Sward Characteristics and Nutritive Value of Two Cultivars of Subterranean Clover

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ABSTRACT : Two cultivars of subterranean clover (*Trifolium subterraneum* L.), "Dinninup" and "Seaton Park", were sown at Shenton Park Field Station, Western Australia, in May 1992 and 1993. The characteristics of Dinninup related to animal production were compared with Seaton Park under grazing conditions with herbage utilization efficiencies of 60% in 1992 and 65% in 1993. The results showed that Dinninup and Seaton Park had similar dry matter digestibility (77-78%) and dry matter production (1,290 kg/ha in 1992; 930 kg/ha in 1993) before flowering initiation even though Dinninup had more ($p<0.05$) branches, leaves and petioles per plant. After flowering, the herbage on offer of Dinninup was higher ($p<0.05$) and dry matter digestibility was lower ($p<0.05$) than that of Seaton Park while the sward structure was similar for both cultivars. The variation in nutritive value among plant parts increased with maturation. Leaf was more digestible than stem and petiole with a higher nitrogen content, and stem had the lowest dry matter digestibility and nitrogen content in late of the season. Sheep did not show any preference for Seaton Park over Dinninup. The predicted bodyweight gain of sheep grazing pure Seaton Park and Dinninup swards using Grazfed software indicated that sheep grazing Dinninup were predicted to have a similar bodyweight gain in early growing stage and a significantly lower gain after flowering compared with those grazing Seaton Park. (***Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 8 : 1192-1199***)

Key Words : Digestibility, Nitrogen Content, Pasture Growth

INTRODUCTION

Subterranean clover (*Trifolium subterraneum* L.) is the most important pasture legume in Australia. Some 40 million hectares of annual pasture are based on subterranean clover and Medicago *spp*. The key to the widespread success of subterranean clover is the large number of cultivars suitable to a wide range of environmental conditions. Dinninup is a favoured cultivar because of its good burr burial, high levels of hardseededness and embryo dormancy, and good tolerance to root rots (Collins et al., 1984). However, early work showed that sheep lost bodyweight in winter when grazing Dinninup, but maintained or gained weight when grazing other cultivars such as Seaton Park (Nicholas, 1972). Purser (1980) also found that intake of sheep grazing Dinninup during winter was only 70-80% of those grazing the cultivar "Daliak". The low animal production on Dinninup-based pasture was explained by its low palatability associated with high levels of formononetin and isoflavones (Nicholas, 1972; Collins et al., 1984). However, this explanation might not be valid for dry, mature subterranean clover where digestion and flow rate of plant material from the rumen are important in regulating forage intake (Demment et al., 1995).

Intake differences between cultivars could also be partly due to differences in seasonal sward structure (Demment et al., 1995). Herbage availability is an important sward characteristic which can regulate grazing behaviour and consequently forage intake. Low availability often reduced intake due to the difficulty in prehension of short herbage. Jamieson and Hodgson (1979) reported that when herbage on offer declined from 3000 to 1000 kg/ha, bite rate and grazing time increased, while herbage intake decreased by 24% and 39% for calves and lambs, respectively. Sward height also influenced grazing behaviour and forage intake (Allen and Whittaker, 1970).

Sward botanical and structural composition and pasture quality are also major determinants of forage intake through modifying grazing behaviour, especially late in the growing season. Birrell (1989) reported that intake rate increased linearly with the amount of green herbage in the sward, and this relationship was modified by digestibility of organic matter (OMD). If OMD was 65%, intake rate was linear over the green herbage mass of 1000-4000 kg DM/ha. Whereas, with an OMD of 70%, intake rate became constant when green herbage mass was only 2000 kg DM/ha. However, there is limited information on the differences in sward structure, herbage availability and nutritive value among subterranean clover cultivars during the growing season. Two experiments were designed to compare the sward characteristics and nutritive value of Dinninup with one of the most popular cultivars, Seaton Park, to investigate the

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factors causing poor animal production on Dinninup pastures.

MATERIALS AND METHODS

Experiment 1 was conducted in 1992 to compare the sward characteristics and nutritive value of two cultivars of subterranean clover, Dinninup and Seaton Park. Seaton Park was used as a control because it commences flowering about the same time as Dinninup (110~113 days from sowing). Seaton Park is a useful and persistent variety in medium rainfall areas and is the most suitable cultivar for the areas with an annual rainfall of 400~600 mm (Collins et al., 1984). Based on the outcomes of Experiment 1, Experiment 2 was conducted in 1993 on the same location to further evaluate the sward characteristics and nutritive value of Dinninup with Seaton Park as a control.

