Plants for grazing systems

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ABSTRACT

Current views and recent research findings on the plant characteristics influencing (a) herbage production and tolerance of grazing and (b) herbage intake and nutritive value, are reviewed and used to define desirable plant ideotypes for grazing systems. The conflict of interest between physical and physiological characteristics conferring high production and consumption potential on the one hand, and flexibility of production and grazing tolerance on the other, is emphasised.

Current progress in and future prospects for the improvement of plants for grazing systems are discussed briefly, with reference to the potential for using mass selection and genetic engineering techniques in the modification of physical and biochemical characteristics. The need for objectivity in screening and evaluation programmes is discussed.

Keywords Herbage production, herbage utilisation, herbage intake, nutritive value, sward structure, plant morphology, tillering activity, plant selection, plant evaluation.

INTRODUCTION

In discussing plants for grazing systems my approach has been to consider specific plant characteristics influencing aspects of pasture/animal inter-relationships. I want to concentrate on two sets of interlocking variables: those affecting production potential and tolerance of grazing activity, and those affecting herbage consumption and the nutritive value of herbage ingested. Wider issues of plant survival, tolerance of climatic extremes and resistance to pests and diseases, though clearly of major importance in themselves (Corkill *et al*, 1981; Burgess and Brock, 1985), are only touched on briefly.

In the context of this Symposium it is convenient to consider first the plant characteristics influencing herbage consumption and nutritive value, before going on to discuss pasture production and grazing tolerance. Attention will be concentrated primarily on recent research findings and the opportunities for further developments in understanding in these sectors, and on the application of research findings to plant improvement and evaluation programmes.

HERBAGE CONSUMPTION AND NUTRITIVE VALUE

Plant morphology

Intake per bite and rate of herbage intake in grazing animals are positively related to both sward height and bulk density (mass per unit volume) (Black, 1990). These sward parameters have their parallels in the morphological characteristics of individual plants, being strongly influenced by variations in leaf size and erectness on the one hand, and by tillering (stolon) activity and tiller numbers on the other.

Sward height and bulk density tend to be negatively related in both genotypic and phenotypic terms, so it is important to understand their relative influence on intake and, perhaps more important, their effective range of influence. Fortunately, initial evidence suggests that the effects of height and bulk density are to a large degree independent and additive, apparently over substantial ranges of variation (Table 1.).

TABLE 1 The influence of variations in sward height (H; cm) and grazed stratum bulk density (D; mg DM/cm^3) on intake per bite (BW; mg DM) in grazing sheep (from Burlison, 1987).

BW = -2.6 + 5.4 (±0.63) H + 43.0 (±17.9)D

n = 17; $R^2 = 0.84$***

where range in	H	= 5.7 - 55.2 cm
" "	D	= 0.12 - 2.04 mg DM/cm^3
" "	BW	= 45 - 326 mgDM

This allows some margin of tolerance in specifying appropriate combinations of plant morphology and tiller density for particular circumstances, but there is need for confirmatory evidence for a range of plants and pasture conditions.

There will be greater confidence in extrapolating from the current closely controlled experiments to field conditions when we have a clearer understanding of the mechanisms underlying the observed intake responses. These mechanisms clearly involve the control of bite dimensions (Burlison., 1987), which are influenced in part by interactions between mouth size and structure, and sward canopy structure (Illius and Gordon, 1987). The associated effects of the population density and structural strength of plant components on biting effort and bite dimensions deserve further investigation (Evans, 1967; Hodgson, 1985).

The link between intake per bite and daily herbage intake (Penning, 1986), implies a behavioural limit to herbage intake, even though the reciprocal changes in intake per bite and biting rate (e.g. Dougherty *et al.*, 1989) can have a substantial moderating effect in many conditions. This theory of intake control, based on behavioural (external) limits, runs essentially parallel to the theory of physical (internal) limitations, mediated by distension of the alimentary tract (Black, 1990), which is long established. In particular, variations in the structural strength of plant tissue may be involved both in the control of bite dimensions (Poppi *et al.*, 1987) and hence rate of intake, and in the rate of comminution of ingested herbage and hence rumen clearance time (Waghorn and Barry, 1987). This is a potentially fruitful area of collaborative work for ethologists and nutritionists with the objective of defining the relative importance of internal and external limitations to intake in grazing animals, the plant characteristics which mediate these effects, and their particular sectors of influence.

