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New opportunities to improve forage based production systems

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ABSTRACT

Pasture based grazing systems in New Zealand provide many benefits such as low costs of production but there are also limitations to current high stocking rate systems. These include inconsistent quality and composition of pasture and therefore animal diet. The requirements for high production and tolerance to frequent grazing limit the number of species which can be successfully grown. The rate of productivity improvement has declined in recent years and new methods of management are needed to increase production and meet changing market requirements. Altering methods of forage presentation has been shown to improve production of milk and meat from pasture by allowing animals to achieve a high daily intake of desirable species such as clover. Further new evidence of the capacity of animals to regulate their intake toward goals other than maximizing daily dry matter intake is presented. It is argued that new opportunities for increasing grassland productivity will need to consider the behavioural responses of animals grazing pasture.

Keywords: pastures; ryegrass; clover; intake; animal behaviour, forage arrangement.

INTRODUCTION

Sheep, beef and dairy production in New Zealand and Australia is based predominantly on grazed pastures. This provides a low cost method for producing quality animal products with a clean, green image and a positive consumer perception for animal welfare. However, these systems also face constraints such as seasonality of pasture availability and quality which compromise both pasture and animal management.

Grazed pastures are complex ecosystems with many interactions occurring among the component species, and between plants and animals. Our understanding of these interactions is incomplete. This paper considers possible methods for overcoming the difficulties associated with providing a more precisely controlled diet to grazing animals. Critical to this is understanding the complexities of plant species interactions and the behavioural characteristics of grazing animals which affect how they manipulate their nutrient intake over time.

LIMITATIONS OF PASTURE

Low-cost pasture has been the basis of meat, dairy and wool production in New Zealand and Australia for many decades. However, in other countries, these industries are lowering their costs of production and eroding some of the traditional competitive advantages of New Zealand and Australia, where pasture production remains static at about 15 tonnes DM utilized per ha per year (Hodgson, 1990, Clark *et al.,* 2001). In addition to yield limitations, feeding animals solely from pastures restricts production through seasonal or unpredictable short-term variations in forage supply, variable nutritive and feeding value, inefficiencies in harvesting and feed related disorders such as bloat (Clark *et al.,* 1997). These limitations become more acute as requirements for animal products move from commodity supply to value-added, requiring delivery within rigid timelines. Attempts to address these limitations must focus on modifying plant growth and quality; devising better strategies to utilize pasture and integrate supplementary feeding; and better understanding the difficulties faced by animals in obtaining an ideal diet from a spatially and temporally complex food source. Models based on the origins of uncertainty and heterogeneity in pasture growth and animal behaviour, but integrated into a farm-system presentation (e.g. DairyMod, Chapman *et al*., 2002) offer tools to help meet this challenge.

Intensive grazing management systems overcome some of these problems by imposing high stocking densities and controlled grazing to minimize selective grazing and maintain a pasture state that optimizes herbage accumulation. This approach fits well with seasonal production systems based on grazing-tolerant species such as perennial ryegrass, and allows high per-hectare production. However, the price of this in mixed species pastures can be restricted feed intake, reduced opportunities for animals to select their diet, lower per-animal production, and excessive grazing pressure leading to problems with persistence of particular species. It also limits the opportunity to use plants that have valuable nutritional attributes, but are unable to "clear the twin hurdles of high total annual DM yield and high metabolizable energy content" under heavy grazing (Clark, 2002).

NOVELTY IN FORAGES

There is a long list of forage species and cultivars available for use in temperate pastures but only a small proportion of these are commonly used. For example, Chapman *et al*. (2001) compiled a database of 36 species and over 220 cultivars available commercially in southern Australia, but most of these play only a small part in grazing systems. Similarly, Charlton & Stewart (2000) documented 23 species and 115 cultivars available in New Zealand and both lists include novel species with better nutritive and feeding value than the mainstream species. Among the higher quality species are timothy, *Lotus corniculatus*, sulla, *Serradella* species, chicory, plantain, and red clover. Most are susceptible to intensive grazing pressure and so are used sporadically in agriculture, usually in special-purpose roles.

