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Opportunities for enhancing the delivery of novel forage attributes

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ABSTRACT

Allocating spatially separated forage choices to grazing animals overcomes constraints inherent in mixed pastures and sustainably delivers the required diet composition, satisfies their desire for mixed diets, and so offers a simple way to enhance the delivery of the benefits of current and novel forage attributes. Sheep offered grass and clover in this way increased daily dry matter intake by 265 g/day (25%, $P<0.05$) compared with conventional pasture and sustained 60-70% clover in their diet. Milk production by cows was boosted by 11% (2.4 kg/cow/day, $P<0.01$). This work highlights that behavioural responses to the method of forage presentation or to novel forage attributes (e.g. high energy forage) at pasture can be complex. Defining the animal behavioural response at an early stage is crucial to capture the benefits and opportunities offered by an increasing capacity to modify forage traits.

Keywords: Forage; management; ryegrass; white clover; grazing behaviour.

INTRODUCTION

We describe recent studies from New Zealand, Australia and United Kingdom exploring some factors that in the past have limited our capacity to deliver the benefits of existing and proposed novel forage attributes. These revisit two major paths for improving the quality and composition of the diet eaten by grazing animals: i) by modifying the way forage is presented to animals (traditionally 'management') to ensure the desirable attributes are actually substantially eaten, and ii) by modifying the forage genome (traditionally 'plant breeding', now 'genetic manipulation') to remedy any deficiencies (eg nutrients). Decades of experience with grass/legume-based systems has highlighted the previous constraints associated with both of these, not unrelated, approaches (see Caradus, 1996; Chapman *et al*., 1996).

Over and above all the complexities of maintaining a balance of plant species in a mixed species community (Schwinning & Parsons, 1996), conventional mixed-species pastures constrain diet composition and nutrient acquisition by grazing animals because selective grazing poses difficulties in achieving a high legume content in both the short and long term. In the short term, animals may succeed in increasing the proportion of a preferred food in their diet but doing so involves a foraging cost seen either as a need to increase the total time spent grazing or as a reduced rate of intake. In the longer term, sustained preference for one component can ultimately reduce the abundance of that component in the diet, by reducing its overall abundance in the sward.

Studies offering animals the choice of alternative forage species such as ryegrass and white clover growing side-by-side, rather than sown as a conventional intermingled mixture, have revealed a preference for mixed diets, with a high proportion of clover (Parsons *et al*., 1994), and provided some evidence that animal performance can benefit from having such a choice. Spatial separation of grass and clover may, therefore, be a very simple and practical novel means for sustaining desirable components in the sward and in the diet and for increasing animal performance. The same spatially separated choices of forages have also been used, in combination with rumenal infusions (e.g. of a water-soluble carbohydrate, sucrose, at pasture), as a procedure for evaluating the benefits of examples for modifying the forage genome.

We describe recent experiments to demonstrate both the opportunities, and some of the previous difficulties, in enhancing the delivery of novel forage attributes, and the importance of addressing the complexities and paradoxes involved in grazing systems as part of an early 'proof of concept' stage for streamlining the development of novel forage technologies.

MATERIALS AND METHODS

Only essential information to describe the general principles in the experimental design, measurements and management of swards and animals is presented.

Treatments and sward management: In all the experiments, animals were offered swards of ryegrass (Lolium perenne L) or of white clover (Trifolium repens L) growing alone as monocultures. The animals were offered either a single species (i.e., the animal had no choice) or they were offered both species growing side-by-side and were free to graze whichever species they wished. Some of the experiments (see results) involved a fourth treatment, a conventional grass/clover interspersed mixture. Monocultures of each species provided the benchmark data on behaviour, and together, provided the expectation for the response when animals had the choice of species, side-by-side, or interspersed. Swards were kept at a uniform sward surface height, such that height itself did not limit intake (at least 6 cm for sheep and at least 10 cm for cattle; Parsons, 1984; Hodgson, 1985). Plots were large enough to ensure that depletion in height did not influence behaviour (even if preference for one species in the choice was strong). Basal applications of P, K and S were applied to all treatments, and N was applied to the grass-only areas.