Plant Composition

Estimates of digestibility (DM, OM and DOMD) and nitrogen (N) concentration have been widely used as general indicators of the nutritive value of herbage for many years (Raymond, 1969), but the importance of more specific indices of nutritional adequacy for particular purposes is now well recognised. In particular, aspects of amino acid balance in plant proteins and their protection from rumen degradation are recognised to be of importance for meat, milk and wool production (Waghorn and Barry, 1987; Black, 1990). Also, because of its importance to both intake potential and nutritive value, much attention has been devoted to developing an understanding of plant structural biochemistry (Norton, 1982; Jones and Wilson, 1987).

Research on the plant secondary compounds, particularly those with toxic or aversive effects, has a long history, and there have been some notable successes in removing or limiting these effects (Barry and Blaney, 1987). This is an area ripe for further development, and particularly for collaborative work involving both the agricultural and natural sciences.

HERBAGE PRODUCTION AND UTILIZATION

Variations in plant morphology and tiller or stolon populations were identified earlier as important factors influencing herbage intake by grazing animals. The same factors have major effects on herbage production and tolerance of grazing, and analysis of the evidence demonstrates the interactive nature of these effects.

Plants with large leaves and erect growth habit tend to have higher growth potential than plants with small leaves and prostrate growth habit grown in the same environment (Rhodes, 1973). This difference may be apparent both within and between plant species. The effect is usually ascribed to the advantages of the larger plants in terms of rate of leaf expansion, and the efficiency of light interception and distribution within the leaf canopy (Rhodes, 1973). However, this production advantage may be offset by the greater sus-

ceptibility of larger, taller plants to grazing damage because of the greater accessibility of leaf tissue or, in extreme cases, the greater risk of meristem damage and tiller death (Edmond, 1964). In these circumstances, recovery after grazing may be a function of tiller production (Hodgson *et al.*, 1981).

Within limits, tiller (stolon) size and population density appear to be negatively related both within and between species (e.g. Kays and Harper, 1974), so it is difficult to combine the attributes of high production and high grazing tolerance. However, species like perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) show a much wider range of phentoypic plasticity in response to variations in management than do others like prairie grass (*Bromus willdenowii*) (Table 2), and flexibility of this kind has clearly been an important determinant of the success of ryegrass and white clover in grazing systems.

TABLE 2 The influence of grazing management on tiller population density and herbage growth per tiller in perennial ryegrass (*Lolium perenne*) and prairie grass (*Bromus willdenowii*) (From Black and Chu, 1989; Xia *et al*, 1990).

	Grazing	
	Hard	Lax
Post-grazing residue (kg DM/ha)		
Perennial ryegrass	1000	2000
Prairie grass	1000	2000
Tiller population/m^2		
Perennial ryegrass	8100-11200	4500-6600
Prairie grass	580±230	1350±230
Growth per tiller (mg DM/d)		
Perennial ryegrass	0.57-0.84	1.24-2.08
Prairie grass	NA	NA

Seasonal range shown.
NA - Not available

PLANTS FOR GRAZING SYSTEMS

The preceding analysis indicates that the plant ideotype best suited to the requirements of grazing systems should possess the following characteristics:

Large leaves and an erect growth habit to encourage high growth rate and high intake potential.

High tillering rate to encourage rapid recovery post-grazing and contribute to high intake potential.

Meristem protection to minimise risk of grazing or treading damage.

Low structural strength to encourage high intake potential.

Low concentration of aversive secondary compounds to minimise adverse intake or health effects.

Specific structural biochemistry and nutrient balance to provide high intake potential and nutritive value.

The difficulties of achieving appropriate combinations of these variables will be apparent. Thus, choices between alternative genotypes are usually compromises based on the balance of advantage for particular circumstances and conditioned by considerations of flexibility in response to management variation. These may be sensible decisions where management flexibility is important (Bryant 1990), but they tend to limit the potential for improvement in plant performance. However, there is little evidence for plant species other than perennial ryegrass and white clover from which to define the balance of characteristics appropriate to specific management conditions or selection objectives.

