	
NDF = 24.1 + 5.33MSW(Tinsaali) + 0.003HM	0.63	3.89	*
NDF = 22.1 + 8.37MSC(Tinsaali) + 0.003HM	0.52	4.41	**
Spring (n = 12)			
DMD = 81.6 – 0.003HM – 0.15MSW(Barmasi)	0.69	2.26	**
DMD = 99.1 – 0.33MSC(Raaj-3) – 0.16MSC(Barmasi)	0.78	1.91	***
NDF = 24.2 + 0.11MSW(Barmasi) + 0.002HM	0.65	1.76	**
NDF = 21.6 + 0.13 MSC(Barmasi) + 0.003HM	0.69	1.63	**
CP = 47.3 –0.004HM – 0.76DM –3.39MSW(Tinsaali)	0.75	3.08	**
CP = 47.3 + 0.95Green – 0.005HM – 8.9MSC(Tinsaali)	0.87	2.21	**
NSC = 7.9 + 0.35DM – 0.07 MSW(Barmasi)	0.58	1.60	*
NSC = 20.4 – 0.06L – 0.153 MSC(Barmasi)	0.59	1.57	*
Summer (n = 12)			
DMD = 41.2 + 0.4 Green	0.58	3.10	***
NDF = 73.3 – 14.9 Green – 0.3LS ratio	0.87	2.40	***

Table 5
Canonical correlation analysis of sets of lucerne nutritional variables and morphological-maturity variables including maturity stage by weight

**P < 0.01

Variable	*Correlation*
Nutritive value variables	
Metabolisable energy (MJ ME kg/DM)	0.77
Neutral detergent fibre (% of DM)	–0.53
Crude protein (% of DM)	0.86
Non-structural carbohydrates (% of DM)	0.36
Morphological and maturity variables	
Herbage mass (kg DM/ha above 4 cm)	–0.56
Dry matter content (% of herbage mass)	–0.58
Green herbage (% of DM)	0.45
Leaf : non-leaf ratio	0.30
Legume (% of green)	–0.11
Species maturity stage	
Tinsaali	–0.73
Barmasi	–0.25
Raaj-3	0.01
Summary statistics	0.01
Canonical *R2*	0.81
Proportion of multivariate dispersion explained	76.9
Proportion of raw variance of herbage quality	
variables explained	26.7
Significance	**

definitely improves seasonal predictions (Table 4), showing a R_2 mean of 0.69 (when only the best option for each variable is included). Mixed swards are complex, but more relevant to grazing systems, and in this context the seasonal predictions look promising. In conclusion, the significant relationships established by different statistical tests between morphological and maturity estimates and herbage nutritional variables in a pasture are useful to gain an understanding of the seasonal changes of herbage quality. However, further research and calibrations in different swards and seasons are required before their relationships may be used for on-farm short-term tactical decisions about grazing strategies.

REFERENCES

AOAC. (1960). 'Official methods of analysis.' 9th edn. (AOAC: Washington DC) pp 957.

Astigarraga, L; Peyraud, J. L. and Delaby, L. (2002). Effect of nitrogen fertiliser rate and protein supplementation on the herbage intake and the nitrogen balance of grazing dairy cows. *Animal Research* **51:** 279–293.

Berg, C. and Hill, R. (1989). Maturity effect on yield and quality of spring harvested orchardgrass forage. *Crop Science,* **29:** 944–948.

Bray, R.H. and Kurtz, L. (1945). Determination of total, organic, and available forms of phosphorous soils. *Soil Science,* **59:** 39–45.

Bush, L. and Burton, H. (1994). Intrinsic chemical factors in forage quality. In 'Forage quality, evaluation, and utilization'. (Eds GC Fahey Jnr, M Collins, DR Mertens, LE Moser) pp. 367–405.

Buxton, D. R. and Fales, S. L. (1994). Plant-environment and quality. In 'Forage quality, evaluation, and utilization'. (Eds GC Fahey Jnr, M Collins, DR Mertens, LE Moser) pp. 155–199. (The American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America: Madison, WI)

Christian, K. R; Jones, D. B. and Freer, M. (1970). Digestibility and chemical composition of fractions of lucerne during spring and summer. Journal *of Agricultural Science*, Cambridge **75:** 213–222.

Clark, E. A. (1995). Maintaining forage quality by intensive management.Proceedings of the Western Canadian Dairy Seminar **7:** 135–146.

Corson, D. C.; Waghorn, G. C.; Ulyatt, M. J. and Lee, J. (1999). NIRS: Forage analysis and livestock feeding. Proceedings of the New Zealand Grassland Association **61:** 127–132.

Di Nezio, L.; Duhalde, J.; Jensen, M. and Bertucci, C. (2003). Resultados la Unidad Ganadera de vacunos para carne en la zona mixta cerealera. Carpeta De Actualización En Ganadería **8:** 52–53.