Experiment 1

1) Pasture establishment and management

Dinninup and Seaton Park were sown on a clay sandy soil at Shenton Park Field Station, Western Australia, in May 1992. Each cultivar was sown at a rate of 60 kg/ha, and was replicated 3 times. Each plot size was 100 m^2 (4×25 m) with 2 m border between plots. A basal dressing of a mixture of superphosphate and potash was applied at 200 kg/ha before sowing.

The plots were grazed at 4-weekly intervals from 7 August until 12 October in 1992. The equivalent of about 50 sheep/ha were used to enable 60% of the available herbage consumed over 2-day period. The grazing intensities were achieved by controlling grazing time according to the amount of herbage remaining after each grazing. Dry matter available before and after grazing was measured to determine the amount of herbage removed by grazing animals.

2) Measurements

Dry matter production : Before and after each grazing, three quadrats (0.1 m^2/each) of plant material were randomly selected from each plot and cut to ground level. The material from each plot was bulked and the fresh weight was recorded. A representative subsample was dried at 80℃ for 48 hours. Dry matter production was calculated using the fresh weight and dry matter content.

Proportion of plant parts : Half of the plant material sampled from each plot were hand sorted into leaves, petioles, stems, flowers, burrs and dead material. All fractions were dried at 80℃ for 48 hours and their proportion of total dry weight calculated.

Nutritive value : Another subsample from each plot was freeze dried for 3 to 4 days, depending on the moisture in the plants. *In vitro* dry matter digestibility (DMD) was estimated using the pepsin-cellulase method (Aufrere and Michalet-Doreau, 1988; Warren and Casson, 1993), and crude protein was analysed using the method described by Harris (1984).

Experiment 2

1) Pasture establishment and management

The same two cultivars of subterranean clover used in Exp. 1 (Dinninup and Seaton Park) were sown on a clay sandy soil in a block of about 1,300 m^2 with 4 replicates at Shenton Park Field Station, Western Australia, in May 1993. Because of the limited amount of seed available from a breeding program, the sowing rate was 30 kg/ha, and the plot size was 4 m^2 (2×2 m) with 1 m border between plots. The plots were surrounded by subterranean clover pastures.

From 17 August, the plots were grazed by sheep at a 2-weekly intervals until 12 October. At each grazing, 30 sheep were used to consume about 65% of the available herbage in a few hours.

In the middle of September, the plots were top dressed with a mixture of superphosphate and potash at a rate of 200 kg/ha. The plots were irrigated from August, until 9 November.

2) Measurements

Sward characteristics : Before each grazing, one quadrat (0.1 m^2) of plant material was randomly cut from each plot to ground level and the fresh weight was recorded. Half of the plant material was dried in an oven at 80℃ for 48 hours to measure dry matter content to calculate dry matter on offer.

From 17 August, one quadrat (0.1 m^2) of plant material was taken randomly from each plot at a 4-weekly interval by cutting the plants to ground level. One subsample was hand sorted into leaves, petioles, stems, flowers and burrs, and dried at 80℃ for 48 hours to estimate the proportions of plant parts. Three plants were randomly selected in each plot to count the numbers of primary branches, and the number of branches, leaves, petioles, peduncles, flowers and burrs. The length of primary branches were also estimated.

Nutritive value : A subsample was freeze dried for chemical analysis and estimation of *in vitro* DMD. *In vitro* DMD was estimated using the same method as in Exp. 1. Nitrogen was analysed using a LECO CHN-1000 combustion system (Anon, 1991). Acid detergent fibre (ADF) and lignin (ADL) were analysed using the methods described by Harris (1984).

3) Statistics

The two experiments were a randomised complete block design. As the objective of this study was to compare the sward characteristics and nutritive value of the two cultivars under same environmental and management conditions, differences between the two cultivars were analysed within each sampling date and within each year (i.e., Exp. 1 and Exp. 2). The variance between cultivars was estimated using a general linear model in Systat (Wilkinson et al., 1992).

RESULTS

Dry matter production

Exp. 1 showed no difference in dry matter production ($p>0.05$) and growth rate between Dinninup and Seaton Park during the experimental period, with a total dry matter production of 3890 and 3830 kg DM/ha, respectively. The average growth rate for the two cultivars were 15, 62 and 46 kg DM/ha/day in August, September and October, respectively. Total dry matter available before the commencement of grazing was 1,290 kg DM/ha.