Animals: The sheep used were non-lactating ewes, aged between 15 and 20 months (45 – 60 kg live weight) grazing freely at pasture. Infusions were conducted using similar sheep, each with a rumen cannula, and carrying a backpack containing a pack of sucrose solution (250 g/l) and a pump operated by a radio-controlled switch such that infusion directly to the rumen took place only during natural bouts

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of grazing (Cosgrove *et al.*, 1999). The experiment with cows (Marotti et al., 2001) used mixed-age Friesians (540 kg LW; 150 days 'in-milk'; receiving oral bloat drench twice-daily) also at pasture. Groups of cows (n=3) were exposed to a particular treatment for 6 days (grass, clover, interspersed mixture or side-by-side choice) in a balanced crossover design, giving four replicates for each treatment group. Milk yields were recorded for the last 3 days of exposure.

Measurements: The animal behaviour response to treatments was described by time spent grazing, preference, and short-term rate of intake. The time spent grazing was recorded either by observation, or use of behaviour recorders (Rutter *et al.*, 1997). If the particular treatment involved a choice between grass and clover, the time spent grazing each species was also recorded. The short-term rate of intake of dry matter was measured by recording weight change during short bouts of grazing in the late afternoon, using the method of Penning & Hooper (1985). Daily intake was estimated as the product of short-term intake rate and the time spent grazing each day. Hand-plucked samples of the herbage were taken to simulate that being grazed, and water-soluble carbohydrate concentration estimated on freeze-dried and ground subsamples by near infrared reflectance spectroscopy.

Experimental design and data analysis: In all cases the unit of replication was the group of animals (typically ≥ 3 per group) exposed to a particular treatment. Replication (3 or 4) was achieved by repeating treatments spatially, or in time, using re-randomised or balanced groups of animals, and treatment means were compared by ANOVA.

RESULTS AND DISCUSSION

We describe the results of three experiments leading to the development of a novel management for enhancing the delivery of a current desirable forage attribute, namely white clover, and one further experiment evaluating a proposed new forage attribute, a raised sugar (energy) content in either grass or clover.

Novel management based on spatial separation of grass and clover

The first experiment was to test whether spatial separation offered sheep the opportunity to combine the high instantaneous intake rate typical from clover with the long grazing time typical from grass (Penning *et al*., 1991), and so to boost intake relative to that grazing either grass alone, or clover alone. The further possibility being tested was that any benefits of being presented with a choice were predominantly derived from the ability to sustain a greater proportion of clover *per se* in the diet.

Separate groups of sheep were offered either grass alone or clover alone and then, after a period of several days on these monocultures, all groups were offered grass and clover growing side-by-side for 2 days. On monocultures sheep spent longer grazing grass (445 mins/day) than clover (325 mins/day) as expected (Table 1).

However, when given the opportunity to graze from both species growing side-by-side, their daily grazing time (500 mins/day; comprising 230 mins/day grazing grass and 270 mins/day grazing clover) was not intermediate (null expectation) but was longer even than that on grass alone. Given that sheep eat clover faster than they eat grass, e.g., 4.0 g DM/min grazing clover cf 2.5 g DM/min grazing grass (Penning *et al*., 1991; this series of experiments), we can calculate that animals presented with a choice might achieve a total daily dry matter intake some 30% greater than that from either grass alone or clover alone. These data confirm an earlier experiment with lactating ewes (Champion *et al*., 1998) that indicated the possibility of a simple, but novel means to boost daily intake. However, it was not clear from the current study if the observed long grazing time could be sustained or if it was a transient effect, perhaps based on novelty.

In the second experiment, sheep were offered the same treatments as those above, with the addition of a fourth treatment, which was a conventional intermingled grass-clover mixture. The animals were observed for a period of 2 weeks exposure to these treatments, to see if the effects above were sustained. Sheep offered the choice of grass and clover growing side-by-side, sustained a diet of 70% clover for 2 weeks, confirming that the response is not transient, but can be sustained for a period that is long enough for benefits to translate into performance. Those offered the choice treatment had a daily dry matter intake 25% greater than those offered only grass (1345 vs 1080 g DM/ha/day, P<0.05), a benefit on top of the high, 70%, clover content in their diet, but their daily intake did not in this case exceed that on clover alone. Offering a choice of separate areas of grass and clover clearly offers opportunities for higher intake and proportion of clover than can be obtained from conventional interspersed mixtures, but low nutrient-demand sheep may not always use that

