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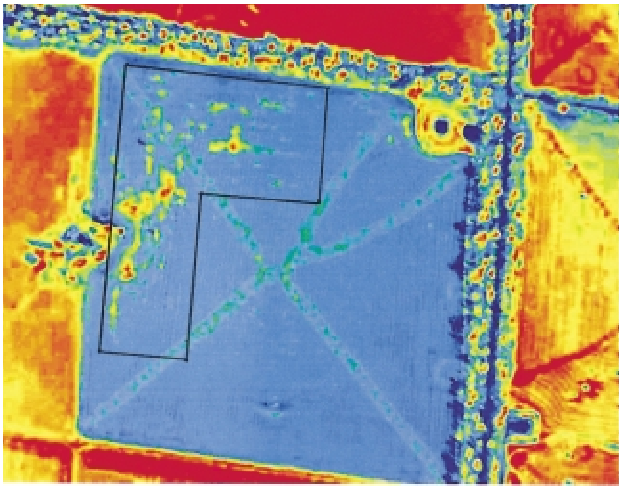

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Post-weaning growth of cattle in northern New South Wales 1. Grazing value of temperate perennial pasture grazed by cattle

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Abstract. This paper describes the botanical components, seasonal herbage mass, and nutritive value of pastures used for post-weaning growth of CRC cattle at Glen Innes before their progression to subsequent finishing and meat quality studies. The pastures under study comprised introduced temperate perennial species (tall fescue, *Festuca arundinacea*; phalaris, *Phalaris aquatica*; perennial ryegrass, *Lolium perenne*; cocksfoot, *Dactylis glomerata*; white clover, *Trifolium repens*; and red clover, *Trifolium pratense*) grazed by yearling cattle and managed according to local practice to maintain herbage mass between pre-determined limits. The study took place on 3 adjacent pasture systems (P1, pasture only; P2, pasture plus formulated pellets fed in later winter–early spring; P3, pasture plus forage crop grazed in later winter–early spring) over the 3 years 1994–96 that included a severe 20-month drought event followed by a drought-recovery phase. Results are discussed in the context of the pasture feed year which was shown to comprise 3 distinct phases: (i) spring primary growth phase, high availability of green herbage mass (2500–4500 kg DM/ha) of very high digestibility (0.80–0.85) and very high N status (about 30 g N/kg DM); (ii) summer–autumn secondary regrowth, high availability of green herbage mass (2500–4000 kg DM/ha) but with only moderate nutritive value (0.65–0.70 digestibility, 15–20 g N/kg DM); and (iii) winter dormancy, low availability of green herbage mass (750–1500 kg DM/ha) but with high nutritive value (0.75–0.80 digestibility, 20–30 g N/kg DM). It was concluded that the limitations of the feed year for yearling cattle in this environment include a feed gap in winter–early spring due to low herbage mass associated with winter cold and a feed gap in summer–autumn associated with moderate nutritive value of secondary regrowth pasture.

Additional keywords: nutritive value, feed-year, backgrounding, improved pastures.

Introduction

The Northern Tablelands of New South Wales is a temperate highland region in eastern Australia where the pasture environment is characterised by relatively high rainfall (average annual rainfall, 750–1250 mm) with marked summer incidence, a 200-day frost interval from April though October and intensely cold winter conditions (Hobbs and Jackson 1977). The pasture contains a wide diversity of native and naturalised grass species (Whalley *et al.* 1978; Lodge *et al.* 1990) and the region is suited to pasture improvement with introduced perennials (tall fescue, *Festuca arundinacea*; phalaris, *Phalaris aquatica*; cocksfoot, *Dactylis glomerata*; perennial ryegrass, *Lolium perenne*; white clover, *Trifolium repens*; and red clover, *Trifolium pratense*) and intensive livestock production (Hartridge and Parker 1979; Anon. 1964). Introduced pasture species occupy some 23% of the total farm area in this region (Archer 1995).

In a computer simulation study of 22 sheep production systems across 10 pastoral environments in Australia (Moore *et al.* 1993), it was concluded that the Northern Tablelands of New South Wales is one of the most reliable and potentially profitable regions for intensive sheep-meat enterprises. This region was shown to have a potentially high turn-off of finished lambs without resorting to special-purpose pastures or forage crops and was purported to require only low levels of supplementary feeding. This high potential for intensive sheep production was attributed to (i) a long pasture growing season due to summer rainfall, and (ii) high diet quality throughout the year.

Despite these favourable characteristics of the Northern Tablelands pasture environment for sheep production, limitations of pasture supply and nutritive value are considered to be likely to limit intensive beef cattle production (Dicker *et al.* 1998). For native pastures (in particular warm-season perennials), these limitations

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include low nutritive value, especially through autumn–winter–spring (Archer and Robinson 1988). For introduced pastures, these limitations include low levels of green herbage mass in winter (McPhee *et al.* 1997) and a progressive decline in nutritive value with onset of maturity through the spring primary growth phase (Ayres *et al.* 1998).

A study was undertaken at Glen Innes Agricultural Research and Advisory Station on the Northern Tablelands of New South Wales in 1994–96 to provide 3 alternative growth pathways for yearling steers to determine: (i) the significance of post-weaning growth for achievement of feed-lot entry specifications (Dicker *et al.* 2001) and; (ii) relationships between post-weaning growth, finishing performance and meat quality (Robinson *et al.* 2001). An ancillary aim was to describe the characteristics of introduced pasture and to determine the potential for pastures in this environment to provide for the nutritional requirements of post-weaning growth of cattle before finishing in the feedlot or at pasture. This study was a component of the work of the Cooperative Research Centre for Cattle and Beef Quality. A second paper in this series (Dicker *et al.* 2001) reports on the significance of these pasture characteristics for the liveweight performance of yearling steers of diverse genetic origin.

Materials and methods

Location

The study was undertaken at Glen Innes (29°44′S, 151°42′E; altitude 1057 m) located centrally in the Northern Tablelands of New South Wales, Australia. Climate is characterised by average annual rainfall of 852 mm with summer dominance (36% incidence between December and February), a wide temperature range, and precipitation exceeding evaporation only in winter months (Table 1). The annual temperature range is 24.3°C, the mean maximum and minimum temperature in the warmest month (January) are 25.0 and 13.4°C, respectively; the mean maximum and minimum temperature in the coldest month (July) are 12.2 and 0.7°C, respectively.

Soil moisture has a well defined seasonal pattern; despite summer rainfall dominance, soil moisture is progressively depleted during spring–summer, remains low and variable in late summer–autumn, and is recharged in winter (Smith and Johns 1975). For introduced temperate perennial pasture species, the seasonal growth rhythm comprises high pasture growth during the spring primary growth phase, moderate pasture growth during the secondary growth phase in summer–autumn, and low growth in winter (Cotsell 1958; Begg 1959; McPhee *et al.* 1997). The major stresses for pasture plants are summer–autumn moisture deficit, close grazing during the winter feed gap, and episodic drought.