Plant Production

Assessment of genetic improvements in pasture production over time is hampered by the absence of any long-run data sets under standard management conditions, but the evidence suggests (Hodgson, 1989) that levels of annual herbage production from grazing system trials in New Zealand have shown only limited increase over a period of 50 years. The levels of production achieved, approaching 20 t DM per ha, may be close to the limits of efficiency in grazing systems (Hodgson, 1989). The scope for further increase in production potential from conventional plant material is uncertain, and may be dependent upon the opportunity to make more use of the greater growth potential of

warm-season (C_4) than of cool-season (C_3) plants (Robson, 1981). Close control of grazing management to allow the potentially more productive species to demonstrate their advantages may be technically possible in future, but this will almost inevitably be at the cost of greater rigidity in farming systems. It is questionable whether this will be a realistic option for the New Zealand pastoral industries (Bryant, 1990), particularly given the return towards simplicity and flexibility which is apparent even in high-cost sectors like Europe and the USA.

Pastoral systems are essentially dependent upon the utilisation of herbage *in situ*. In these circumstances, seasonality of production is likely to be more important than annual herbage production, and the ability of plants to retain nutritive value during periods of field storage is also important.

Ultimately, seasonality of production is dependent upon seasonal changes in temperature, sunlight and water supply which set absolute limits to plant growth (Korte *et al.*, 1987). As a consequence, species differences in seasonal production are generally quite limited (e.g. Thomson *et al*, 1988),. However even minor variations in seasonality of production may be of importance in marginal conditions, particularly where seasonal differentials in product price are high. Additionally, high-value production systems provide greater opportunity for the use of plant species which do have particular seasonal growth potential.

Nutritive value and intake potential

Extensive research programmes under grazing and indoor feeding conditions have demonstrated species and cultivar differences in intake and nutritive value, particularly between grasses and legumes but also between grass species (Ulyatt, 1981; Waghorn and Barry, 1987). However, there are few authenticated examples of successful attempts to influence the nutritive value of plants by deliberate selection. Selection for low leaf strength in perennial ryegrass (Easton, 1989) provides one example, with consequent advantages to herbage intake at least under indoor conditions (Table 3.).

More success has been achieved in selection to eliminate or reduce the concentrations of harmful biochemicals from otherwise useful plant species. Examples are cyanogens (Corkill, 1952) and oestrogens (Barry and Blaney, 1987) in legumes. Recently, the developing understanding of the aetiology of Ryegrass Staggers offers the opportunity to develop an infective endophyte free of the toxic effects of the lolitrem B tremorgen. (Barry and Blaney, 1987). These successes reflect the advantages of both a clearly defined selection objective and a relatively simple mechanism of genetic control.

TABLE 3 The influence of leaf shear strength on the voluntary intake (g/kg$^{0.75}$/d) and digestibility (%DM) of perennial ryegrass by sheep (from Inoue *et al.*, 1989).

	Selection		SE of Mean
	Low	High	
Shear strength (Newton/leaf)	9	13	0.4***
DM intake (g/kg/d)	102	86	3.0***
Ruminating (min/kg DM)	426	542	13.8***
DM digestibility (%)	73.0	76.4	0.5*

There is little evidence of any attempt to focus plant breeding or selection programmes specifically on the morphological plant characteristics influencing intake potential. Paradoxically, selection of erect genotypes may enhance intake potential under grazing conditions though at the risk of some loss in tolerance of close grazing (e.g. Fraser, 1985; Black and Chu, 1989).

SELECTION AND EVALUATION OF PLANT MATERIAL

General plant attributes like production potential or nutritive value are difficult subjects for screening and selection because of their non-specific nature. It is important to maintain efforts to define specific attributes of proved value to plant production and/or utilisation which can then be incorporated into improvement programmes or management strategies. This is particularly true of characteristics under simple genetic control, where manipulation of a simple gene set can influence a specific character with little consequence to the rest of the genome. Currently the greatest scope for manipulation of specific characteristics ap-

pears to be in the field of plant biochemistry. A recent example is speculation on the use of genetic engineering techniques to introduce condensed tannins into white clover in order to control bloat and improve N utilisation (Barry and Blaney, 1987). It seems highly unlikely that the quantitative plant characters discussed earlier will be under simple genetic control of this kind, but their definition for use in objective mass-selection programmes is nevertheless important.