The results of Exp. 2 also indicated that Dinninup and Seaton Park had similar growth rate early in the season, with an average dry matter yield prior to the first grazing being 930 kg DM/ha. However, from September, Dinninup had a higher dry matter on offer ($p<0.05$) than Seaton Park (figure 1).

Sheep did not show grazing preference for a particular cultivar. During the grazing period in Exp. 1, sheep removed similar amounts of dry matter from Dinninup and Seaton Park plots (1,800 kg DM/ha vs 1,870 kg DM/ha). This comprised 1483, 299 and 18 kg DM/ha of leaf, petiole and other components (e.g. flowers), respectively, from Dinninup plots. Comparable data for Seaton Park plots were 1261, 581 and 29 kg DM/ha. Sheep consumed more petioles from Seaton Park plots than from Dinninup plots ($p<0.05$).

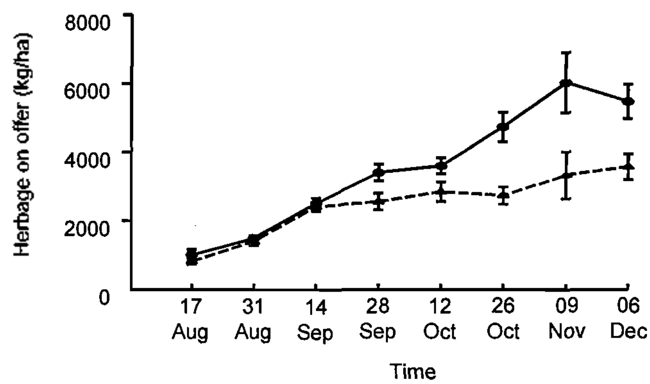

Figure 1. Variation in dry matter on offer (kg/ha) between Dinninup (●) and Seaton Park (▲) during the growing season in 1993

Table 1. Proportion of plant parts (%) of Dinninup and Seaton Park during the growing season (Exp. 2)

Cultivar	August	September	October	November
			Leaf	
Dinninup	68.9	49.0	32.6[b]	21.1[b]
Seaton Park	66.9	47.7	26.4[a]	15.9[a]
SEM	1.75	1.86	1.94	1.26
			Petiole	
Dinninup	29.7	27.6[b]	26.3[b]	21.8[b]
Seaton Park	28.6	22.5[a]	19.2[a]	15.5[a]
SEM	1.16	1.32	1.59	1.58
			Stem	
Dinninup	1.4[a]	21.1[a]	32.0[a]	27.3[a]
Seaton Park	4.6[b]	25.5[b]	42.1[b]	38.1[b]
SEM	0.87	1.34	2.45	2.41
			Flower & burr	
Dinninup	0	2.3[a]	9.1[a]	29.9
Seaton Park	0	4.0[b]	12.4[b]	30.4
SEM		0.46	0.84	1.27

[a,b] Values within a column with different letters are different ($p<0.05$).

The proportion of plant parts

Results were similar for Exp. 1 and Exp. 2, and so the data from Exp. 2 only are given in table 1. Dinninup had higher proportions of leaves and petioles ($p<0.05$) than Seaton Park in October and November (table 1). Seaton Park showed a more rapid development indicated by higher proportion of stem ($p<0.01$) in the sward from August through to November.

The number and length of plant parts

There was no difference ($p>0.05$) in the length of petiole and peduncle between the two cultivars at early flowering (September 14) or after cessation of flowering (November 9; Exp. 2). The average length of grazed petiole, ungrazed petiole and ungrazed peduncle for the two cultivars were 3.6, 3.7, and 2.5 cm at early flowering and 2.1, 3.0 and 2.1 cm after cessation of flowering, respectively. The length of branch was 5 cm shorter ($p<0.05$) for Dinninup (6.9 cm) than for Seaton Park (12.3 cm) at early flowering, and was similar (9.0 *vs* 10.0 cm) for the two cultivars after cessation of flowering.

The number of plant parts is shown in table 2. Dinninup had more branches, petioles, leaves and flowers per plant ($p<0.05$) than Seaton Park at early flowering (September 14). However, there was no difference ($p>0.05$) in the number of plant parts after cessation of flowering (November 9) except that Dinninup still had 4 more primary branches per plant than Seaton Park ($p<0.05$).

