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# Nutritive value of pastures and rangelands

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## SUMMARY

The ‘nutritive value’ of herbage to grazing animals is the result of the modification of the intrinsic attributes of herbage by the circumstances of the grazing situation and especially the amount and structure of the sward and its species composition.

The potential ‘voluntary intake’ of herbage and the digestibility of the ingested diet are the most important measures of intrinsic herbage quality and are usually positively correlated. These are related to differences in the chemical composition of plant species and their morphology, especially the proportion of green leaf and the age of plant tissue. In general, potential voluntary intake and digestibility are higher in sown grasses and legumes than in indigenous grasses, sedges and dwarf shrubs.

Grazing ruminants usually select herbage of higher quality than the mean of that available to them; the extent to which they can do so being governed by the spatial distribution of different plant components and to some extent by animal factors such as species, age and physiological state. The complex and dynamic nature of the animal: plant interface is discussed and illustrated by reference to experimental data from sown swards and indigenous plant communities grazed by sheep of differing age, at different heights and with or without additional sources of nutrient such as milk or supplement. These illustrations emphasize the importance of the processes of both herbage ingestion and plant tissue turnover as well as nutritional parameters in influencing ‘nutritive value’.

Key words: diet, digestibility, grazing, herbages, intake, nutrition, pastures, rangelands, sheep, sward height.

## YFIRLIT

*Næringargildi úthaga og afrétta*

Næringargildi gróðurs fyrir beitardýr ákvarðast af gróðurbreytingum við beit en einkum af samsetningu og þykkt grassvarðarins og plöntutegundum.

Mikilvægustu eiginleikar plantnanna felast í því hversu mikið af þeim skepnurnar geta étið og hversu meltanlegar þær eru. Jákvætt samhengi er venjulega á milli þessara eiginleika en þeir eru tengdir breytileika í efnainnihaldi og byggingu einstakra plöntutegunda, sérstaklega hlutfalli grænna blaða og aldri einstakra plöntuhluta. Venjulega geta skepnurnar étið og melt meira af sáðgresi og belgjurtum heldur en af hálfgrösum, störum og trjákenndum gróðri.

Jórturdýr á beit velja venjulega gróður með meiri meltanleika heldur en meðalmeltanleiki þess gróðurs er sem þau hafa aðgang að. Hversu mikið val þau hafa byggist á dreifingu hinna ýmsu plöntuhluta í sverðinum og að sumu leyti fer þetta eftir því hvaða búfjártegund um er að ræða, aldri dýrsins, atgervi o.fl. Hið flókna og ,,dynamíska“ samspil búfjár og gróðurs er rætt og skýrt með tilvísun í rannsóknir á beit sauðfjár á mismunandi aldri, með eða án mjólkur eða kjarnfóðurs, á sáðgresi og hálfgrös af mismunandi hæð. Lögð er áhersla á mikilvægi áts og uppskeru, auk næringarfræðilegra þátta sem hafa áhrif á næringargildið.

## INTRODUCTION

The nutritive value of pastures and rangelands can not be considered solely in terms of the chemical composition of its constituent species but most also be considered in terms of the modification of the intrinsic attributes of herbages by the circumstances of the grazing situtation. Pastures and rangelands in northern areas of Europe embrace a broad spectrum of plant species and sward conditions, ranging from intensively-managed sown grassland to indigenous plant communities on extensive systems where little management of domesticated ruminants and their pasture is practised. In extensively managed indigenous pastures, the diversity of plant species and biomass, and their spatial distribution are likely to be greater than on sown grassland. The range of intensive and extensive grazing conditions in the UK exploited by sheep is slightly narrower than in some other northern European countries; nevertheless this range of conditions serves to illustrate the thesis outlined earlier that nutritive value results from the modification of intrinsic herbage quality by sward conditions and the grazing animals.

## INTRINSIC QUALITY OF HERBAGE

Measurement of intrinsic herbage quality such as potential voluntary intake and digestibility can be best measured by the controlled feeding of harvested herbage indoors. They are usually viewed as a means of describing the potential to supply energy to grazing animals. There are wide differences in digestibility between plant families, species, their different morphological components within-species and particularly due to the physiological state of these components; for example dead leaf is less digestible than is live leaf and the digestibility of reproductive stem declines markedly with flowering (Demarquilly and Jarrige, 1971; Terry and Tilley, 1964). There are several methods of predicting digestibility and in the experience of the authors the most accurate prediction is by the *in vitro* process of Tilley and Terry (1963); in using the technique it is better to use standards appropriate to those of the species under test, particularly when dealing with indigenous species (Milne, 1977; Armstrong *et al.*, 1989).

