
NEW ZEALAND SOCIETY
ANIMAL PRODUCTION
VOLUME 62 2002

The potential to increase production efficiency from animal-pasture systems

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ABSTRACT

Future increases in production efficiency of milk production from pasture will be brought about primarily by increasing the genetic potential of cows to produce milk solids, and by developing grazing systems which combine a high level of herbage utilisation/ha with high dry matter intakes.

Grazing often underutilises herbage in spring, which leads to a reduction in quantity and quality of herbage in summer and autumn with a consequent accelerated decline in cow performance. Higher grazing stocking rates in spring combined with the conservation of a greater pasture area for silage produces an improved pasture and provides additional forage for supplementation in summer and autumn.

At present the amount and seasonability of milk production in New Zealand is dictated by pasture production. This gives large variations in production between and within years, and may not represent the most efficient way of using milk processing plant or of satisfying the market's needs. Consideration may have to be given to less rigid systems of production involving more flexibility in calving date and a greater use of conserved feed.

Keywords Dairy cattle, grazing, production efficiency.

INTRODUCTION

In animal-pasture systems where the basic resourses of land, labour and capital are relatively fixed, increases in production efficiency have to be brought about mainly by changes in management. Indeed because of pressures on the price of agricultural products arising from surpluses on the world market such improvements are imperative for the survival of many farm businesses.

The production or economic efficiency of a system can potentially be increased in several ways; by reducing inputs to achieve the same output, by increasing output with the same inputs, or by increasing inputs and outputs in such a ratio that the value of the extra output exceeds the cost of the extra inputs. Unfortunately in animal-pasture systems where the inputs are few, there are less alternatives for change than in more complex animal systems which use a range of inputs produced on the farm or which are purchased.

In this paper discussion is restricted to animal-pasture systems for dairy cattle.

LIMITATION TO INCREASING EFFICIENCY

The complex interrelationship of soil, plant and animal presents problems in predicting the outcome in any management decision. Nevertheless recent development in the understanding of sward dynamics (Bircham and Hodgson, 1983; Parsons and Johnson, 1986) and of grazing behaviour and intake (Hodgson, 1982, 1986; Leaver, 1986a) have highlighted many of the limiting factors to increased efficiency. The major areas for improvement are in the utilisation of herbage/ha and in the intake of grazed herbage (and hence in animal performance).

UTILISATION OF HERBAGE

The utilisation of herbage dry matter (DM)/ha or more precisely the utilisation of metabolisable energy (UME)/ha is closely related to the economic performance of dairy herds (Leaver, 1983). In the U.K. the UME on costed dairy farms is the single measurement which relates most strongly to the gross margin (income minus variable costs)/ha. It is calculated quite simply from the annual milk sales/cow, the annual purchased feed/cow and the annual stocking rate. The utilisation of herbage can be increased by producing more/ha and/or by the cows eating a greater proportion of the herbage grown.

Herbage Varieties

Under grazing conditions, rainfall, nutrient supply and grazing management are the most influential factors affecting the production and utilisation of herbage. The development of new varieties of grass and clover will lead to a gradual increase in output/ha (Goold, 1985). Nonetheless, progress in plant breeding is by nature relatively slow. Also the assessment of species and varieties grown as individual populations, often at high nutrient inputs and harvested by cutting, can lead to a mistaken view of the ability of the variety to perform under grazing conditions, in combination with other species-varieties, and at different nutrient inputs (Dibb and Haggar, 1979). Whilst cut plots are a useful screening process for new varieties, evaluation under farm-type conditions is essential. As UME/ha is mainly affected by rainfall, nutrient input and grazing management, breeding of new varieties for other characteristics such as persistency, nutrient content and disease or pest resistance may be equally desirable objectives.