TABLE 1: Grazing time, intake rate and calculated daily intake (product of grazing time and intake rate) of sheep offered grass alone or clover alone, and when offered grass and clover growing side-by-side, the expected grazing time and daily intake if these behaviours were a simple linear combination of behaviour on grass and clover alone, and the observed grazing time and daily intake calculated from the observed grazing time.

		grass		clover
offered alone				
grazing time (min/day)		445		325
intake rate (g DM/min)		2.5		4.0
daily intake (g DM/day)		1110 (2.5 x 445)		1300 (4.0 x 325)
offered side-by-side				
grazing time	- expected[1]	1/2 (445)	+ 385	1/2 (325)
	- observed[2]	230	+ 500	270
intake rate		2.5		4.0
daily intake	- expected[1]	555	+ 1200	650
	- calculated[2]	575	+ 1655	1080

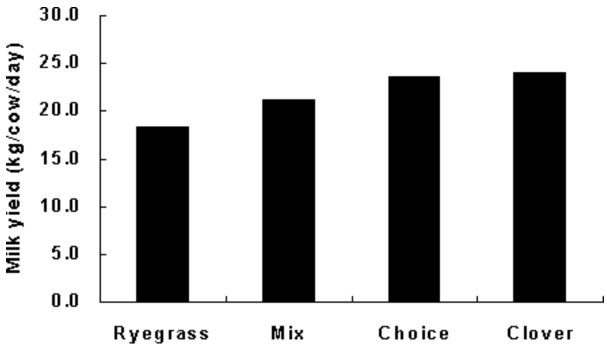
[1]Derived from the values for grazing time and daily intake that would be expected if behaviour on the side-by-side choice were a simple linear combination of these behaviours on each species alone.

[2]Experimentally observed grazing time, and intake rates as for grass alone and clover alone, used to derive calculated daily intake.

opportunity to eat more than on clover alone.

The third experiment, conducted in southwest Victoria, Australia, examined the effect of the same methods of presenting forage species on milk yield in dairy cows, where the effects of the novel management on performance could be seen directly. Cows offered the choice of grass and clover growing side-by-side sustained a diet of 70% clover and boosted daily milk yield by 11% (2.4 kg/cow/day, P<0.01) compared with a conventional interspersed grass-clover mixture (Figure 1). The potential for this management is perhaps better reflected in the 28% increase in milk yield of the choice treatment relative to that from grass alone, for interspersed mixtures typically have an even lower proportion of clover (5-15%) than the 22% achieved in this experiment. This performance boost is consistent with parallel studies in the UK where offering lactating cows grass and clover growing side-by-side (all cows received 4 kg/cow daily of concentrate in addition to pasture) generated an increase in milk yield of 10% (2.9 l/cow/day), sustained over 6 weeks, compared with a conventional mixture (Nuthall *et al*., 2000).

FIGURE 1: Daily milk yield (kg/cow/day) of cows in mid lactation offered ryegrass or white clover only, an interspersed ryegrass-white clover mix (22% white clover), and the choice of ryegrass and white clover growing side-by-side (Marotti et al., 2001). Pooled SEM 0.52.



Enhancing the delivery of a novel forage attribute

New technologies offer the potential to improve forage attributes for animals (e.g., increased energy content, special nutrients, flavours, anthelmintics) or for consumers, via milk or meat products (eg healthy lipid profiles, minerals). Here we describe the results of one experiment exploring opportunities for enhancing the delivery of the benefits of such developments, using the example of a proposed increase in energy content in either the grass or the clover.

We simulated an increase in one particular soluble carbohydrate (sucrose) in forage by infusing directly into the rumen. This was because, although ryegrass genotypes of contrasting water soluble carbohydrate (wsc) concentration are available, any benefits of these might arise from factors other than wsc concentration *per se* (as discussed later).

Sheep were infused with a sucrose solution (250 g/l) either while they were grazing grass only or while they were grazing clover only, to simulate the effect to the animal of an increased plant water soluble carbohydrate concentration of 100g/kg DM in either species. A difference of this magnitude has been achieved in selected lines of ryegrass (Humphreys, 1989). Sheep received the infusion only while they were grazing, such that the amount of sucrose solution received was in direct proportion to the amount of dry matter eaten, and, more important, the intake of sucrose was potentially under the direct control of the sheep simply by varying the time they spent grazing. Sheep receiving the sucrose solution while grazing grass or clover reduced the total time spent grazing compared with similar control sheep receiving an infusion of water (Table 2), and as a result their daily dry matter intake was marginally lower (P=0.09). The calculated daily intake of soluble carbohydrate from all sources (forage plus infusion) was consequently similar for both infused and control sheep.