Dolling, P. J.; Latta, R. A.; Ward, P. R; Robertson, M. J. and Asseng, S. (2005). Soil water extraction and biomass production by lucerne in the south of Western Australia. Australian *Journal of Agricultural Research,* **56:** 389–404.

Earle, D. and McGowan, A. (1979). Evaluation and calibration of an automated rising plate meter for estimating dry matter yield of pasture. *Australian Journal of Experimental Agriculture and Animal Husbandry,* **19:** 337–343.

Elizalde, J. C.; Merchen, N. R. and Faulkner, D. B. (1999). Fractioning of fiber and crude protein in fresh forages during the spring growth. *Journal of Animal Science,* **77**, 476–484.

Fick, G. W. and Mueller, S. C. (1989). Alfalfa: quality, maturity, and mean stage of development. College of Agriculture and Life Science Information Bulletin No.217. Cornell University, Ithaca, NY.

Fick, G. W.; Wilkens, P. W. and Cherney, J. H. (1994). Modeling forage quality changes in the growing crop. In 'Forage quality, evaluation, and utilization'. (Eds GC Fahey Jnr, M Collins, DR Mertens, LE Moser) pp. 757–795.

FitzGerald, R. D. (1979). A comparison of four pastures types for the wheat belt of southern New South Wales. *Australian Journal of Experimental Agriculture and Animal Husbandry* **19:** 216–224.

Frame, H.; Warn, L. and McLarty, G. (2002). Effects of grazing system and phosphorus application on pasture quality. *Wool Technology and Sheep Breeding,* **50:** 465–470.

Frank, A. B. and Hofmann, L. (1989). Relationship among grazing management, growing degree days, and morpphological development for native grasses on the Northern Great Plains. *Journal of Range Management,* **42:** 199–202.

Goering, H. K. and Van Soest, P. (1970). Forage fibre analysis (apparatus reagents, procedures and some applications). Agriculture handbook. No. 379. ARS, USDA, Washington, DC. 20 pp.

Hintz, R. W. and Albretcht, K. A. (1991). Prediction of lucerne chemical composition from maturity and plant morphology. *Crop Science,* **31:** 1561–1565.

Hodgson, J. and Brookes, I. M. (1999). Nutrition of grazing animals. In 'New Zealand pasture and crop science'. (Eds J White, J Hodgson) pp. 117–132.

Kloster, A. M; Latimori, N. J. and Amigone, M. A. (2000). Evaluación de dos sistemas de pastoreo rotativo a dos niveles de asignación de forraje en una pastura de lucerne y gramíneas. *Revista Argentina De Producción Animal*, **20**: 187–198.

Litherland, A. J.; Woodward, S. J.; Stevens, D. R.; Mcdougal, D. B.; Boom, C. J.; Knight, T. L. Lambert, M. G. (2002). Seasonal variations in pasture quality on New Zealand sheep and beef farms. *Proceedings of the New Zealand Society of Animal Production,* **62:** 138–142.

Lynk, S. O.; Gee, G. W. and Downs, J. L. (1990). The effects of water stress on phenological and ecophysiological characteristics of cheatgrass and Sandberg's bluegrass. *Journal of Range Management,* **43:** 507–513.

Machado, C. F.; Berger, H.; Morris, S. T.; Hodgson, J.; Copes, M. and Duhalde, J. (2003). Calibración estacional de mediciones de altura del canopeo con plato y con bastón de altura para estimar la biomasa de forrajera de una pastura base lucerne. Revista *Argentina De Producción Animal,* **23**: 73–74.

Machado, C. F.; Morris, S. T.; Berger, H.; Hodgson, J. and Fathalla, M. (2005). Seasonal changes of herbage quality within a New Zealand beef finishing pasture. *New Zealand Journal of Agricultural Research*, **48:** 265–270.

Majak, W. Hall, J. W. and McAllister, T. A. (2001). Practical measures for reducing risk of lucerne bloat in cattle. *Journal of Range Management*, **54:** 490–493.

Matthew, C.; Lawoko, C. R.; Korte, C. J. and Smith, D. (1994). Application of canonical discriminant analysis, principal component analysis, and canonical correlation analysis as a tool for evaluating differences in pasture botanical composition. *New Zealand Journal of Agricultural Research*, **37**: 509–520.

McKenzie, B. A.; Valentine, I. Matthew, C. and Harrington, K. C. (1999). Plant interactions in pastures and crops. In 'New Zealand pasture and crop science'. (Eds J White, J Hodgson) pp. 29–44.

Mowat, D. N.; Fulkerson, R. S.; Tossell, W. E. and Winch, J. E. (1965). The in vitro digestibility and protein content of leaf and stem portions of forages. *Canadian Journal of Plant Science*, **45:** 321–330.