Experimental site

The study site comprised most of the land area (340 ha) of Glen Innes Agricultural Research and Advisory Station. The soil is an acidic self-mulching, heavy clay-loam derived from basaltic parent material (Ug5.15, Northcote 1974); soil nutrient status for each pasture system is presented in Table 2. Pasture species comprising introduced cool-season perennials (tall fescue, phalaris, cocksfoot, perennial

Table 1. Rainfall, evaporation and ambient temperature at Glen Innes (Bureau of Meteorology Weather Station No. 056013); long-term means and recorded values for the experimental period of the study (1994–1996)

Long-term means (LTM) are based on 87 years (1910–1999) of records for rainfall and 29 years (1970–1999) of records for temperature and evaporation

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
							Rainfall (mm)						
LTM	108	94	69	41	51	56	58	49	56	78	85	109	852
1994	76	115	96	34	4	37	10	21	30	37	47	165	670
1995	132	80	32	9	54	74	22	1	84	49	167	91	794
1996	283	119	28	19	137	40	61	50	90	41	77	148	1093
							Pan evaporation (mm)						
LTM	167	137	133	96	62	48	53	74	105	136	153	174	1388
1994	212	109	101	87	83	52	53	86	141	162	178	170	1433
1995	147	114	148	114	54	35	63	92	89	114	138	164	1272
1996	138	144	119	113	62	48	51	74	122	132	158	185	1346
							Ambient temperature (°C)						
LTM													
Max.	25.0	24.4	23.0	19.8	16.3	12.9	12.2	13.8	16.5	19.7	22.2	24.5	
Min.	13.4	13.3	11.4	7.9	5.0	1.9	0.7	1.3	4.1	7.1	9.8	12.1	
1994													
Max.	27.5	24	20.5	19.9	17.4	13.6	13.9	14.5	17.4	21.4	24	25.9	
Min.	14.5	13.2	9.9	7.2	2.8	1.1	–1.2	–0.3	2.4	5.8	10.5	12.3	
1995													
Max.	24.1	22.9	24.3	19.5	16.7	12.3	11.9	17	17.1	20	23	23.4	
Min.	12.9	13.1	11	5.7	6	2.4	0.4	1.5	4.2	6.6	11.1	11.2	
1996													
Max.	25.0	23.4	22.5	20.6	16.9	14.3	11.8	14.6	16.7	19.8	21.8	24.4	
Min.	13.9	10.9	9.9	5.8	5.7	3.9	0.4	1.3	4.0	7.2	8.4	11.2	

Table 2. Soil nutrient status of the 3 pasture systems (P1, pasture only; P2, pasture plus formulated pellets in late winter–early spring; P3, pasture plus forage crop in late winter–early spring) at Glen Innes from soil testing in August 1996

Sampling depth was 0–10 cm

Pasture system	pH[A]	Phosphorus[B] (mg/kg)	Sulfur[C] (mg/kg)
Block 1 (west-facing slopes)			
Pasture P1	5.1	24	14
Pasture P2	5.0	20	15
Pasture P3	5.2	24	15
Block 2 (hilltops)			
Pasture P1	5.0	25	13
Pasture P2	5.0	22	12
Pasture P3	5.2	20	12
Block 3 (east-facing slopes)			
Pasture P1	5.0	16	11
Pasture P2	5.1	19	10
Pasture P3	5.1	20	11

[A]Determined in a 1:5 soil:0.01 mol/L $CaCl_2$ slurry. [B]Bray -1 available phosphate. [C]KCl 40 sulfur.

ryegrass, white clover, red clover) predominated from pasture establishment in previous years. The land area was blocked into 3 land classes according to topography and aspect (Block 1: west-facing slopes, Block 2: hilltops, Block 3: east-facing slopes). A fourth block was utilised for short duration grazings on 3 occasions in the first year of the study but this block was subsequently excluded for logistical reasons. Superphosphate fertiliser was applied annually at application rates of 175–350 kg/ha to maintain high soil phosphate status.

Pasture systems

Each of the 3 blocks was subdivided into 3 equal pasture areas; pasture P1 for cattle grazing pasture only, pasture P2 for cattle grazing pasture plus formulated pellets in winter, and pasture P3 for cattle grazing pasture plus forage crop in winter. There was no replication of the pasture systems; the primary aim of the study was to provide 3 contrasting pasture systems to promote 3 alternative (cattle) growth pathways. A detailed description of the winter supplements, the allocation of cattle to their pasture systems, grazing and supplementary feeding protocols, and the management of cattle is provided in Dicker *et al.* (2001). In summary, the following protocols were adopted:

(i) The pasture systems (P1, P2, P3) were grazed at equal stocking rates (1.0–1.5 steer equivalents/ha) except in late winter–early spring when P3 cattle had access to an adjacent forage crop.

(ii) The grazing management system employed was ‘intermittent grazing’ in which cattle were moved between their respective treatment areas in accordance with total herbage mass limits of 1500–2500 kg DM/ha in drought years (1994–95) and 2000–3000 kg DM/ha during the drought recovery phase (1996). The record of livestock movements indicates that this resulted in grazing periods of about 20–30 days and rest periods of 40–60 days, depending on block size.

(iii) Cattle were moved in synchrony between the 3 blocks and stock movements were initiated when total herbage mass for P1 pasture declined to the lower herbage mass limit. Accordingly, the pasture systems within a land-class block were grazed simultaneously to avoid confounding of grazing time and land-class.

(iv) The formulated pellet supplement was provided to P2 cattle during late winter–early spring; the supplements were fed in pellet form in mobile troughs located in the P2 pasture areas.

(v) A 30-ha forage crop (*Lolium multiflorum* cv. Concord) was subdivided into 3 equal areas and rotationally grazed by P3 cattle (150–175 animals, depending on year) during late winter–early spring months coinciding with feeding the formulated pellets to P2 cattle.

Observations

The pasture data were obtained by sampling 4 fixed transects in each pasture area. The transects, 200 m in length, were permanently positioned to include the range of species diversity in each pasture area but excluded unrepresentative campsites, roads and gullies. The timing of pasture measurements corresponded with the introduction of animals to a new pasture block. On each sampling occasion, 15 sites were randomly sampled along each transect using a 30 by 30 cm quadrat frame. Species composition (%) was estimated using Botanal procedures (Hargreaves and Kerr 1978). Total herbage mass (kg DM/ha) and green herbage mass content (%) were estimated using ‘double sampling’ procedures (Morley *et al.* 1964) and regression analysis. Forage samples were obtained in conjunction with the pasture observations by taking a pluck sample (using power clippers to ground level) adjacent to each quadrat site and compositing 15 subsamples for each transect. Nutritive value assay was undertaken on whole shoots, green and senesced fractions; *in vitro* digestibility (% OM basis) was determined by a 2-step procedure comprising 48 h incubation in rumen fluid–artificial saliva followed by 48 h incubation in pepsin solution as described by Ayres (1991); nitrogen content (N, g N/kg DM) was determined using the Kjeldahl procedure (AOAC 1980) using a Kjeltec Auto 1030 (Tecador AB, Sweden); organic matter (OM, %) was determined by ashing at 580°C for 16 h in a muffle furnace.

Data analysis

In the statistical model for determination of pasture characteristics, transects served as replications and variation amongst quadrat sites served as sampling error. The mean and standard error (s.e.) of herbage mass, *in vitro* digestibility, nitrogen content and botanical composition across 4 transects were calculated using GENSTAT 5 (Payne *et al.* 1987).

Results

Seasonal conditions

The study period included a 20-month drought event in 1994–95 that was the most severe drought recorded on the Northern Tablelands this century (Ayres *et al.* 1996, 1997). Seasonal conditions during the study comprised low rainfall in 5 of 6 seasons from autumn 1994 to winter 1995, followed by above average rainfall in summer 1995 and average rainfall in subsequent seasons to summer 1996 (Table 1). The significance of the rainfall events for soil moisture balance is described graphically in Figure 1.