Recent research in New Zealand has progressively concentrated on specific sets of plant characteristics which may provide appropriate focus for improvement programmes. A good example is development of white clover cv. "Grasslands Tahora" as a consequence of improved understanding of the dynamics of stolon and leaf production (Brock *et al.*, 1989) and their implications to plant survival and production. However, as potential users of improved genetic material we need to recognise the sensitive nature of the procedures required to achieve effective balance across complexes of specific characteristics which may, as in the case of some of the examples quoted earlier, be mutually incompatible. For example, the success of a programme to improve the nutritive value of a grass by selecting for enhanced digestibility may be negated if this results in a plant with leaves which are less erect, and less resistant to treading damage or pathogen attack.

Objectivity in selection programmes must be matched by objectivity in evaluation of plant material in order to allow pastoralists and their advisers to make informed choices about material suitable for their own circumstances. This requires, at the outset, an assessment of physiological and morphological responses to a range of management regimes which are controlled, as far as possible, in relation to defined plant characteristics. This should provide a basis for identifying appropriate production systems and appropriate management strategies to cater for the observed strengths and weaknesses of new plant material, but the available information is currently confined largely to the long-established perennial ryegrass and white clover.

Testing in production systems is a logical and necessary next step, with emphasis on the need to work within the constraints of systems in which both animal and pasture targets are defined objectively. This is generally the most difficult sector of evaluation to carry through effectively, and it can be demanding of resources. However, it is essential to a proper understanding of the potential of new plant material and its value in commercial farming conditions. It is to be regretted that current research policy bears particularly hard on the funding for this kind of work.

CONCLUSIONS

In this paper I have tried to focus on both the needs and the opportunities for research on plants for grazing systems. The main theme has been the importance of objectivity - in defining research goals and observation procedures, selection criteria and evaluation parameters.

In reviewing the subject of plants for grazing systems, it is apparent that one of the major dilemmas of the grassland world for many years - the apparent conflict of interest between production potential and tolerance of management flexibility - has still not been successfully resolved. However, there is increasing understanding of the ways in which the physical, physiological and biochemical characteristics of plants interact to influence herbage production and utilisation under a range of management strategies. This should provide us in the future with a more objective basis for defining areas of conflict and the means to limit them.

Better definition of specific plant characteristics influencing components of production and utilisation in grazing systems should provide a firmer basis for plant breeding programmes and for efficient evaluation techniques. However, there must still be considerable doubt about the extent to which such characteristics can be generalised across species from the current narrow information base. Resolution of this question will require careful coordination of eroding research and development resources at the interface between the plant and animal sciences.

REFERENCES

Barry, T.N.; Blaney, B.J. (1987) Secondary compounds of forages In *The Nutrition Of Herbivores* Eds J.B. Hacker; J.H. Ternouth. Academic Press, Sydney pp. 91-119.

Black, C.K.; Chu, A.C.P. (1989) Searching for an alternative way to manage prairie grass. *Proceedings of the New Zealand Grassland Association 50*: pp. 219-223.

Black, J.L. (1990) Nutrition of the grazing ruminant. *Proceedings of the New Zealand Society of Animal Production* (In Press)

Brock, J.L.; Caradus, J.R.; Hay, M.J.M. (1989) Fifty years of white

clover research in New Zealand *Proceedings of the New Zealand Grassland Association 50*: pp. 25-37.

Bryant, A.M. (1990) Present and future grazing systems. *Proceedings of the New Zealand Society of Animal Production 50*: 35-38.

Burgess, R.E.; Brock, J.L. (1985) Using Herbage Cultivars. *New Zealand Grassland Association Grassland Research and Practice No. 3.*

Burlison, A.J. (1987) Sward canopy structure and ingestive behaviour in grazing animals. Ph.D thesis, University of Edinburgh.

Corkill, L. (1952) Cyanogenesis in white clover (*Trifolium repens L.*). VI Experiments with high glucoside and glucoside-free strains. *New Zealand Journal of Science and Technology 34A*: pp. 1-16.

Corkill, L.; Williams, W.H.; Lancashire, J.A. (1981) Pasture species and cultivars for regions. *Proceedings of the New Zealand Grassland Association 42*: pp. 100-122.

Dougherty, C.T.; Bradley N.W.; Cornelius, P.L.; Lauriault, L.M. (1989). Ingestive behaviour of beef cattle offered different forms of lucerne (*Medicago sativa L.*) *Grass and Forage Science 44*: pp.335-342.

Easton, H.S. (1989) Variability of leaf shear strength in perennial ryegrass *New Zealand Journal of Agricultural Research 32*: pp. 1-6.