Role of germplasm improvements

The rate of gain in the agronomic performance of ryegrass-white clover based grasslands through breeding between 1940 and 1970 was estimated (from diverse sources) to be between 20 and 30% (Woodfield, 1999). The germplasm improvements would have played a small but significant part in industry productivity gains during that period. But these estimates of gain from breeding *per se* are largely based on dry matter yields, often measured when growing as pure swards not mixed pastures, and seldom in terms of grazing animal performance.

There have been few direct environmental tests of the hypothesis that plant breeding has increased production per hectare (Woodward *et al.,* 2001; Chapman *et al.,* 1996). Both studies highlight how complex it is to deliver benefits of forage breeding improvements in grazing systems. Woodward *et al.* (2001) compared combinations of 'new' and 'old' ryegrass and white clover cultivars and showed a significant effect on milk production only when new clover lines were combined with old ryegrass lines because this combination allowed greater clover content in the sward.

New technologies offer the promise of rapid improvements in the productivity of forage germplasm by expanding the boundaries of plant variation using recombinant DNA techniques. Targets of research include plant nutritional attributes such as lignin biosynthesis, fructan metabolism, by-pass protein, condensed tannin biosynthesis and modified soluble carbohydrate or lipid profiles (Spangenberg *et al.,* 2001, Hancock & Ulyatt, 2001). Most of these targets carry the assumption that improved nutritive value will translate readily to increased animal intake or production. However, while this assumption may be achieved in stall-feeding systems (Miller *et al.,* 2000), the benefits may be harder to deliver in grazing situations.

DELIVERING FORAGE ATTRIBUTES

Delivering novel forage attributes requires that the desired trait be expressed reliably under diverse field conditions; the 'host plant' must comprise a significant proportion of feed on offer and be sustainably accessible to grazing animals; ingestion of the forage must not negatively affect intake; there must be complementarity, not antagonism with other dietary components; and the nutritional attribute must improve the animal's attempts to maximize its own long-term fitness. That is, it must be possible to control the delivery of forage-based nutrients to the rumen in significant quantities (enough to bring about the desired growth and/or production responses) and the result must be positive for the animal. Some of the critical steps in this pose problems if the example of utilizing the attributes of white clover in mixed pastures is a guide to success. White clover is renowned for its feeding value, but it is well recognized that the benefit of improved agronomic potential in legumes is diluted by the failure of legumes to consistently contribute more that about 20% of total annual herbage accumulation in intensively grazed, high rainfall pastures (Caradus *et al.,* 1996; Doyle *et al.,* 2000). Ruminants clearly prefer clover to grass (Newman *et al.,* 1992), and this preference is often expressed as selective grazing of clover in mixtures with grass (e.g. Curll *et al.,* 1985; Ridout & Robson, 1991). Selective grazing exacerbates the competitive disadvantage of clover compared to companion grasses and this further limits clover growth in the mixture, restricting daily intake because of the increased foraging time required to seek and ingest spatially dispersed clover (Parsons *et al.,* 1994b). The nutritional quality of legumes (high N) itself creates patches in clover content in pastures when high N (as urine) is returned particularly to mixed swards (Schwinning & Parsons, 1996a, b; Chapman *et al*., 1996). Attempts to modify grass/legume associations need to focus on both forage species and on the animal/plant/nutrient interactions, not on one species alone.

BEHAVIOURAL RESPONSES AT PASTURE

Current limits to animal productivity from pasture suggest we should be open to new ways of identifying and overcoming complex constraints. Over and above limitations imposed by competition between forage species are constraints associated with animal behavioural requirements at pasture. Spatial and temporal variability is a characteristic of pastures, resulting in a complex array of nutrients to animals. There is little doubt that animals respond to this, but the basis for, and consequences of, their responses are harder to pinpoint (Dumont *et al.,* pers. comm.; Provenza *et al.,* 1997, and references therein). One concern is that animals may control, even limit their intake to maximize long-term fitness (Newman *et al.,* 1995) rather than maximize daily intake. Whatever the basis, elastic and unpredictable foraging responses and variability of the pasture environment create a challengingly complex system in which to deliver nutrients to animals to achieve growth and production targets.