Botanical composition

Data for pasture species composited into the 5 species categories: introduced grasses, introduced legumes, annual grasses, native grasses, and broadleaf weeds are provided in Tables 3, 4 and 5. Under the severe drought conditions of 1994 and 1995, the pastures remained dominated by introduced perennial grasses but with only trace levels of companion legumes; the P1 pasture typically comprised 70–90% introduced grasses, P2 pasture comprised 70–80% introduced grasses, and P3 pasture comprised 60–90%

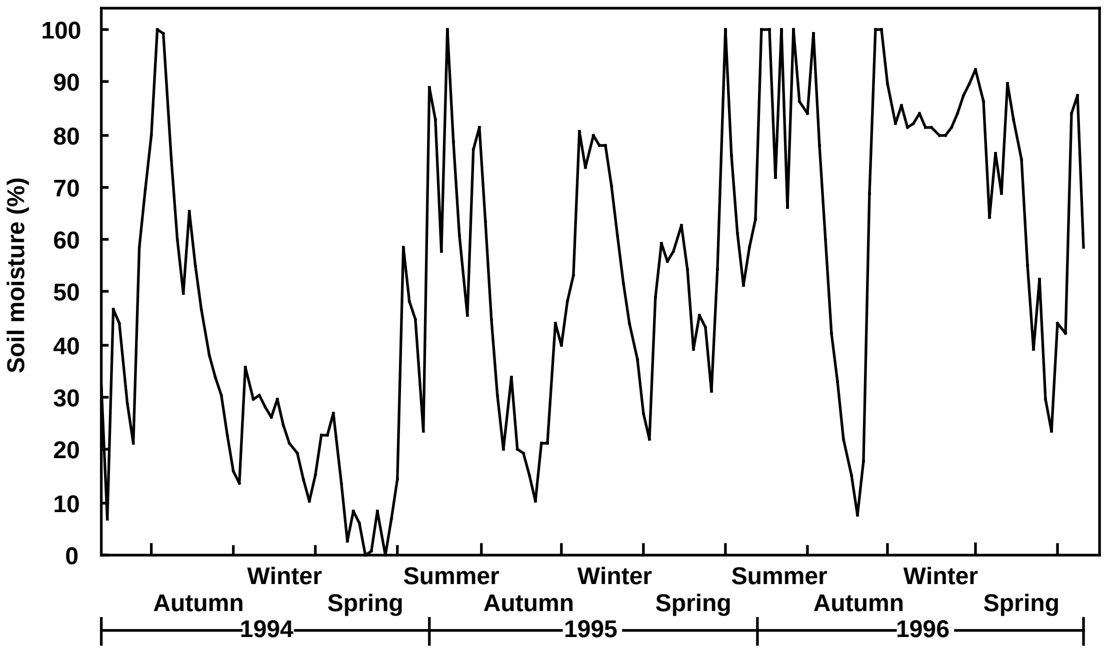

Figure 1. Soil moisture balance (relative available soil moisture as percentage of water-holding capacity) after Smith and Johns (1975) at Glen Innes for the period 1994–1996.

introduced grasses. Native grasses were uniformly a minor, but consistent, sward component (10–30%) with presence predominant in summer–autumn. For P1 and P3 pastures, broadleaf weeds were present in all seasons but only at trace levels (0–5%), and annual grasses were present principally as summer annuals but with only low presence (5–15%). In P2 pasture, annual grasses–broadleaf weeds constituted a major sward component not only in summer–autumn (30–50%) but also in winter (10–30%). During the drought-recovery phase in 1996, white clover increased dramatically in all 3 pastures from a germination event in February 1996 and rapidly assumed major sward presence (10–40%) expanding to 40–70% presence by spring 1996. Recovery of introduced species was marked with introduced grasses plus legumes constituting in excess of 90% botanical content for P1 and P3 pastures, and 70–90% for P2 pasture.

Herbage mass

Data for total herbage mass are provided in Tables 3, 4 and 5 and data for green herbage mass are plotted in Figures 2, 3 and 4. The seasonal pattern of herbage mass was similar for the 3 pastures and comprised increasing levels of green herbage mass through spring, declining levels of green herbage mass (but high levels of senesced residues) in mid summer through autumn, and low levels of green herbage mass in winter. The green component of herbage mass was typically greatest in summer (62–85, 65–80 and 60–79% over the 3 summers for P1, P2 and P3 pastures, respectively), and least in winter (9–28, 10–31 and 6–32% over the 3 winters for P1, P2 and P3 pastures, respectively).

In the drought years 1994 and 1995, green herbage mass was at a maximum in spring at 1000–2000, 1500–2500 and 1000–1500 kg DM/ha for P1, P2 and P3 pastures, respectively; and at a minimum in winter at 500, 250–500 and 250 kg DM/ha for P1, P2 and P3 pastures, respectively. During the drought recovery phase in 1996, green herbage mass in spring was 3500–4000, 2500–4000 and 2000–5000 kg DM/ha for P1, P2 and P3 pastures respectively; and in winter was 750–1500, 1000–1500, and 1500–2000 kg DM/ha for P1, P2 and P3 pastures, respectively.

Nutritive value

Data for *in vitro* digestibility and N content for the green and senesced fractions of herbage mass are presented in Figures 2, 3 and 4. The seasonal patterns of digestibility and N content were markedly consistent for the 3 pasture systems. The digestibility of green herbage mass progressively declined through spring from 0.80–0.85 to 0.67–0.70, remained relatively constant over summer–autumn at 0.65–0.70 and was uniformly high through winter at 0.75–0.80. The N content of green herbage mass progressively declined through spring from 30 to 20 g N/kg DM, remained relatively constant during summer–autumn at 15–20 g N/kg DM, and in winter increased from 20 to 30 g N/kg DM. The nutritive value of the senesced fraction remained in the range 0.35–0.55 digestibility and 7–12 g N/kg DM year-round and there were no discernible seasonal patterns or differences between the 3 pastures in the nutritive value of the senesced fraction. The

Table 3. The botanical composition (% DM) and total herbage mass (kg DM/ ha) of temperate perennial pasture grazed by steers; P1 pasture

Values are mean ± s.e.