Nutritive value of whole plant

Variation in DMD between the two cultivars was not significant ($p>0.05$) in either experiment before early October (table 3). Thereafter, the DMD of Dinninup declined rapidly and was 4 percentage units lower ($p<0.05$) than that of Seaton Park in both November and December in Exp. 2.

There was no difference ($p>0.05$) in nitrogen content between the two cultivars in Exp. 1 at any stage of growth (August-October). However, the variation in nitrogen content between the two cultivars interacted with the maturity stage of the plants in Exp. 2, where Dinninup had a higher ($p<0.05$) nitrogen content in early September and a lower nitrogen content in November and December compared with Seaton Park (table 4).

Table 2. Number of plant parts (no/plant) of Dinninup and Seaton Park during the growing season (Exp. 2)

Cultivar	Primary branch	Subbranch	Petiole	Leaf	Burr	Flower
			Early flowering			
Dinninup	25.2^b	22.2^b	235.9^b	140.3^b	82.8	47.2^b
Seaton Park	21.3^a	5.2^a	129.0^a	83.5^a	68.6	21.5^a
SEM	0.85	3.79	20.68	11.58	9.63	5.64
			Cessation of flowering			
Dinninup	20.8^b	27.8	188.3	159.1	114.0	46.7
Seaton Park	15.0^a	37.3	176.4	146.9	87.7	51.5
SEM	0.97	6.82	27.25	21.07	15.11	6.51

a,b Values within a column with different letters are different ($p<0.05$).

Table 3. *In vitro* dry matter digestibility (%) of Dinninup and Seaton Park grown at Shenton Park Field Station, Western Australia (Exp. 1 and 2)

Time	August	September	October	November	December
			Exp. 1		
Dinninup	78.7	74.1	65.0		
Seaton Park	78.3	73.6	67.0		
SEM	0.46	0.80	0.54		
			Exp. 2		
Dinninup	77.0	73.3	68.2	52.2^a	47.4^a
Seaton Park	77.8	71.8	66.4	56.9^b	51.7^b
SEM	0.67	0.62	0.41	1.00	0.86

a,b Values within a column with different letters are different ($p<0.05$).

Exp. 2 also indicated that ADF was 1.8 and 2.0 percentage units lower ($p<0.05$) for Dinninup than for Seaton Park in September and October respectively without any difference at other sampling times. ADL was similar ($p>0.05$) for the two cultivars throughout the experiment.

Nutritive value of plant parts

The DMD and nitrogen content of plant parts (Exp. 2) are listed in table 5. There was no difference ($p>0.05$) in DMD of leaves and petioles between the two cultivars from August to October. The stem DMD of Dinninup was about 4 percentage units higher ($p<0.01$) than that of Seaton Park in September and was similar ($p>0.05$) in October.

The nitrogen concentration in leaf and petiole was lower in August and September and higher in October ($p<0.05$) for Dinninup than for Seaton Park, with the nitrogen content in stem being consistently higher ($p<0.01$) for Dinninup than for Seaton Park in September and October.

The results in table 5 also indicated that leaf was more digestible ($p<0.01$) than stem in October for both cultivars. Petioles had very similar DMD with leaves in August and September, lower ($p<0.01$) DMD than leaves, and higher ($p<0.01$) DMD than stems in October.

Table 5. *In vitro* dry matter digestibility (%) and nitrogen content (% DM) of plant parts of Dinninup and Seaton Park during the growing season grown at Shenton Park Field Station, Western Australia (Exp. 2)

Cultivar	Fraction	August	September	October
		DMD		
Dinninup	Leaf	74.2	71.9	67.1
Seaton Park	Leaf	74.7	69.6	69.1
SEM		0.72	1.14	2.07
Dinninup	Petiole	73.8	71.0	65.4
Seaton Park	Petiole	72.4	68.6	67.5
SEM		0.80	0.80	0.55
Dinninup	Stem		71.3^b	63.2
Seaton Park	Stem		67.9^a	62.5
SEM			1.16	0.71
		Nitrogen		
Dinninup	Leaf	5.34^a	5.39^a	4.99^b
Seaton Park	Leaf	5.49^b	5.46^b	4.84^a
SEM		0.03	0.02	0.02
Dinninup	Petiole	2.63^a	2.52^a	2.32^b
Seaton Park	Petiole	2.72^b	2.58^b	2.24^a
SEM		0.02	0.05	0.05
Dinninup	Stem		2.67^b	2.03^b
Seaton Park	Stem		2.49^a	1.95^a
SEM			0.07	0.04

^{a,b} Values within a column with different letters are different ($p<0.05$).