There is, however, more variation in the 'voluntary intake' characteristics of plants or their components than in digestibility, though there is usually a positive relationship between the two indices. This is to be expected since they are both largely influenced by the proportion of structural carbohydrate and its composition (Osbourn, 1981). There may, of course, be wide differences in voluntary intake between sheep of different age or physiological state, but voluntary intake (preferably using standard animals) is the most useful and important criterion in determining the digested energy intake that may be achieved at pasture. The close relationship between intake and digestibility and the decline in both with maturity is well illustrated by the data shown in Figure 1 (Armstrong and Hodgson, 1986; Milne *et al.*, 1979). This includes data on high quality ryegrass and clover, the major indigenous plant communities, such as hill grasses and sedges, and also heather, which is usually of low digestibility. It can be seen that the response in potential intake to increasing digestibility of heather is less than with grasses (Milne, 1974; Milne *et al.*, 1979). This indicates a controlling mechanism or mechanisms which are quite different for heather compared to other herbage species studied (see Milne, 1974).

There are also differences between grass species in intake/digestibility relationships (Minson *et al.*, 1964), but these are relatively small. Furthermore the higher intake relative to digestibility of legumes (especially white clover) compared to grasses is probably the principal reason why sheep production, especially of lambs, from grass/clover pastures is greater than from monospecific grass pas-

tures (Thomson, 1984). This potential advantage of white clover, which also reflects a higher efficiency of utilisation of nutrients as well as of intake, is at least as apparent in mixtures with *Agrostis*/*Festuca* (the most productive 'hill' plant community) as it is with ryegrasses (Armstrong and Eadie, 1973).

### *Crude protein*

The crude protein content of herbages tends to be positively associated with digestibility, but in temperate grasslands it is not regarded as a primary limitation to intake or indeed to animal performance, except in late pregnancy or early lactation (Munro and Walters, 1986). A measure of protein degradability is required to allow more precise estimates as to whether protein requirements are being met. Such information does not exist for many herbages and further work is needed to establish protein degradability values. Factors such as the presence of tannins in heather may be important in reducing the availability of the crude protein in the digestive tract to sheep and these are more likely to be important in rangeland situations than in sown grassland (Milne, 1974).

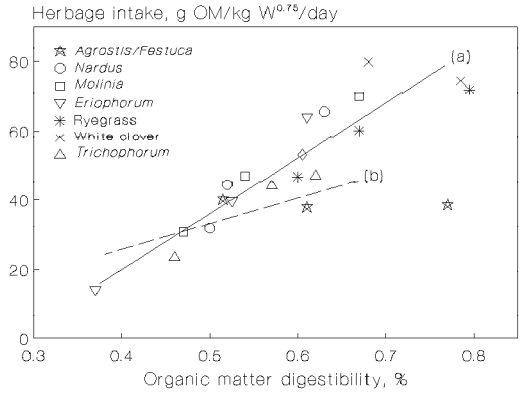


**Figure 1**. Relationship between organic matter intake of herbage and organic matter digestibility of (a) grasses and sedges (*Agrostis*/*Festuca*, *Nardus stricta*; *Molinia caerulea*, *Eriophorum vaginatum*, ryegrass; white clover, *Trichophorum caespitosum*) (Armstrong and Hodgson, 1986) and (b) grazed heather (Milne *et al.*, 1979) by sheep (after Milne, 1985).
*1. mynd. Samband áts og meltanleika lífræns efnis hjá sauðfé sem fær (a) grös og starir (Armstrong og Hodgson, 1986) og (b) lyng (Milne o.fl., 1979). (Samkvæmt Milne, 1985).*

### *Mineral content*

On natural vegetation the dietary intake of mineral macro elements and trace elements is not likely to reduce animal performance except on certain underlying soil types which are known to create deficiencies. However, where the nutrient status of the soil is increased, for example by applying lime and phosphate and reseeding with 'improved' grasses and clover, then mineral imbalances may occur and some form of trace element supplementation with copper or cobalt may increase animal productivity (Frame *et al.*, 1985).