Similarities in results between the current study, based on simulating a change to a plant characteristic, and studies with ryegrass selected for high water soluble carbohydrate indicate that realising the potential to boost performance

TABLE 2: Effect of elevated water-soluble carbohydrate (wsc) in forage (simulated via infusion of sucrose into the rumen, or directly using selected cultivars of ryegrass) on wsc concentration in the diet, time spent grazing, short-term intake rate and daily intake of dry matter and wsc.

	via infusion[1]					via selected lines[2]		
	grass		clover			grass		
	control	high wsc	control	high wsc	signif. (P)	control	high wsc	signif. (P)
wsc in diet[3] (g/kg DM)	115	175	144	244	-	98	138	-
grazing time (min/day)	360	325	285	265	0.005	634	626	NS
intake rate (g DM/min)	4.4	4.4	6.0	3.9	NS	1.26	1.07	NS
daily intake (g DM/day)	1600	1414	1708	1014	0.09	748	626	NS
daily intake of wsc (g/day)	183	248	246	248	NS	73	86	-

[1]Sheep received an infusion of water (control) or sucrose solution (250g/l) to simulate a forage with elevated soluble carbohydrate (high wsc), during periods of grazing (for methodology see Cosgrove *et al.* 1999). Significance (P) refers to infusion treatment main effect.

[2] Forage lines were Fennema (control) and AberDove (high wsc) perennial ryegrass (for methodology see Cook *et al.* 2000).

[3] Concentration of wsc in the diet calculated from amount in the forage consumed plus that infused, and daily intake of dry matter. Means not statistically compared (-).

by increasing energy content in forage (as opposed to as a supplement), requires a carefully focussed approach. Lee *et al.* (2000) measured greater liveweight gain of lambs on the high wsc ryegrass (mean difference between high and low wsc lines, 33 g/kg DM), but they could not determine whether the response arose from higher wsc concentration *per se* or from the associated lower structural fibre concentration. In a range of 15 diploid, tetraploid and tetraploid-hybrid ryegrass cultivars that differed substantially in many characteristics, including soluble carbohydrate concentration (Cook *et al*., 2000), daily dry matter intake from 'AberDove' (138 g wsc/kg DM), was similar to that from 'Fennema' (98 g wsc/kg DM) (Table 2). Attributes such as nitrogen concentration and digestibility were significantly, and positively, correlated with daily intake. Cows fed high (234 g/kg DM) or medium (194 g/kg DM) wsc lines of ryegrass had similar daily dry matter intake and milk yield (Miller *et al*., 2000). The higher wsc concentration, and the higher energy:protein ratio, greatly increased the efficiency of utilisation of protein in the diet, and reduced urinary-N output, which alone offers environmental benefits. But the lower concentration of crude protein in the herbage and so in the diet from the high wsc grass, reduced the total N intake, and in that particular experiment offset the benefits of high N use efficiency, giving only the same milk yield.

CONCLUSIONS

Our capacity to deliver the potential benefits of novel forage attributes under grazing is faced with overcoming all the factors that in the past have limited the delivery of preferred forage species, such as clover, as well as by the animals response to the novel agent. The merits of new traits will not be fully realised if the species carrying that trait can be sustained only as a low proportion of the vegetation and diet. A simple management overcomes some of these constraints by enabling animals to sustain a high proportion of a preferred species in their diet, and further on-farm development is warranted. Using the example of a high water soluble carbohydrate (in our studies, sucrose, or in studies overseas an unspecified suite of sugars) we have suggested that improving animal diet and performance by manipulating forage characteristics requires a carefully focussed approach if the benefits are to be fully realised. We stress that different forms of sugar may behave differently in the digestive tract, and not all forms of sugar have been evaluated. We also emphasise that increasing energy intake by other means (e.g., by supplementation) has clear benefits, but delivering increased energy by altering the energy/protein proportion poses different questions. Animals at pasture may alter grazing behaviour to regulate energy and protein intake. It is vital to address the complexities and paradoxes involved in grazing systems as part of an early 'proof of concept' stage to streamlining the development of novel forage technologies.

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