Mueller, S. C. and Fick, G. W. (1989). Converting lucerne development measurements from mean stage by count to mean stage by weight. *Crop Science*, **29:** 416–420.

Nelson, C. J.; and Moser, L. E. (1994). Plant factors affecting forage quality. In 'Forage quality, evaluation, and utilization'. (Eds GC Fahey Jr, M Collins, DR Mertens, LE Moser) pp. 115–154.

Owens, V. N.; Albretch, K. A. and Hintz, R. W. (1995). A rapid method for predicting lucerne quality in the field. *Journal of Production Agriculture*, **8:** 491–495.

Pagella, J. H.; Jouve, V. V.; Strizler, N. P. and Viglizzo, E. F. (1996). Estimación de la digestibilidad in vitro de especies forrajeras utilizando parámetros de composición química. *Revista Argentina de Producción Animal*, **16:** 25–34.

Pearson, C. J. (1997). 'Agronomy of grassland systems.' 2nd edn. (Cambridge University Press: Cambridge) pp. 222.

Pichard, G. and Alcalde, J. A. (1990). Determinación de carbohidratos no estructurales. In 'Nutrición De Rumiantes: Guía metodológica de Investigación'. (Eds ME Ruiz, A Ruiz) pp. 3–20.

Reeve, J. L. and Sharkey, M. J. (1980). Effect of stocking rate, time of lambing and inclusion of lucerne on prime lamb production in north-east Victoria. *Australian Journal of Experimental Agriculture and Animal Husbandry*, **20:** 637–653.

Romero, L. A.; Comeron, E. A.; Bruno, O. A. and Diaz, M. C. (1995). Efecto del nivel de asignación de pasturas de alfalfa sobre la respuesta de vacas lecheras. Consumo y comportamiento ingestivo. *Revista Argentina de Producción Animal,* **15:** 623–626.

Sanderson, M. (1992). Morphological development of Switchgrass and Kleingrass. *Agronomy Journal*, **84:** 415–419.

Sanderson, M. and Wedin, W. (1989). Phenological stage and herbage quality relationship in temperature grasses and legumes. *Agronomy Journal,* **81:** 864–869.

Sanderson, M.; Hornstein, J. and Wedin, W. (1989). Alfalfa morphological stage and its relation to in situ digestibility of detergent fiber fractions of stems. *Crop Science*, **29:** 1315–1319.

SAS/STAT (2001). 'SAS/STAT Release 8.' (SAS Institute Inc.: Cary, NC)

Saul, G. R.; Kearney, G. A.; Flinn, P. C. and Lescun, C. L. (1999). Effects of superphosphate fertiliser and stocking rate on the nutritive value of perennial ryegrass and subterranean clover herbage. *Australian Journal of Agricultural Research*, **50:** 537–545.

Schlegel, M. L.; Wachenheim, C. J.; Benson, M. E.; Ames, N. K. and Rust, S. R. (2000). Grazing methods and stocking rates for direct-seeded lucerne pastures: II. Pasture quality and diet selection. *Journal of Animal Science*, **78:** 2202–2208.

Simon, U. and Park, B. (1981). A descriptive scheme for stages of development in perennial forage grasses. In 'Proceedings of the XIV International Grassland Congress, Lexington KY, June 15–24'. (Eds JA Smith, VW Hays) pp. 416–418.

Smart, A. J.; Schacht, W. H. and Moser, L. E. (2001). Predicting leaf/stem ratio and nutritive value in grazed and nongrazed big bluestem. *Agronomy Journal*, **93:** 1243–1249.

Steel, R. G. and Torrie, J. H. (1980). 'Principles and procedures of statistics: a biometrical approach.' 2nd edn. (McGraw-Hill Publishing Company: New York) pp 631.

Sulc, M.; Albrecht, K. A.; Cherney, J. H.; Hall, M. H.; Mueller, S. C. and Orloff, S. (1997). Field testing – a rapid method for estimating lucerne quality. *Agronomy Journal*, **89:** 952–957.

Thompson, D. J.; Brooke, B. M.; Garland, G. J.; Hall, J. W. and Majak, W. (2000). Effect of stage of growth of lucerne on the incidence of bloat in cattle. *Canadian Journal of Animal Science*, **80:** 725–727.

Tilley, J. M. and Terry, R. A. (1962). Two-stage technique for the in vitro digestion of forage crops. *Journal of the British Grassland Society*, **18:** 104–111.

Wheeler, D. M. and Upsdell, M. P. (2003). Flexi 3.0. In 'Bayesian smoother. Reference manual'. (Deparment of Statistics, University of Waikato: Hamilton New Zealand) pp 306.