## THE PLANT:ANIMAL INTERFACE

The potential voluntary intake and to a lesser extent digestibility of herbages is inevitably modified by previous grazing history as well as by climatic and seasonal factors. The way in which pastures are managed offers opportunities to maximise the potential voluntary intake and digestibility (Eadie, 1970; Arnold, 1981). In particular the intensity and duration of grazing by ruminant species determines the frequency and severity of defoliation. This influences herbage growth rate and hence the amount of herbage and its distribution and composition which is available for subsequent grazing. Some understanding has been gained of how the complex relationships between grazing animals, particularly sheep, and their pasture may influence the level of nutrition achieved. The maintenance of constant sward conditions on both sown swards and indigenous communities under continuous grazing has been a successful approach in achieving that understanding. In particular "sward height" (a measure of the 'average' height of lamina above ground level) has been shown to be a major determinant of herbage intake (Figure

2) (Bircham, 1981; Hodgson, 1981a; Penning, 1986). Important contributions to this better understanding of the plant:animal interface have been made by concurrent measurements of ingestive behaviour, such as grazing time/day, rate of biting during grazing, and bite mass (Hodgson, 1986; Penning, 1986) and those of the sward such as herbage mass and structure under both continuous and rotational grazing (Hodgson, 1981b, Penning *et al.*, 1989). In summary, these data show that shorter sward heights were associated with increased grazing time and faster rates of biting, though such adaptation was not usually sufficient to totally compensate for reduced bite mass and hence daily herbage intake was reduced.

Positive relationships between sward height and diet digestibility on ryegrass swards have also been found (see Hodgson, 1977); this is to be expected because younger (and more digestible) leaves tend to occur in the upper horizons of the sward (Vine, 1977; Grant *et al.*, 1985). These relationships may not be simple because of the extent to which sward structure may influence selection opportunity; for example, Barthram and Grant (1984) showed that the pseudostem layer appears to act as a barrier to defoliation on very short swards. The tiller density of the sward also influences ingestive behaviour and intake; for example Hepp (1989) showed that less dense ryegrass aftermaths led to lower bite masses and hence lower intakes by ewes and weaned lambs in late summer than was the case on more dense swards maintained by continuous grazing at the same height. However, comparison of data from this and other studies with high proportions of clover in swards (R.H. Armstrong, unpublished data) shows that the presence of a significant proportion of clover appears to override this disadvantage of aftermath swards.

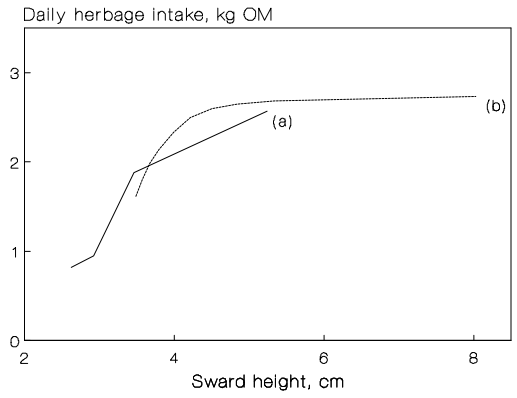


**Figure 2**. The influence of sward height upon the herbage intake of lactating ewes; (a) Bircham, 1981, (b) Penning, 1986 (after Hodgson, 1986).
*2. mynd. Áhrif hæðar gróðurs á át mjólkandi áa; (a) Bircham, 1981, (b) Penning, 1986. (Samkvæmt Hodgson, 1986).*

Furthermore, with weaned lambs in late summer grazing relatively short ryegrass swards, the direction og change in sward height has been shown to be at least as important as sward height in influencing live weight change (Alcock *et al.*, 1986; Doney *et al.*, 1987). In a recent similar experiment Armstrong *et al.* (1990) also showed that lamb growth rate was positively associated with sward height (constant 3.5 cm and 6.0 cm) and also with sward height change (increasing or decreasing between these heights); these differences in liveweight change are associated with differences in herbage intake but not in diet digestibility.

Evidence for the particular importance of the composition of the grazed horizon in influencing diet selection has been reported by Milne *et al.* (1982). They showed that higher proportions of white clover in the diet of sheep than in a ryegrass/clover sward could largely be explained by a higher proportion of clover in the grazed sward horizon than in the sward as a whole. The separate advantages for lamb growth of a high clover content and increasing sward heights are additive (Vipond *et al.*, 1989); further work is needed to identify the roles of selection and intake in this effect.