DISCUSSION

The outcomes of these experiments indicated variation in sward characteristics and nutritive value between two cultivars with a similar flowering time. Differences in particular characteristics varied in magnitude during the growing season, which has important implications to pasture management under grazing conditions.

Dry matter production

Dinninup was a productive cultivar during the growing season. In winter, the growth rate of Dinninup was as high as Seaton Park, which would have a great value in animal production systems during this particular period when herbage availability is one of the key factors limiting intake of grazing animals. After flowering, Dinninup showed potential for high dry matter production and offered more feed reserves for summer grazing than Seaton Park. Thus

Table 4. Nitrogen content (%) of Seaton Park and Dinninup grown at Shenton Park Field Station, Western Australia (Exp. 1 and 2)

Time	August	September	October	November	December
			Exp. 1		
Dinninup	3.28	3.82	3.23		
Seaton Park	3.41	3.82	3.34		
SEM	0.07	0.06	0.06		
			Exp. 2		
Dinninup	4.16^a	3.67^b	2.61	2.27^a	2.61^a
Seaton Park	4.24^b	3.47^a	2.69	2.53^b	2.73^b
SEM	0.04	0.06	0.06	0.05	0.04

^{a,b} Values within a column with different letters are different ($p<0.05$).

Dinninup was superior over Seaton Park in dry matter production late in the season with similar grazing intensities for both cultivars.

There was a seasonal change in growth rate of both cultivars, with the lowest growth rate in winter (16 kg/ha/day) and the highest growth rate in early spring (67 kg/ha/day). This result was in agreement with Dunlop et al. (1984) who found that growth rate varied from 17 kg/ha/day during 42 days following January rains to 50 kg/ha/day between late August and mid-September for annual pastures. This seasonal growth rate of annual pastures is a reflection of seasonal changes in light intensity and temperature which have strong influences on the leaf expansion rate and consequently leaf area index (Doyle et al., 1993).

Palatability

Palatability did not seem to be a factor limiting the intake of Dinninup by grazing animals in the current experiments. The results from Exp. 1 indicated that sheep removed similar amounts of dry matter during the grazing period from Seaton Park and Dinninup plots. This does not support the suggestion that Dinninup has poor palatability in winter caused by high levels of formononetin and total isoflavones (Nicholas, 1972; Collins et al., 1984), but is consistent with the finding that Dinninup and Seaton Park did not differ in their preference index in both September and October (Dunlop, 1986).

Dry, mature Dinninup material might have a low intake than Seaton Park due to its low digestibility. It has been well documented that intake is controlled by both palatability and rumen load. The latter is more important for mature pastures because digestibility and rate of ingesta passage and reticulo-rumen fill are the primary mechanisms of intake regulation in range ruminants (Weston, 1985). It is expected that over-matured plants under high herbage availability are more resistant to breakdown during chewing and ruminating, and have longer retention time in the rumen, leading to a lower intake. Sheep have been shown to have a preference for material of high digestibility and are able to select diets consistently higher in digestibility than material on offer (Mulholland and Coombe, 1979).

Nutritive value

Rank in nutritive value for Dinninup and Seaton Park changed seasonally. Before November, Dinninup and Seaton Park did not have any difference in DMD (Exp. 1 and 2) even though Dinninup had a high nitrogen content and a low ADF in the early season (Exp. 2). The variation in nitrogen and fibre content did not make significant contribution to the variation in DMD because lignin content, the key factor limiting dry matter digestion, was similar for both cultivars during the season. The low DMD of Dinninup late in the growing season might be a result of over-maturation of plants associated with the accumulation of structural components, and the contents of tannin and p-coumaric acid in plant tissues. These were reported to increase with maturation in perennial grasses and legumes (Buxton et al., 1987; Hornstein et al., 1989; Goto et al., 1991). However, there is little data directly showing the relationships between these chemical components and DMD in subterranean clover.

The nutritive value of plant parts of subterranean clover differed significantly after flowering initiation and the differences in DMD between leaf and stem increased as maturity advanced. Leaf was the most digestible fraction with a higher nitrogen content than both stem and petiole. This was consistent with the results found in grasses and perennial legumes (Terry and Tilley, 1964). It has been recognised that leaf contains lower cellulose, ADF, NDF, lignin and higher crude protein, essential and non-essential amino acids (Hardwick, 1954; Hume et al., 1968; Stockdale, 1992), and is easier to break into small particles in the rumen with a high passing rate from rumen (McLeod et al., 1990).