Recent insights in this area suggest productivity gains and greater precision in delivery of forage nutrients may be possible if management systems allow expression of these behaviours. For example, intensive rotational grazing and strip-grazing promote greater uniformity of defoliation and control over intake but in so doing constrain animals to eating less selectively. Intensive management systems aim for high pasture utilization and natural behaviours such as preference, social interactions and the bewildering patterns of heterogeneity in vegetation these create have often been considered irrelevant in these systems.

Here we outline three examples to demonstrate how an understanding of the behavioural responses of animals may open new opportunities for grazing systems. Firstly, ruminants have a high preference (70%) for clover compared with ryegrass (Newman *et al.,* 1992; Parsons *et al.,* 1994b). They can seldom satisfy that preference from typical mixed-species pastures because the proportion of clover is too low. Recent work has

TABLE 1: Effects of different pasture arrangement on dairy cow dry matter intake and milk production and sheep live weight gain.

		Treatments						Statistical Significance[2]
		Clover alone	Ryegrass alone	Mixture	Ryegrass + Clover Side-by-side			
Measurement	**Data Set[1]**				**Total**	**Ryegrass**	**Clover**	
EstimatedDaily Intake (kg/day)	Dairy Cow Trial	21.2	16.9	18.6	21.0	3.5	17.5	ND[3]
Production	Dairy Cow Trial	24.2	18.6	21.3	23.3	-	-	P < 0.01
	Sheep Trial	345	185	205	330	-	-	P < 0.01

[1]Dairy Cow Trial: see Marotti *et al*. (2001) for experimental details; Sheep Trial: see Cosgrove *et al*. (2002) for experimental details.
[2]The P values shown indicate the significance of differences among the four main treatments not the components of the side-by-side treatment.
[3]The daily intake values are derived from the product of short-term intake rate and daily grazing time (data not shown here) so no statistical analysis has been carried out on daily intake

investigated a simple novel management system based on growing grass and clover separately and allowing animals to freely choose from each. Milk production of Friesian dairy cows in mid-lactation (Marotti *et al*., 2001) and liveweight gain of newly weaned lambs offered this novel feed presentation (Cosgrove *et al*., 2001) was similar to that of animals offered pure clover, and considerably better than those offered only ryegrass, or a conventional grass/clover mixture (see Table 1). This system allows animals to easily satisfy their preference for a mixed diet with a high proportion of clover compared with animals grazing a grass/clover mixture.

A second example of opportunity in novel grazing systems may arise from exploiting the diurnal pattern of preference shown by animals (Parsons *et. al.,* 1994a) where sheep in particular, show a strong preference for clover in the morning with this preference diminishing as they progressively add grass to their diet during the day. The reasons for this are not fully understood though the pattern can be shown to be consistent with maximizing fitness (Newman *et al.,* 1995). Eating clover ensures a more rapid intake of nutrients compared with ryegrass and this may be behaviourally important early in the morning. Dry matter and soluble carbohydrates accumulate in grasses during the day, and grasses have greater concentrations of fibre. Therefore eating more grass in the afternoon when time can be spent ruminating fibre during the night may be preferable to the animal and consistent with maximizing fitness. Again, developing management systems to accommodate the expression of these behaviours, rather than suppress them, may enable greater precision of nutrient delivery to animals.