Many swards are made up of the combination of two or more plant species and species selection can be an important deter-

minant of the overall nutritive value of the diet. As has been illustrated with ryegrass and white clover swards, the vertical distribution of species influences diet compostion. Horizontal variation in spatial distribution of species or plant communities is also important in influencing diet composition, both as relatively small patches, e.g. *Nardus* tussocks (Figure 3; Grant *et al.*, 1985) and also as larger scale mosaics of different hill communities such as *Agrostis/Festuca*, *Nardus* and heather (Hunter, 1962). In the latter investigation behavioural studies showed that the differing distribution of such communities led to different patterns of grazing intensity, which were ultimately associated with different levels of sheep performance. More detailed studies of ingestive behaviour, diet selection and herbage intake on discrete areas of these 'hill' communities (Armstrong and Hodgson, 1986; Hodgson *et al.*, 1990) show wide differences in digestible energy intake between communities and between seasons. Subsequently Grant and Gordon (1990) have discussed broader evidence showing that the height of the preferred grasses in simple two-community complexes, as an index of digestible energy intake, is an important determinant of diet composition and hence of the overall nutritive value of the diet.

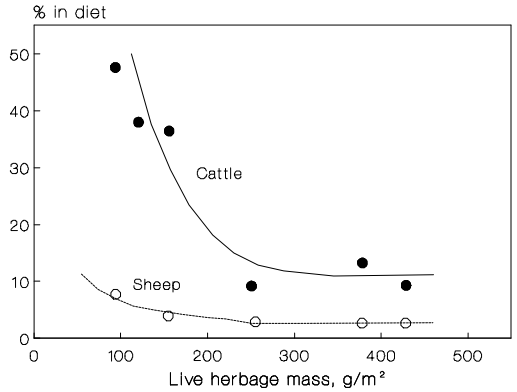


**Figure 3**. The relationships between the proportion of *Nardus* in the diet of sheep and cattle grazing a community dominated by *Nardus stricta* and the mass of live herbage in between-tussock areas (after Grant and Hodgson, 1986).
*3. mynd. Hlutfall finnungs í fóðri sauðfjár og nautgripa, sem beitt er á gróðurlendi er einkennist af finnungi, og uppskera lifandi gróðurs milli brúska. (Samkvæmt Grant og Hodgson, 1986).*

### *Supplementation*

The milk supply to suckling young stoch and the ingestion of concentrate supplements may both influence nutrient supply because of the effects on overall diet digestibility or through the effects of partial substitution of herbage. In general, supplements tend to partially replace herbage rather than increase total nutrient supply, especially with higher quality herbage. Further, the level of substitution tends to be greater on taller than on shorter swards, though the effects are complex and imperfectly understood (Milne *et al.*, 1981; Doney *et al.*, 1984). These effects influence the overall nutrition derived from the total diet and can be an important influence on the potential nutritive value of herbages.

## CONCLUSION

Further understanding of the animal:plant interface and its influence on nutritive value are required. A knowledge of digestibility, the chemical composition and in particular the potential intake rate of herbage species will continue to be important parameters in aiding the understanding of diet selection within and between plant communities and hence the overall nutritive value of the diet obtained from complex swards.

## REFERENCE

**Alcock**, M.B., H. **Clark** & A. **Harvey**, 1986. The implications of sward height for animal and herbage production from perennial ryegrass. In: *Grazing* (ed. J. Frame). British Grassland Society Occasional Symposium No. 19: 105–113.

**Armstrong**, R.H., T.G. **Common** & G.J. **Davies**, 1989. The prediction of the *in vivo* digestibility of the diet of sheep and cattle grazing indigenous hill plant communities by *in vitro* diges-

tion, faecal nitrogen concentration or 'indigestible' acid detergent fibre. *Grass and Forage Science* **44**: 303–313.

**Armstrong**, R.H., T.G. **Common** & H.K. **Smith**, 1986. The voluntary intake and *in vivo* digestibility of herbage harvested from indigenous hill plant communities. *Grass and Forage Science* **41**: 53–60.

**Armstrong**, R.H. & J. **Eadie**, 1973. Lamb growth on grass and clover diets. *Proceedings of the British Society of Animal Production* **2**: 68 (abstract).

**Armstrong**, R.H & J. **Hodgson**, 1986. Grazing behaviour and herbage intake in cattle and sheep grazing indigenous hill plant communities. In: *Grazing Research at Northern Latitudes* (ed. Ólafur Gudmundsson). Plenum, London (published in association with NATO Scientific Affairs Division): 211–218.