The higher DMD in leaf than in stem in the current work contrasts with other findings (Hume et al., 1968; Taylor et al., 1989; Rossiter et al., 1994). Hume et al. (1968) found that DMD of leaf was 7-10 percentage units lower than DMD of stem for two ungrazed dry mature subterranean clover cultivars ("Woogenellup" and "Yarloop"), and petioles were more like stems than leaves in both chemical composition and digestibility. Taylor et al. (1989) also reported that stem-enriched material of "Mt Barker" from slightly grazed sward was more digestible than either the leaf-enriched material or the whole plant material. These conflicting results might be caused by the differences in pasture management and environmental conditions where plants grew.

Sward structure

Variation in sward structure between cultivars was significant. There were more branches, leaves and petioles per plant for Dinninup, with the branches being 5 cm shorter at early flowering due to its later elongation of stems. This morphological difference did not cause any variation in DMD because of the high digestibility of all plant parts and the low proportion of stem in the swards. However, the morphological differences between cultivars disappeared after cessation of flowering except for the high dry matter on offer of Dinninup. Thus it is expected that the Dinninup sward would be denser and shorter than a Seaton Park sward during early growth under a similar plant density. High dry matter on offer of Dinninup

Table 6. The predicted body weight gain (g/day) of mature Merino wether (48 kg liveweight) grazing pure Dinninup and Seaton Park swards using Grazfed model

Cultivar	August	September	October	November	December
Dinninup	162	174	160	-4[a]	6[a]
Seaton Park	158	169	128	32[b]	19[b]

[a,b] Values within a column with different letters are different ($p<0.05$).

late in the growing season could have positive effects on animal intake, but this may be countered to some extent by its poor quality.

Animal production

Using DMD (table 3), herbage on offer (figure 1) and the proportion of dead material in the swards (Ru, 1996), the bodyweight gain of mature Merino wethers grazing these pure subterranean clover swards was predicted using Grazfed model (Anon, 1989). The results indicate that sheep grazing Dinninup in November and December are likely to maintain or lose bodyweight while those grazing Seaton Park pastures are likely to have a bodyweight gain of 19-30 g/day (table 6). The poor animal production from Dinninup was largely a result of the low DMD associated with poor utilisation efficiency of nutrients and the constraint of forage intake by the rumen load.

In conclusion, previous work has suggested that Dinninup is less palatable for sheep and is associated with poor animal production. The current experiments, however, indicate that Dinninup is a productive cultivar for dry matter production, and has a similar palatability as Seaton Park during the growing season. The poor digestibility of Dinninup late in the growing season may be compensated by its high feed reserve for summer grazing, which needs to be considered for an effective pasture management strategy.

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REFERENCES

Allden, W. G. and I. A. Whittaker. 1970. The determinants of herbage intake by grazing sheep The interrelationship of factors influencing herbage intake and availability. Aust. J. Agric. Res. 21:755-766.

Anon. 1989. Nutritional Management System for Grazing Animals. CSIRO, Canberra, Australia.

Anon. 1991. Instruction Manual for CHN 1000. LECO Corporation, USA.

Aufrere, J. and B. Michalet-Doreau. 1988. Comparison of methods for predicting digestibility of feeds. Anim. Feed Sci. Technol. 20:203-218.

Birrell, H. A. 1989. The influence of pasture and animal factors on the consumption of pasture by grazing sheep. Aust. J. Agric. Res. 40:1261-1275.

Buxton, D. R., J. S. Hornstein and W. F. Wedin. 1987. Structural neutral sugars in legumes and grass stems in relation to digestibility. Crop Sci. 27:1279-1285.

Collins, W. J., C. M. Francis and B. J. Quinlivan. 1984. Registered cultivars of subterranean clover--their origin, identification and potential use in Western Australia. Western Australian Department of Agriculture Bulletin No. 4083.

Demment, M. W., J. L. Peyraud and E. A. Laca. 1995. Herbage intake at grazing a modelling approach. In Recent Development in Nutrition of Herbivores. M. Journet, E. Grenet, M. H. Farce, M. Theriez and C. Demarquilly (Eds). INRA, Clermont-Ferrand, France, pp. 121-141.