Month	Introduced grasses	Introduced legumes	Annual grasses	Native grasses	Broadleaf weeds	Total herbage mass
			1994			
May	67 ± 14	13 ± 7	0 ± 0	18 ± 6	2 ± 1	2987 ± 263
July	88 ± 5	4 ± 3	5 ± 2	0 ± 0	3 ± 3	1980 ± 94
Sept.	78 ± 12	12 ± 6	0 ± 0	8 ± 5	2 ± 1	1694 ± 253
Oct.	79 ± 7	6 ± 1	0 ± 0	14 ± 7	1 ± 1	1228 ± 188
Nov.	98 ± 1	2 ± 1	0 ± 0	0 ± 0	0 ± 0	3079 ± 180
Nov.[A]	90 ± 5	1 ± 1	0 ± 0	7 ± 4	2 ± 1	815 ± 85
Dec.	68 ± 7	1 ± 1	0 ± 0	28 ± 6	4 ± 1	1574 ± 183
Dec.[A]	65 ± 5	2 ± 1	8 ± 5	23 ± 7	2 ± 1	1328 ± 428
			1995			
Feb.	74 ± 8	2 ± 1	14 ± 10	0 ± 0	10 ± 4	4530 ± 737
Mar.	31 ± 12	1 ± 1	15 ± 6	53 ± 11	1 ± 1	5313 ± 316
Apr.	63 ± 11	0 ± 0	7 ± 6	28 ± 13	2 ± 1	1624 ± 66
May	38 ± 5	3 ± 2	4 ± 3	54 ± 9	1 ± 1	4004 ± 974
June	70 ± 8	0 ± 0	0 ± 0	28 ± 8	1 ± 1	1140 ± 58
July	71 ± 6	1 ± 1	2 ± 2	22 ± 4	4 ± 2	1348 ± 131
July[A]	86 ± 11	1 ± 1	1 ± 1	32 ± 10	0 ± 1	1506 ± 125
Sept.	78 ± 10	9 ± 7	4 ± 3	7 ± 2	2 ± 1	2291 ± 279
Oct.	75 ± 9	5 ± 4	2 ± 1	16 ± 6	3 ± 1	2860 ± 273
Nov.	71 ± 5	15 ± 5	2 ± 2	9 ± 2	4 ± 2	3002 ± 88
Dec.	63 ± 3	10 ± 1	2 ± 2	20 ± 5	5 ± 2	3019 ± 569
			1996			
Jan.	22 ± 4	19 ± 9	8 ± 8	49 ± 4	3 ± 1	5026 ± 1177
Feb.	28 ± 7	31 ± 8	11 ± 11	30 ± 4	1 ± 1	4194 ± 567
Mar.	19 ± 4	44 ± 8	10 ± 9	26 ± 7	1 ± 1	4504 ± 651
Apr.	50 ± 14	11 ± 3	18 ± 10	20 ± 8	0 ± 0	5566 ± 1262
June	46 ± 5	37 ± 3	5 ± 4	8 ± 4	3 ± 1	2651 ± 780
July	49 ± 8	40 ± 8	1 ± 1	5 ± 2	4 ± 2	4005 ± 373
Aug.	43 ± 6	46 ± 6	1 ± 1	9 ± 5	1 ± 1	3667 ± 377
Oct.	27 ± 6	68 ± 8	1 ± 1	0 ± 0	4 ± 2	4066 ± 263
Nov.	30 ± 4	67 ± 4	0 ± 0	0 ± 0	2 ± 1	5692 ± 507
Dec.	40 ± 5	55 ± 5	1 ± 1	1 ± 1	4 ± 3	5694 ± 893
Dec.[A]	48 ± 2	33 ± 7	0 ± 0	8 ± 3	10 ± 4	4431 ± 444

[A]Sequential sampling occasions in the same month.

portion of whole shoots was always intermediate in nutritive value between the green and senesced fractions.

Discussion

Previous research on the pasture feed year in this environment has been based on monoculture plot studies (Archer and Robinson 1988; Robinson and Archer 1988), binary swards grazed by sheep (McPhee *et al.* 1997; Ayres *et al.* 2000), or mixed swards set stocked with sheep (Roe *et al.* 1959; Langlands and Bennett 1973; Langlands and Holmes 1978). The significance of the present study is that it is the first description of the pattern of seasonal variation in herbage mass and nutritive value for mixed swards grazed by cattle in this environment.

Despite drought, the 3 pasture systems remained dominated by the introduced perennial grasses tall fescue, phalaris and cocksfoot; native grasses (principally *Bothriochloa* and *Danthonia* spp.) were a minor, but persistent, sward component. Annual grasses and broadleaf weeds showed low presence and presented mainly as summer invaders. White clover was present at trace levels during the drought but recovered dramatically following a germination event in February 1996 to become a major sward component (40–60% clover presence). An analysis of the effects of contrasting grazing management in winter on botanical composition will be reported later; in summary P2 pasture showed a reduced level of presence of introduced species (about 70–90% compared with >90% introduced species for

Table 4. The botanical composition (% DM) and total herbage mass (kg DM/ha) of temperate perennial pasture grazed by steers supplemented with formulated pellets in late winter–early spring; P2 pasture

Values are mean ± s.e.

Month	Introduced grasses	Introduced legumes	Annual grasses	Native grasses	Broadleaf weeds	Total herbage mass
			1994			
May	52 ± 10	8 ± 4	11 ± 3	6 ± 5	23 ± 9	2355 ± 97
July	68 ± 8	12 ± 7	12 ± 9	0 ± 0	7 ± 3	3152 ± 887
Sept.	71 ± 11	12 ± 9	14 ± 6	2 ± 1	1 ± 1	1563 ± 152
Oct.	70 ± 7	5 ± 3	14 ± 5	3 ± 3	9 ± 7	455 ± 175
Nov.	88 ± 5	2 ± 2	2 ± 2	0 ± 1	7 ± 4	874 ± 241
Nov.[A]	65 ± 10	13 ± 3	2 ± 2	9 ± 7	11 ± 2	2450 ± 167
Dec.	68 ± 3	15 ± 4	4 ± 2	9 ± 5	14 ± 5	1579 ± 352
Dec.[A]	59 ± 11	7 ± 3	19 ± 6	4 ± 4	11 ± 6	1063 ± 317
			1995			
Feb.	83 ± 6	2 ± 1	12 ± 5	1 ± 1	3 ± 2	5044 ± 262
Mar.	35 ± 6	1 ± 1	41 ± 12	17 ± 9	6 ± 4	5105 ± 1090
Apr.	26 ± 8	2 ± 1	46 ± 11	21 ± 4	5 ± 3	1059 ± 238
May	52 ± 12	3 ± 3	5 ± 4	32 ± 17	6 ± 5	1120 ± 155
June	78 ± 8	1 ± 1	2 ± 2	14 ± 9	4 ± 3	1184 ± 296
July	50 ± 5	8 ± 4	18 ± 7	19 ± 11	4 ± 2	1240 ± 94
July[A]	44 ± 7	7 ± 2	26 ± 9	21 ± 7	2 ± 1	1355 ± 122
Sept.	66 ± 7	4 ± 2	11 ± 4	17 ± 8	2 ± 1	1738 ± 221
Oct.	64 ± 2	10 ± 2	13 ± 6	1 ± 1	13 ± 4	3044 ± 656
Nov.	38 ± 4	24 ± 8	27 ± 9	4 ± 3	6 ± 2	3814 ± 472
Dec.	54 ± 7	26 ± 8	3 ± 1	8 ± 4	9 ± 6	4003 ± 709
			1996			
Jan.	17 ± 3	16 ± 7	33 ± 9	25 ± 6	8 ± 5	3512 ± 688
Feb.	17 ± 6	23 ± 4	32 ± 11	27 ± 9	2 ± 1	2717 ± 234
Mar.	34 ± 5	13 ± 4	27 ± 8	24 ± 9	1 ± 1	2820 ± 250
Apr.	48 ± 11	8 ± 2	24 ± 9	16 ± 9	4 ± 3	3323 ± 97
June	35 ± 8	40 ± 7	4 ± 3	16 ± 4	5 ± 2	3700 ± 181
July	52 ± 2	20 ± 6	22 ± 7	3 ± 3	3 ± 1	4085 ± 398
Aug.	38 ± 8	41 ± 11	1 ± 1	12 ± 4	7 ± 7	2636 ± 158
Oct.	39 ± 7	51 ± 5	2 ± 1	0 ± 0	8 ± 1	3591 ± 199
Nov.	33 ± 3	56 ± 2	3 ± 2	1 ± 1	7 ± 2	6004 ± 277
Dec.	48 ± 9	29 ± 10	11 ± 6	3 ± 3	9 ± 6	4624 ± 434
Dec.[A]	40 ± 5	31 ± 4	5 ± 3	3 ± 2	2 ± 8	4739 ± 280

[A]Sequential sampling occasions in the same month.

P1 and P3 pastures) presumably associated with close grazing stimulated by supplementary feeding in winter–spring. Despite these botanical composition differences, green herbage mass and the digestibility and N content of green herbage mass were similar for the 3 pasture systems across seasons and years.