**Armstrong**, R.H., E. **Robertson** & E.A. **Hunter**, 1990. The effect of direction of change in sward height, and in sward structure, on the ingestive behaviour and performance of weaned lambs grazing ryegrass. In: *Soil-Grassland-Animal Relationships*. Proceedings of the 13th General Meeting of the European Federation, Banska Bystrica, Czechoslovakia: 147–150.

**Arnold**, G.W., 1981. Grazing behaviour. In: *Grazing Animals* (ed. F.H.W. Morley). Elsevier, Amsterdam: 79–104 .

**Barthram**, G.T. & S.A. **Grant**, 1984. Defoliation of ryegrass-dominated swards by sheep. *Grass and Forage Science* **39**: 211–219

**Bircham**, J.S., 1981. *Herbage, Growth and Utilisation under Condinuous Stocking Management*. Ph.D. thesis. University of Edinburgh.

**Demarquille**, C. & R. **Jarrige**, 1971. The digestibility and intake of forages from artifical and natural grasslands In: *Proceedings of the 4th Meeting of the European Grassland Federation, Lausanne, France, 1971*: 91–106.

**Doney**, J.M., J.A. **Milne**, I.R. **White**, P.M. **Colgrove** & M.D. **Lloyd**, 1987. Live-weight gain of weaned lambs grazing swards increasing, decreasing or at constant surface heights. *Animal Production* **44**: 471 (abstract).

**Doney**, J.M., A.D.M. **Smith**, D.A. **Sim** & D. **Zygoyannis**, 1984. Milk and herbage intake of suckled and artificially reared lambs at pasture as influenced by lactation pattern. *Animal Production* **38**: 191–199.

**Eadie**, J., 1970. Sheep production and pastoral resources. In: *Animal Populations in Relation to their Food Resources*. British Ecological Society Symposium No. 10, Oxford, Blackwell: 7–24.

**Frame**, J., P. **Newbould** & J.M.M. **Munro**, 1985. Herbage production from the hills and uplands. In: *Hill and Upland Livestock Production* (eds T.J. Maxwell & R.G. Gunn). British Society of Animal Production, Occasional Symposium No. 10: 9–38.

**Grant**, S.A. & I.J. **Gordon**, 1990 Experimental approaches to component modelling of ruminant herbivore-vegetation relationships in native grasslands. In: *Vegetation-Herbivore Relationships in Native Grasslands,* and *Proceedings of a Japanese Grassland Society Symposium, Shiobara, Japan, December 1990*: In press.

**Grant**, S.A. & J. **Hodgson**, 1986. Grazing effects on species balance and herbage production in indigenous plant communities. In: *Grazing Research at Northern Latitudes* (ed. Ólafur Gudmundsson). Plenum, London (published in association with NATO Scientific Affairs Division): 69–77.

**Grant**, S.A., D.E. **Suckling**, H.K. **Smith**, L. **Torvell**, T.D.A. **Forbes** & J. **Hodgson**, 1985. Comparative studies of diet selection by sheep and cattle: The hill grasslands. *Journal of Ecology* **73**: 987–1004.

**Hepp**, C., 1989. *Interactions between Sward Conditions and the Intake and Grazing Behaviour of Sheep in the Autumn*. M.Phil. thesis. University of Edinburgh.

**Hodgson**, J., 1977. Factors limiting herbage intake by the grazing animal. In: *Proceedings of International Meeting on Animal Production from Temperate Grassland, Dublin*: 70–75.

**Hodgson**, J., 1981a. Influence of sward characteristics on diet selection and herbage intake by the grazing animal. In: *Nutritional Limits to Animal Production from Pastures* (ed. J.B. Hacker). Commonwealth Agricultural Bureaux, Farnham: 153–166.

**Hodgson**, J., 1981b. Variations in the surface characteristics of the sward and the short-term rate of herbage intake by calves and lambs. *Grass and Forage Science* **36**: 49–57.

**Hodgson**, J., 1986. Grazing behaviour and herbage intake. In: *Grazing* (ed. J. Frame). British Grassland Society, Occasional Symposium No. 19: 51–64.

**Hodgson**, J., T. **Forbes**, R.H. **Armstrong**, M.M. **Beattie** & E.A. **Hunter**, 1990. Comparative studies of the ingestive behaviour and herbage intake of sheep and cattle grazing indigenous hill plant communities. *Journal of Applied Ecology*: In press.