The third example relates to animals preference for a mixed diet. Ruminants graze in clearly defined bouts or meals. Those grazing ryegrass alone take longer meals, but fewer each day compared to animals grazing clover alone. The rate of dry matter intake from clover is higher than it is from grass, suggesting that shorter meals and shorter time spent grazing each day reflects the shorter time required to satisfy dry matter intake. However recent studies (Marotti *et al.,* 2001; Cosgrove *et al.,* 2002), where sheep or cattle were allowed to freely choose from both species, showed that they graze from both species during most meals. These ‘mixed meals’ are often longer than expected on the basis of behaviour when grazing either species alone, raising the possibility that the purpose of grazing in meals is to regulate inflow of nutrients not simply dry matter intake. The mechanisms by which a combination of two species might overcome a constraint associated with ingestion of either alone is currently under further investigation. There is evidence (Dumont *et al., pers. comm.*; Champion *et al.,* 1998) that animals have higher total intake when offered a desirable choice. This indicates potential for further gains in intake and performance, if practical management systems can be developed and implemented.

ANIMAL-NUTRIENT INTERACTIONS

In the following section we consider whether modification to the nutritional characteristics of forages may help boost the productivity of grazing systems. Although increases in total pasture growth may equate to increased total animal production, this will not necessarily hold for capturing the benefits of plants that have been selected for altered nutrient composition *per se*. To illustrate this we refer to tests on ryegrass lines selected for higher sugar concentration, both to provide direct increases in energy availability to animals, but also to improve microbial capture of nitrogen as a consequence of forage protein breakdown in the rumen. While the high sugar grasses modify the balance of carbon and nitrogen in the rumen, which alone may have environmental benefits by reducing nitrate release in urine, or offer opportunities for manipulating methane output, their role in increasing animal production has been more difficult to establish. In grazing studies using pure grass swards, high sugar grasses increased liveweight gain by lambs, but that response could not be attributed solely to the increased sugar concentration because these lines also had a lower concentration of fibre (Lee *et al*., 2000). Grazing high sugar grasses has been shown to increase milk yield by dairy cows (Miller *et al.,* 2000) but this response was due to the animals having a greater intake of high sugar grasses *per se* and not due to any change in the efficiency of protein capture. To separate the effects of high soluble carbohydrate and high rumen degradable protein on intake and patterns of grazing behaviour, studies have been conducted where changes in forage nutrient concentrations have been simulated by ruminal infusions at pasture. These studies indicate that animals control the inflow of these nutrients through the frequency and duration of grazing bouts (Cosgrove *et al*., 1999, 2001). Whether changes in plant composition (e.g. sugar) to capture more ruminally degraded protein will work synergistically, or against the animals own attempts to control rumen and/or blood metabolites e.g. ammonia, is being tested. The conventional approach to improving diet quality is to develop rations with optimal nutrient content. As with all supplements at pasture, it is the animal's capacity (infuriating as it may be) to control intake behaviour that reduces the full potential of modifying nutrient supply in this way–though the net benefits in animal performance are undeniable.

As well as providing effective delivery of novel nutrients to animals, future grazing systems also face challenges in capturing potential benefits arising from genetic improvements to animals. Cows with genetic superiority for milk production cannot reach that potential on grazed pasture alone, leading to suggestions that changes to forage production and management systems, particularly increasing nutrient intake, would be necessary for cows to express their genetic potential (Kolver *et al.,* 2000). An alternative strategy to meet their nutrient needs by using energy dense feeds is unlikely to be economic, especially in New Zealand, further indicating that the current system requires changes to meet future production demands.

CONCLUSIONS

The ability of the animal industries in New Zealand and Australia to remain profitable and competitive has largely been a function of increasing productivity from low-cost forage-based systems. To accelerate the rate of productivity gains from their current levels, new ways of feeding animals on forage diets must be devised to combine the relatively low cost structure of our current systems with the greater precision in nutrient allocation possible in concentrate systems. There is recent, strong evidence that animals grazing pasture regulate their intake towards goals other than maximizing daily dry matter intake. Identifying and manipulating the behavioural responses of animals could open important new opportunities for improving productivity and product quality in the grazing industries.

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