In this environment, the growth periodicity of introduced species has an intrinsic rhythm that is characterised by high growth during the spring primary growth phase, moderate growth in summer–autumn during the secondary regrowth phase, and low growth in winter (Cotsell 1958; Begg 1959). The competing influences of this pattern of herbage growth with herbage defoliation by grazing animals determines that total herbage mass is at a maximum level in spring–summer and declines over late summer–autumn to reach a minimum level from mid winter (McPhee *et al*. 1997). Because the green content of herbage is also at a maximum in spring–summer due to warm-season growth and at a minimum in winter due to the effects of intensive frosting on leaf senescence, the availability of green herbage mass is high in summer and low in winter (Ayres *et al.* 2000). In the present study, green content of herbage was about 10% in winter and about 70% in summer. Except for drought months when the level of green herbage mass was very low (especially in winter, about 250 kg DM/ha), the data generally show that the pattern of availability of green herbage mass and nutritive value of green herbage mass comprised 3 distinct phases. These can be summarised as follows: (i) spring, high green herbage mass (2500–4500 kg DM/ha) with high legume presence resulting

Table 5. The botanical composition (% DM) and total herbage mass (kg DM/ha) of temperate perennial pasture grazed by steers supplemented with forage crop in late winter–early spring; P3 pasture

Values are mean ± s.e.

Month	Introduced grasses	Introduced legumes	Annual grasses	Native grasses	Broadleaf weeds	Total herbage mass
			1994			
May	37 ± 11	9 ± 5	31 ± 7	16 ± 5	7 ± 4	2290 ± 77
July	88 ± 5	5 ± 3	3 ± 3	3 ± 2	2 ± 1	2935 ± 448
Sept.	62 ± 12	14 ± 13	15 ± 6	1 ± 6	8 ± 5	1661 ± 176
Oct.	71 ± 6	5 ± 3	3 ± 2	10 ± 2	12 ± 7	2587 ± 495
Nov.	89 ± 3	1 ± 1	0 ± 0	0 ± 0	10 ± 3	1216 ± 677
Nov.[A]	82 ± 3	0 ± 0	0 ± 0	13 ± 3	4 ± 1	956 ± 72
Dec.	81 ± 11	0 ± 0	5 ± 4	12 ± 7	1 ± 1	2005 ± 222
Dec.[A]	55 ± 7	6 ± 4	7 ± 4	22 ± 9	10 ± 5	1948 ± 498
			1995			
Feb.	94 ± 2	3 ± 1	1 ± 1	0 ± 0	2 ± 1	4514 ± 423
Mar.	53 ± 47	0 ± 0	21 ± 10	26 ± 14	0 ± 0	6643 ± 568
Apr.	50 ± 4	0 ± 0	1 ± 1	46 ± 3	3 ± 1	1960 ± 143
May	59 ± 6	1 ± 1	6 ± 5	27 ± 8	8 ± 8	2229 ± 315
June	86 ± 7	0 ± 0	3 ± 2	11 ± 6	0 ± 0	2310 ± 331
July	66 ± 6	2 ± 1	0 ± 0	29 ± 5	2 ± 1	1317 ± 39
July[A]	67 ± 7	2 ± 1	8 ± 4	22 ± 8	1 ± 1	1615 ± 79
Sept.	82 ± 6	4 ± 3	3 ± 1	10 ± 4	1 ± 1	2640 ± 211
Oct.	73 ± 4	4 ± 2	2 ± 1	13 ± 5	8 ± 6	2500 ± 183
Nov.	63 ± 4	24 ± 5	0 ± 0	6 ± 3	7 ± 2	3564 ± 161
Dec.	73 ± 5	16 ± 7	1 ± 1	5 ± 3	4 ± 1	4508 ± 416
			1996			
Jan.	28 ± 8	12 ± 3	28 ± 12	29 ± 7	2 ± 1	3671 ± 267
Feb.	28 ± 3	21 ± 6	23 ± 10	26 ± 10	2 ± 1	2864 ± 340
Mar.	32 ± 5	12 ± 2	31 ± 11	25 ± 8	1 ± 1	3087 ± 394
Apr.	58 ± 10	9 ± 2	23 ± 10	8 ± 3	3 ± 2	3749 ± 334
June	41 ± 6	41 ± 8	1 ± 1	16 ± 1	3 ± 1	4864 ± 697
July	37 ± 8	57 ± 8	2 ± 1	4 ± 0	1 ± 1	5696 ± 566
Aug.	50 ± 6	43 ± 5	6 ± 2	0 ± 0	1 ± 1	3426 ± 369
Oct.	35 ± 4	63 ± 4	0 ± 0	0 ± 0	2 ± 1	5877 ± 446
Nov.	32 ± 4	64 ± 4	0 ± 0	0 ± 0	4 ± 1	7886 ± 366
Dec.	50 ± 9	33 ± 8	1 ± 1	1 ± 1	4 ± 2	5433 ± 1036
Dec.[A]	57 ± 5	32 ± 5	0 ± 0	2 ± 2	8 ± 5	10400 ± 716

[A]Sequential sampling occasions in the same month.

in very high digestibility (0.80–0.85) and very high N content (about 30 g N/kg DM). With onset of maturity through spring, nutritive value of green herbage mass progressively declined to 0.67–0.70 digestibility and 20 g N/kg DM; (ii) summer–autumn, high green herbage mass (2500–4000 kg DM/ha) with relatively constant but only moderate digestibility (0.65–0.70) and moderate N content (15–20 g N/kg DM); (iii) winter, low green herbage mass (750–1500 kg DM/ha) but with high digestibility (0.75–0.80) and high N content (20–30 g N/kg DM).

Roe *et al.* (1959) were the first to report the significance of green herbage mass for animal production in this environment. For native pastures, sheep liveweight and wool growth were found to be unrelated to total herbage mass but were closely related to green herbage mass, and the annual pattern of availability of green herbage mass comprised a peak level (1100 kg DM/ha) in spring, declining to a very low level (about 100 kg DM/ha) in winter. The work of Hamilton *et al.* (1973) in this same environment extended studies on green herbage mass to the introduced perennial grasses phalaris, tall fescue, perennial ryegrass and cocksfoot in monoculture and confirmed that diet quality was closely related to the availability of green herbage mass. Langlands and Holmes (1978) examined seasonal variation in the diet of cattle grazing both native pasture (complex of *Poa sieberana, Themeda australis, Sorghum leiocladum, Sporobolus elongatus, Eragrostis* spp., *Bothriochloa macra, Panicum effusum, Bromus molliformis, Danthonia* spp., *Microlaena stipoides*) and introduced pasture (phalaris, white clover). Seasonal variation in digestibility and N