**Hodgson**, J. & S.A. **Grant**, 1980. Grazing animals and forage resources in the hills and uplands. In: *The Effective Use of Forage and Animal Resources in the Hills and Uplands* (ed. J. Frame). British Grassland Society, Occasional Symposium No. 12: 41–57.

**Hunter**, R.F., 1962. Hill sheep and their pasture: A study of sheep-grazing in south-east Scotland. *Journal of Ecology* **50**: 651–680.

**Milne**, J.A., 1974. The effects of season and age of stand on the nutritive value of heather (*Calluna vulgaris* L. Hull) to sheep. *Journal of Agricultural Science, Cambridge* **83**: 281–288.

**Milne**, J.A., 1977. A comparison of methods of predicting the *in vivo* digestibility of heather by sheep. *Journal of the British Grassland Society* **32**: 141–147.

**Milne**, J.A., 1985. Nutritional needs of sheep in the hills and uplands. In: *Hill and Upland Livestock Production* (eds T.J. Maxwell & R.G. Gunn). British Society of Animal Production, Occasional Publication no. 10: 39–48.

**Milne**, J.A., L. **Bagley** & S.A. **Grant**, 1979. Effects of season and level of grazing on the utilization of heather by sheep. 2. Diet selection and intake. *Grass and Forage Science* **34**: 45–53.

**Milne**, J.A., J. **Hodgson**, R. **Thompson**, W.G. **Souter** & G.T. **Barthram**, 1982. The diet ingested by sheep grazing swards differing in white clover and perennial ryegrass content. *Grass and Forage Science* **37**: 209–218.

**Milne**, J.A., T.J. **Maxwell** & W. **Souter**, 1981. Effect of supplementary feeding and herbage mass on the intake and performance of grazing ewes in early lactation. *Animal Production* **32**: 185–195.

**Minson**, D.J., C.E. **Harris**, W.F. **Raymond** & R. **Milford**, 1964. The digestibility and voluntary intake of S22 and H.1 ryegrass, S170 tall fescue, S84 timothy, S215 meadow fescue and germinal cocksfoot. *Journal of the British Grassland Society* **19**: 298–305.

**Munro**, J.M.M. & R.J.K. **Walters**, 1986. The feeding value of grass. In: *Grazing* (ed. J. Frame). Britsh Grassland Society, Occasional Symposium No. 19: 65–78.

**Osbourn**, D.F., 1981. The feeding value of grass and grass products. In: *Grass, its Production and Utilisation* (ed. W. Holmes). Blackwell Scientific Publications, Oxford: 70–124

**Penning**, P.D., 1986. Some effects of sward conditions on grazing behaviour and intake by sheep. In: *Grazing Research at Northern Latitudes* (ed. Ólafur Gudmundsson). Plenum, London (published in association with NATO Scientific Affairs Division): 219–226.

**Penning**, P.D., A.J. **Parsons**, G.E. **Hooper** & R.J. **Orr**, 1989. Responses in ingestive behaviour by sheep in response to changes in sward structure. In: *Proceedings of the 16th International Grassland Congress, Nice, France, October 1989*. French Grassland Society, Versailles, Cedex, France: 791–792.

**Terry**, R.A. & J.M.A. **Tilley**, 1964. The digestibility of the leaves and stems of perennial ryegrass, cocksfoot, timothy, tall fescue, lucernine and sainfoin, as measured by an *in vitro* procedure. *Journal of the British Grassland Society* **19**: 363–372.

**Thomson**, D.J., 1984 The nutritive value of white clover. In: *Forage Legumes* (ed. D.J. Thomson). British Grassland Society, Occasional Symposium No. 16: 78–92.

**Tilley**, J.M.A. & R.A.**Terry**, 1963. A two-stage technique for the *in vitro* digestion of forage crops. *Journal of the British Grassland Society* **18**: 104–111.

**Vine**, A., 1977. *Development of a Pasture Model for Grazing Studies*. Ph.D. thesis. University of Edinburgh.

**Vipond**, J.E., J.A. **Milne**, G. **Swift**, J. **Fitz-Simmons**, T.H. **McClelland** & E.A. **Hunter**, 1989. Ewe and lamb performance on perennial ryegrass and perennial ryegrass plus white clover swards under controlled sward heights. *Animal Production* **48**: 648 (abstract).

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