Edmond, D.B. (1964) Some effects of sheep treading on the growth of 10 pasture species. *New Zealand Journal of Agricultural Research 7*: pp. 1-16.

Evans, P.S. (1967) Leaf strength studies of pasture grasses. II Strength, cellulose content and schlerenchyma tissue proportions of eight grasses grown as single plants. *Journal of Agricultural Science, Cambridge 69*: pp. 175-181.

Fraser, T.J. (1985) Role of Matua prairie grass in an all-grass system for prime lamb production. *Proceedings of the New Zealand Grassland Association 46*: pp. 157-161.

Hodgson, J. (1985) The control of herbage intake in the grazing ruminant. *Proceedings of the Nutrition Society 44*: pp. 339-346.

Hodgson, J. (1989) Pasture Production. *Dairyfarming Annual 41*: pp. 76-82.

Hodgson, J.; Bircham, J.S.; Grant, S.A.; King, J. (1981) The influence of cutting and grazing management on herbage growth and utilisation. In: *Plant Physiology and Herbage Production* Ed C.E.Wright. *British Grassland Society Occasional Symposium No 13* pp. 51-62.

Illius, A.W.; Gordon, I.J. (1987) The allometry of food intake in grazing ruminants. *Journal of Animal Ecology 56*: pp. 989-999.

Inoue, T.; Brookes, I.M.; Barry, T.M.; John, A. (1989) Effects of selection for shear strength on the voluntary intake and digestion of perennial ryegrass fed to sheep. *Proceedings of the New Zealand Society of Animal Production 49*: pp. 221-224

Jones, D.I.H.; Wilson, A. (1987) Nutritive quality of forage. In: The Nutrition Of Herbivores Eds J.B. Hacker and J.H. Ternouth. Academic Press, Sydney pp. 65-89

Kays, S.; Harper, J.L. (1974) The regulation of plant and tiller density in a grass sward. *Journal of Ecology 62*: pp. 97-105.

Korte, C.J.; Chu, A.C.P.; Field, T.R.O. (1987) Pasture Production. In *Livestock Feeding On Pasture* Ed A.M.Nicol. *New Zealand Society of Animal Production Occasional Publication No. 10*, pp.7-20

Norton, B.W. (1982) Differences between species in forage quality. In *Nutritional Limits to Animal Production from Pasture* Ed J.B. Hacker. *Commonwealth Agricultural Bureaux, Farnham Royal* pp. 89-110.

Penning, P.D. (1986) Some effects of sward conditions on grazing behaviour and intake by sheep. In: *Grazing Research At Northern Latitudes* Ed *O.* Gudmundsson. Plenum Press, New York pp. 219-226.

Poppi, D.P.; Hughes, T.P.; L'Huillier, P.J. (1981) Intake of pasture by grazing ruminants In *Livestock Feeding On Pasture* Ed A.M. Nicol. *New Zealand Society of Animal Production Occasional Publication No. 10* pp.55-63.

Raymond, W.F. (1969) The nutritive value of forage crops. *Advances in Agronomy 21* : 2-108.

Rhodes, I. (1973) Relationship between canopy structure and productivity in herbage grasses and its implications for plant breeding. *Herbage Abstracts* 43: pp. 129-133

Robson, M.J. (1981) Potential production - what is it, and can we increase it? In: *Plant Physiology And Herbage Production* Ed C.E. Wright. *British Grassland Society Occasional Symposium No. 13* pp. 5-18.

Thomson, N.A.; Lagan, J.F.; McCallum, D.A.; Prestidge, R. (1988) An evaluation of Grasslands Roa tall fescue and Grasslands Maru phalaris for dairying. *Proceedings of the New Zealand Grassland Association 49*: pp. 187-191.

Ulyatt, M.J. (1981) The feeding value of temperate pasture In *Grazing Animals* Ed F.H.W. Morley. Elsevier, Amsterdam pp. 125-141.

Waghorn, G.C.; Barry, T.N. (1987) Pasture as a nutrient source In: *Livestock Feeding On Pasture* Ed A.M. Nicol. *New Zealand Society of Animal Production Occasional Publication No. 10*, pp. 21-37.

Xia, X.J.; Hodgson, J.; Matthew, C.; Chu, A.C.P. (1990). Tiller populations and tissue turnover in a perennial ryegrass pasture under hard and lax spring and summer grazing. *Proceedings of the New Zealand Grassland Association 51*: pp. 119-121.