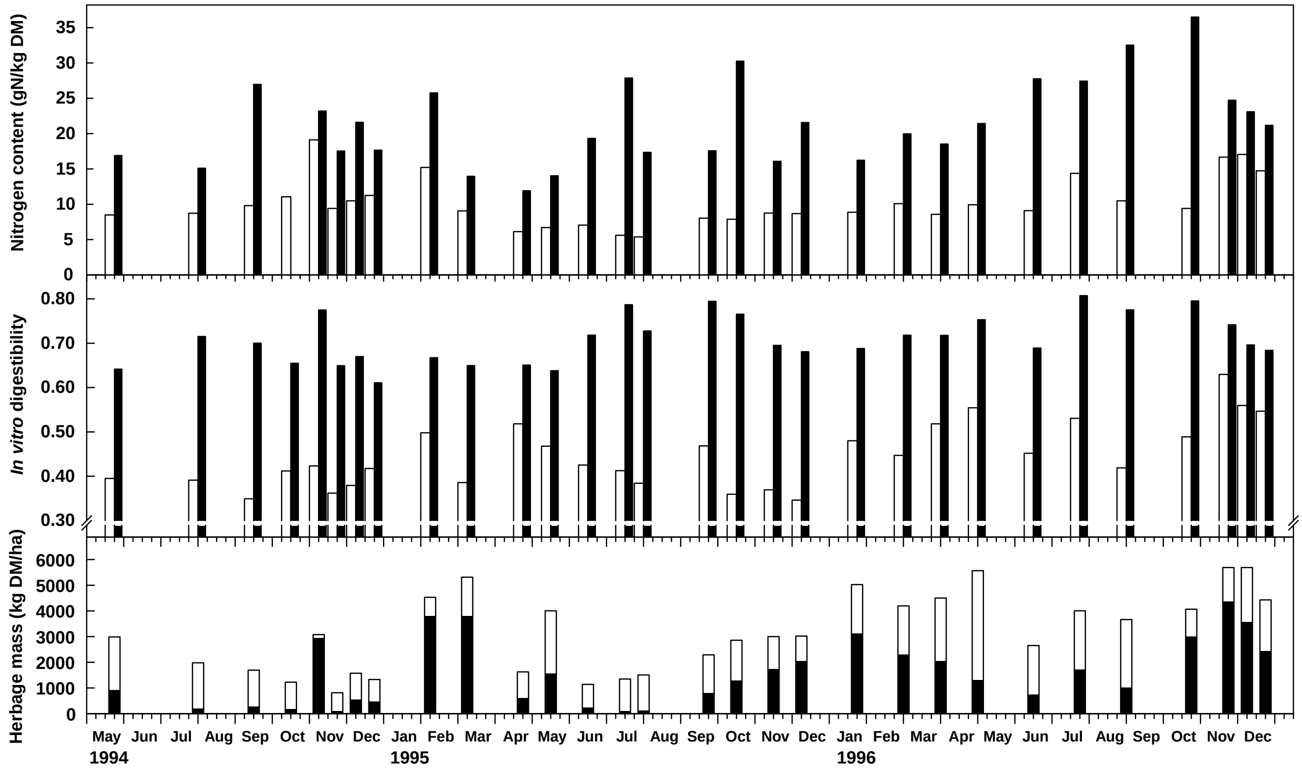

Figure 2. Seasonal patterns of herbage mass (green fraction, solid bars; senesced fraction, open bars) and nutritive value (*in vitro* OM digestibility, N content) of temperate perennial pasture grazed by steers unsupplemented in late winter–early spring (P1 pasture).

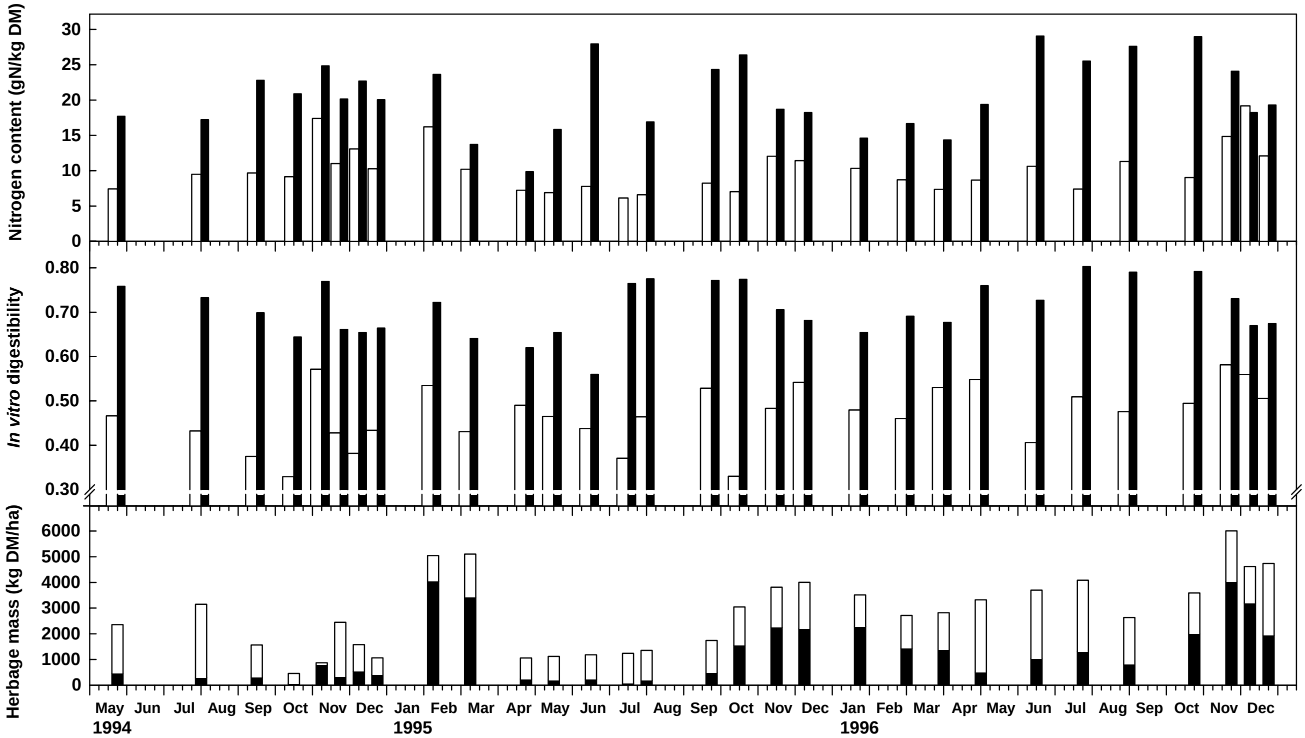

Figure 3. Seasonal patterns of herbage mass (green fraction, solid bars; senesced fraction, open bars) and nutritive value (*in vitro* OM digestibility, N content) of temperate perennial pasture grazed by steers provided with a formulated supplement in late winter–early spring (P2 pasture).