Doyle, P. T., M. Grimm and A. N. Thompson. 1993. Grazing for pasture and sheep management - annual pasture zone. In Pasture Management: Technology for the 21st Century. D. Kemp and D. Michalk (Eds). CSIRO/AWRDC, Melbourne, Australia, pp. 71-90.

Dunlop, A. C. 1986. Preference ranking of some temperate pasture species by sheep in pens. Proceedings of the Australian Society of Animal Production. Vol. 16:191-194.

Dunlop, A. C., J. W. Bowden and G. M. Allen. 1984. The effect of stocking rate on dry matter production of Mediterranean annual pastures. Proceedings of the Australian Society of Animal Production. Vol. 15:333-336.

Goto, M., A. H. Gordon and A. Chesson. 1991. Changes in cell-wall composition and degradability of sorghum during growth and maturation. J. Sci. Food Agric. 54:47-60.

Hardwick, N. E. 1954. Changes in the major chemical constituents of subterranean clover (*Trifolium Subterraneum* L.) during growth. I. The carbohydrates. Aust. J. Agric. Res. 5:372-382.

Harris, L. E. 1984. Nutrition Research Techniques for Domestic and Wild Animals. Vol. 1, An international record system and procedures for analysing samples. Lorin E. Harris, USA.

Hornstein, J. S., D. R. Buxton and W. F. Wedin. 1989. Cell-wall carbohydrates in leaves, stems and herbage of alfalfa and red clover. Crop Sci. 29:1319-1324.

Hume, I. D., M. Somers and N. R. McKeown. 1968. Nutritive evaluation of two strains of mature subterranean clover. Aust. J. Exp. Agric. Anim. Husb. 8:295-300.

Jamieson, W. S. and J. Hodgson. 1979. The effects of variation in sward characteristics upon the ingestive behaviour and herbage intake of calves and lambs under a continuous stocking management. Grass Forage Sci. 34: 273-382.

McLeod, M. N., P. M. Kennedy and D. J. Minson. 1990. Resistance of leaf and stem fractions of tropical forage to chewing and passage in cattle. Br. J. Nutr. 63:105-119.

Mulholland, J. G. and J. B. Coombe. 1979. A comparison of the forage value for sheep of buckwheat and sorghum stubbles grown on the Southern Tableland of New South Wales. Aust. J. Exp. Agric. Anim. Husb. 19:297-302.

Nicholas, D. A. 1972. Different pasture plants have different grazing values. West. Aust. J. Agric. 13:123-124.

Purser, D. B. 1980. Nutritive value of Mediterranean pastures. In Grazing Animals. F. H .W. Morley (Ed). Elsevier Scientific Publishing Company, Amsterdam. pp. 159-180.

Rossiter, R. C., G. B. Taylor and L. Klein. 1994. Environmental effects, in particular of rainfall, on the digestibility of dry mature subterranean clover. Aust. J. Exp. Agric. 34:25-32.

Ru, Y. J. 1996. The influence of cultivar variation on the potential productivity of swards of subterranean clover when utilised by grazing animals. Ph.D. Dissertation. The University of Adelaide.

Stockdale, C. R. 1992. The nutritive value of subterranean clover herbage grown under irrigation in Northern Victoria. Aust. J. Agric. Res. 43:1265-1280.

Taylor, G. B., R. C. Rossiter, D. B. Purser and W. J. Collins. 1989. The intake and digestibility of dry mature subterranean clovers. In Proceedings of XVI International Grassland Congress, Nice, France, pp. 809-810.

Terry, R. A. and J. M. A. Tilley. 1964. The digestibility of the leaves and stems of perennial ryegrass, cocksfoot, timothy, tall fescue, lucerne, and sainfoin, as measured by an *in vitro* procedure. J. Br. Grassl. Soc. 19:363-372.

Warren, B. E. and T. Casson. 1993. The pepsin-cellulose technique for predicting the digestibility of forages by ruminants. Technical report, Western Australian Department of Agriculture, Katanning, Western Australia.

Weston, R. H. 1985. The regulation of feed intake in herbage-fed ruminants. Proceedings of the Nutrition Society of Australia. Vol. 10:55-62.

Wilkinson, L., M. Hill, J. P. Welna and G. K. Birkenbeuel. 1992. SYSTAT for Windows: Statistics.' 5th edn. SYSTAT, Inc., Evanston, IL.