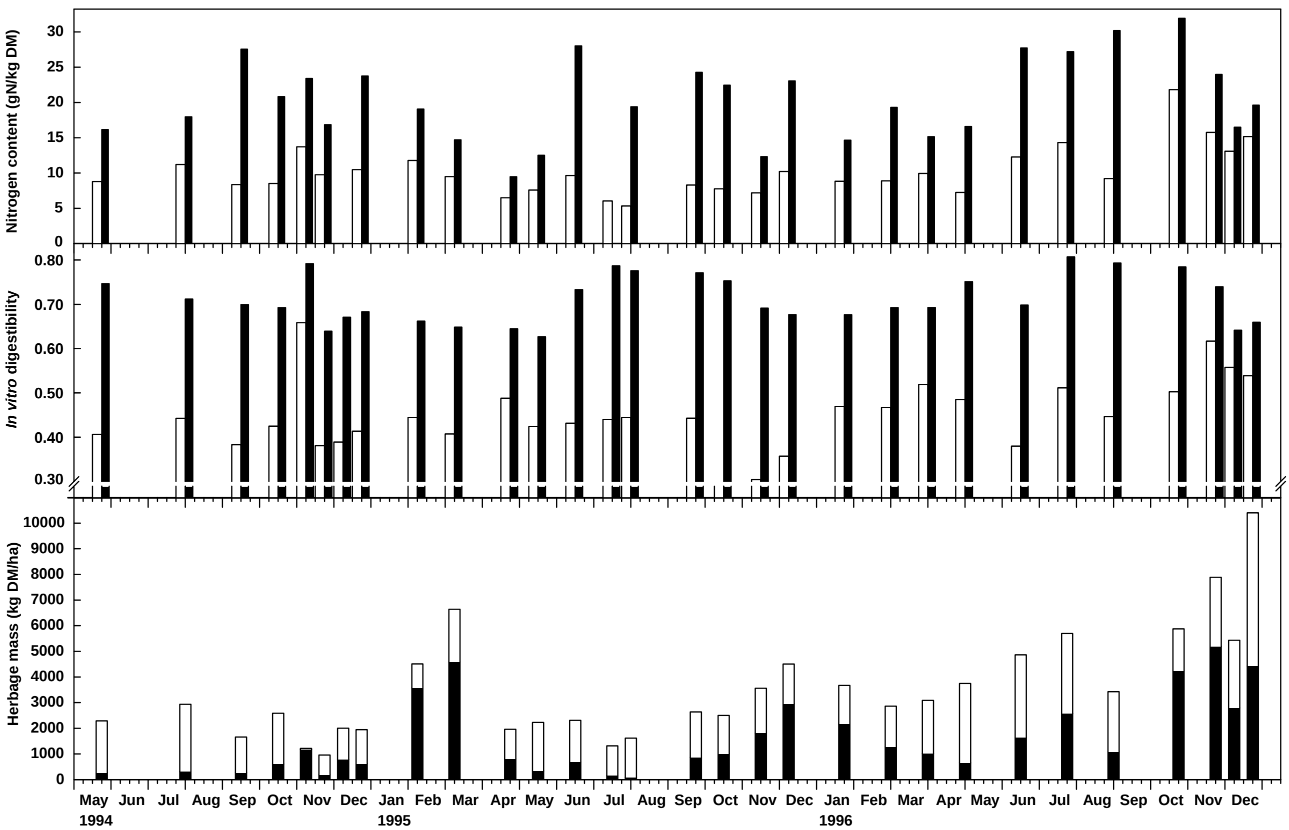

Figure 4. Seasonal patterns of herbage mass (green fraction, solid bars; senesced fraction, open bars) and nutritive value (*in vitro* OM digestibility, N content) of temperate perennial pasture grazed by steers provided with access to forage crop in late winter–early spring (P3 pasture).

content of the diet for both pasture types was marked, peaking in spring–early summer, and declining over summer to a minimum in winter. These differences were attributed to seasonal changes in green herbage mass that contained greater concentrations of N, P, S, Mg and K than the senesced fraction.

In this environment, under conditions conducive to the expression of genetic potential of pasture species (i.e. monoculture, irrigation, and with liberal application rates of P and N fertiliser), significant differences in nutritive value between species and consistent seasonal patterns have been shown to occur (Archer and Robinson 1988). Their study of of the nutritive value of white clover, tall fescue, phalaris and a wide range of warm-season native grasses and winter-green native grasses in monoculture showed that the digestibility of the green component of white clover generally exceeded that of all grasses, and the digestibility of the green component of tall fescue and phalaris was greater than that of native grasses, especially in winter. Through spring, the digestibility of the green component of all species declined and then remained at a lower but relatively constant level through summer–autumn. The digestibility of the senesced component was generally in the range 0.45–0.60 for introduced grasses, with highest values in spring and lowest values in autumn. The N content of the green component of white clover (about 30–40 g N/kg DM) was consistently higher than the grasses. Phalaris had higher N content than tall fescue (30 compared with 20 g N/kg DM), and the N content of the senesced component was generally in the range 10–15 g N/kg DM. Results from the present study showing seasonal patterns in nutritive value of grass–legume mixed swards based on introduced species are consistent with the results of Archer and Robinson (1988) for the same species in monoculture.

The present results are also in general agreement with knowledge of the pattern of change in the nutritive value of pasture plants in relation to different stages of phenological maturity (Minson *et al*. 1960; Waite *et al.* 1964; Fleming 1973; Sullivan 1973; Jones and Wilson 1987; Givens *et al.* 1989; Wilman *et al.* 1994) and extend knowledge for this environment from species in monoculture (Archer and Robinson 1988; Ayres *et al.* 1998) to mixed swards under grazing. The results show that for introduced species, the broad seasonal pattern comprises high nutritive value of cool-season vegetative growth in winter, progressive decline in nutritive value through the spring primary growth phase, and lower but relatively uniform nutritive value of secondary regrowth in summer–autumn.

The sharp decline in the nutritive value of green herbage mass over spring (digestibility decline from 0.80–0.85 to 0.67–0.70 and N content decline from 30 to 20 g N/kg DM) warrants special consideration. This progressive decline in digestibility represents a rate of decline of 0.0023 per day and is consistent with the values of 0.0020–0.0035 per day for perennial ryegrass, Italian ryegrass and tall fescue reported by Givens *et al.* (1989), and 0.0016 per day for white clover reported by Ayres *et al.* (1998). For white clover, this decline in digestibility was accompanied by a 0.20 decline in voluntary intake by sheep (Ayres *et al.* 1998). Moreover, data for subterranean clover (Mulholland *et al.* 1996) and white clover (Ayres *et al.* 1998) show that decline in N content with advancing maturity in spring is also accompanied by changes in protein degradability components (rumen degradable protein, digestible undegradable protein, metabolisable protein). For example, for white clover, metabolisable protein at the ripe seed stage was limiting for microbial protein synthesis and below the requirement for animal maintenance (Ayres *et al.* 1998).

Because this decline in nutritive value with onset of maturity is primarily associated with ageing of leaf (Wilman *et al.* 1994), there would seem to be little opportunity for preferential grazing to remediate a corresponding decline in diet quality. In the present study, the lower level of nutritive value attained by the end of spring was thereafter maintained at about 0.65–0.70 digestibility and 15–20 g N/kg DM through the secondary regrowth phase in summer–autumn. This data for relatively lower nutritive value of summer regrowth is supported by the work of Givens *et al.* (1989) who reported that the summer regrowth of perennial ryegrass and Italian ryegrass was relatively higher in structural fibre and lignin, and relatively lower in crude protein and metabolisable energy concentration than spring or autumn forage.

Conclusion

The data describe the key botanic, herbage mass, and nutritive value characteristics of introduced temperate perennial pasture grazed by cattle during post-weaning growth in this summer-rainfall environment. The results are of special interest because they extend knowledge of the grazing value of pasture based on introduced species from monoculture plots to paddock-scale mixed swards grazed by cattle. The results illustrate the pervading limitation imposed on grazing performance by the winter feed gap first suggested by Cotsell (1958) and Begg (1959). On the strength of the results presented in this study, and a consideration of the relevant literature, evidence also exists to support the occurrence of a summer–autumn feed-gap due to the sub-optimal nutritive value of green herbage mass from late spring through summer–autumn. Our second paper (Dicker *et al.* 2001) in this series reports on the significance of these feed gaps for the post-weaning growth of steers.

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References

AOAC (1980) 'Official methods of analysis of the AOAC (13th edn).' (Association of Official Agricultural Chemists: Washington, DC)

Anon. (1964) Soil and pasture research on the Northern Tablelands, New South Wales. CSIRO in cooperation with New South Wales Department of Agriculture. (CSIRO: Melbourne)

Archer KA (1995) The New South Wales pasture base. In 'Proceedings of the 10th annual conference of the Grassland Society of New South Wales'. (Eds JF Ayres, DL Michalk, H Lloyd-Davies) pp. 10–13. (Grassland Society of NSW Inc.)

Archer KA, Robinson GG (1988) Agronomic potential of native grass species on the Northern Tablelands of New South Wales. II. Nutritive value. *Australian Journal of Agricultural Research* **39,** 425–436.

Ayres JF (1991) Sources of error with *in vitro* digestibility assay of pasture feeds. *Grass and Forage Science* **48**, 89–97.

Ayres JF, Turner AD, Kamphorst PG (1996) The persistence of introduced pasture species through severe drought on the Northern Tablelands of New South Wales. In 'Proceedings of the 11th annual conference of the Grassland Society of NSW'. (Eds J Virgona, D Michalk) pp. 137–139. (Grassland Society of NSW Inc.)

Ayres JF, Turner AD, Kamphorst PG (1997) Drought recovery of temperate perennial pasture on the Northern Tablelands. In 'Proceedings of the 12th annual conference of the Grassland Society of NSW'. (Eds A Bowman, D Michalk) pp. 115–117. (Grassland Society of NSW Inc.)

Ayres JF, McPhee MJ, Turner AD, Curll ML (2000) The grazing value of tall fescue (*Festuca arundinacea*) and phalaris (*Phalaris arundinacea*) for sheep production in the Northern Tablelands of New South Wales. *Australian Journal of Agricultural Research* **51** (1), 57–68.

Ayres JF, Nandra KS, Turner AD (1998) A study of the nutritive value of white clover (*Trifolium repens* L.) in relation to different stages of phenological maturity in the primary growth phase in spring. *Grass and Forage Science* **53**, 250–259.

Begg JE (1959) Annual pattern of soil moisture stress under sown and native pastures. *Australian Journal of Agricultural Research* **10**, 518–529.

Cotsell J (1958) Assessment of some of the factors involved in the formulation of an animal/pasture pattern for high production. In 'Australian agrostology conference. Vol. 1, Part 2'. pp. 58.1–58.10)

Dicker RW, Ayres JF, Dobos RC, McPhee MJ, Nandra KS, Turner AD (1998) The pasture feed-base for beef cattle production on the northern tablelands of New South Wales: a review. *Animal Production in Australia* **22**, 181–184.

Dicker RW, Ayres JF, McPhee MJ, Kamphorst PG, Turner AD, Robinson DL, Oddy VH (2001) Post-weaning growth of cattle in northern New South Wales. 1. Growth pathways of steers. *Australian Journal of Experimental Agriculture* **41,** 971–979.

Fleming GA (1973) Mineral composition of herbage. In 'Chemistry and biochemistry of herbage'. (Eds BW Butler, RW Bailey) Vol 1. pp. 529–566. (Academic Press: London and New York)

Givens DI, Everingham JM, Adamson AH (1989) The nutritive value of spring-grown herbage produced on farms throughout England and Wales over four years. 1. The effect of stage of maturity and other factors on chemical composition, apparent digestibility and energy values measured *in vivo*. *Animal Feed Science and Technology* **27,** 157–172.

Hamilton BA, Hutchinson KJ, Annis PC, Donnelly JB (1973) Relationships between the diet selected by grazing sheep and the herbage on offer. *Australian Journal of Agricultural Research* **24,** 271–277.

Hargreaves JNG, Kerr JD (1978) 'BOTANAL — a comprehensive sampling and computing procedure for estimating pasture yield and composition. 1. Field sampling.' CSIRO Division of Tropical Crops and Pasture, Tropical Agronomy Technical Memorandum No. 8, Brisbane.

Hartridge F, Parker R (1979) 'Pastoral research on the Northern Tablelands, New South Wales.' NSW Agriculture monograph, NSW Agriculture, Orange, Australia.

Hobbs JE, Jackson IJ (1977) Climate. In 'An atlas of New England. Vol. 2. The Commentaries'. (Eds DAM Lea, JJ Pigram, LM Greenwood) pp. 75–99. (Department of Geography, University of New England: Armidale)

Jones DIH, Wilson AD (1987) Nutritive quality of forage. In 'Nutrition of herbivores'. (Eds JB Hacker, JH Ternouth) pp. 65–89. (Academic Press: Sydney)

Langlands JP, Bennett IC (1973) Stocking intensity and pastoral production. 1. Changes in the soil and vegetation of a sown pasture grazed by sheep at different stocking rates. *Journal of Agricultural Science, Cambridge* **81,** 193–204.

Langlands JP, Holmes CR (1978) The nutrition of ruminants grazing native and improved pasture. 1. Seasonal variation in the diet selected by grazing sheep and cattle. *Australian Journal of Agricultural Research* **29,** 863–874.

Lodge GM, Robinson GG, Simpson PC (1990) 'Grasses — native and naturalised'. NSW Agriculture Agfact P2.5.32, Orange.

McPhee MJ, Ayres JF, Curll ML (1997) Growth periodicity of introduced pastures on the Northern Tablelands of New South Wales. *Australian Journal of Agricultural Research* **48**, 831–841.

Minson DJ, Raymond WF, Harris CE (1960) Studies in the digestibility of S37 cocksfoot, S23 ryegrass and S24 ryegrass. *Journal of the British Grassland Society* **15,** 174–180.

Moore AD, Donnelly JR, Freer M, Langford CM (1993) 'Production systems studies — evaluating proposed management systems for elite lamb production in south-eastern Australia by computer simulation'. CSIRO report to the Meat Research Corporation.

Morley FHW, Bennett D, Clark KW (1964) 'The estimation of pasture yield in large grazing experiments.' CSIRO Division of Plant Industries Field Station Record No. **3**, pp. 43–47.

Mulholland JG, Nandra KS, Scott GB, Jones AW, Coombes NE (1996) Nutritive value of subterranean clover in a temperate environment. *Australian Journal of Experimental Agriculture* **36**, 803–814.

Northcote KH (1974) 'A factual key for the recognition of Australian soils.' (Rellim Technical Publications: Glenside, South Australia)

Robinson DL, Oddy VH, Dicker RW, McPhee MJ (2001) Post-weaning growth of cattle in northern New South Wales. 3. Carry-over effects on finishing, carcass characteristics and intra-muscular fat. *Australian Journal of Experimental Agriculture* **41**, 1041–1049.

Payne RW, Lane PW, Ainsley AE, Bicknell KE, Digby PGN, Harding SA, Leech PK, Simpson HR, Todd AD, Verrier PJ, White RP, Gower JC, Tunnicliffe Wilson G, Paterson LJ (1987) 'Genstat 5 reference manual.' (Clarendon Press: Oxford, UK)

Robinson GG, Archer KA (1988) Agronomic potential of native grass species on the Northern Tablelands of New South Wales. 1. Growth and herbage production. *Australian Journal of Agricultural Research* **39**, 415–423.

Roe R, Southcott WH, Newton-Turner H (1959) Grazing management of native pastures in the New England region of New South Wales. I. Pasture and sheep production with special reference to systems of grazing and internal parasites. *Australian Journal of Agricultural Research* **10**, 530-554.

Smith RCG, Johns GG (1975) Seasonal trends and variability of soil moisture under temperate pasture on the Northern Tablelands of New South Wales. *Australian Journal of Experimental Agriculture and Animal Husbandry* **15**, 250–255.

Sullivan JT (1973) Drying and storing herbage as hay. In 'Chemistry and biochemistry of herbage'. (Eds GW Butler, RW Bailey) pp. 1–31. (Academic Press: London and New York)

Waite R, Johnston MJ, Armstrong DG (1964) The evaluation of artificially dried grass as a source of energy for sheep. 1. The effect of stage of maturity on the apparent digestibility of ryegrass, cocksfoot and timothy. *Journal of Agricultural Science Cambridge*, **62**, 391–398.

Whalley RDB, Robinson GG, Taylor JA (1978) General effects of management and grazing domestic livestock on the rangelands of Northern Tablelands N.S.W. *Australian Rangelands Journal* **2**, 174–190.

Wilman D, Acuna PGH, Michaud PJ (1994) Concentrations of N, P, K, Ca, Mg and Na in perennial ryegrass and white clover leaves of different ages. *Grass and Forage Science* **49**, 422–428.

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