Nitrogen Fertilizer

The future role of nitrogen (N) fertilizer to increase output depends on its unit cost and the response in herbage DM yield which is achieved. The value of this DM response is in turn dependent on animal product price. In the U.K., grass plots show responses to N of 15-25 kg DM/kg N (Holmes, 1968; Reid, 1978). However, under farm conditions a mean response of only 8 kg DM/kg N has been reported (Leaver, 1985). This discrepancy can be accounted for by the on-farm utilisation losses associated with grazing and ensiling, the return of nutrients to the soil from dung, urine and slurry and the contribution of clover. Similar low responses to N have been reported in New Zealand (Holmes and Wheeler, 1973; Ball *et al.,* 1978). The response to N under grazing is probably less than under cutting (Jackson and Williams, 1979) and so recommendations for N fertilizer use must be soundly based on output/unit input results measured under farm-type conditions.

In clover-based systems because of the sensitivity of clover to fertilizer N and the resulting substitution of fertilizer for clover N, the responses to strategic application of N must be evaluated in the long term.

Sward Dynamics

The grazed sward is in a dynamic state of growth, senescence and defoliation. The control of sward height by grazing affects the balance of growth and senescence and hence utilisation (Fig. 1). A new leaf is produced on each tiller or perennial ryegrass about every 11 d in spring and summer, and as the tiller maintains only 3 live leaves the average longevity is about 4-5 weeks (Davies, 1977). The grazing pressure thus influences not only the utilisation of herbage but also the amount of green leaf available for photosynthesis and the proportion of live and senescent material.

In swards grazed with sheep on set-stocking, maximum utilisation of DM/ha has been achieved at sward heights of 2.5-6.0 cm (Bircham and Hodgson, 1983; Grant *et al.,* 1983). At greater heights the increased rates of senecence exceed the increased rates of growth, and net production declines (Fig. 1). Below this range of sward heights inadequate green leaf is available for photosynthesis. In swards grazed by cattle a more uneven mosaic of grazed and ungrazed patches develops than in sheep grazed swards. Consequently, there is a need for more research into optimum sward conditions for net production of herbage in swards grazed by cattle for both set-stocking and rotational grazing management.

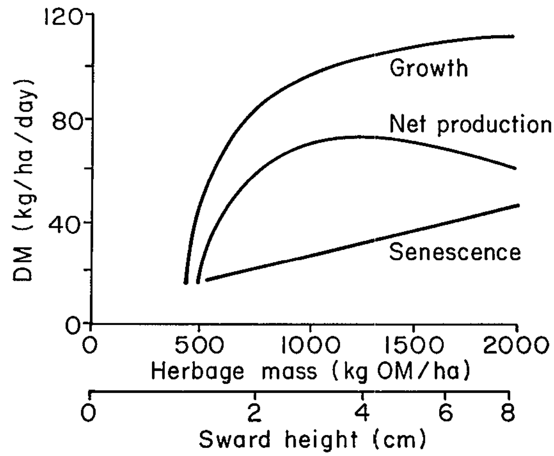

FIG. 1 Relationship between total growth, senescence and net production (Bircham and Hodgson, 1983)

The frequency and severity of defoliation of tillers affects tiller population density. This has implications for the longevity of the sward and also for DM production. Swards with a high tiller population density as with set-stocking often produce a similar DM yield to those with infrequent defoliation and low tiller density. The reduced DM production/tiller with set-stocking is compensated for by the greater number of tillers (Grant *et al.,* 1983).

It is clear from studies of sward dynamics that there is scope for improvement in DM utilisation/ha on many farms, through better control by management of the frequency and severity of grazing. Nevertheless due to the limited available knowledge on sward dynamics with grazing dairy cows, the provision of detailed management recommendations is difficult.

HERBAGE INTAKE

It is not uncommon for grazing cows to fail to achieve their potential intake (Leaver, 1985). The main factors constraining herbage intake are herbage availability (herbage mass or sward height) and herbage quality (digestibility and contamination). Any supplementation fed will depress herbage intake (Leaver, 1986a; Meijs and Hoekstra, 1984).

Grazing Behaviour

Studies of grazing behaviour have shown the ability or willingness of the grazing animal to harvest the pasture are important factors determining intake

(Hodgson, 1986). Herbage intake is a product of grazing time, rate of biting and bite size.

As herbage availability declines, bite size also declines and although grazing time and rate of biting may be increased in an attempt to compensate, intake is reduced. This is particularly true on set-stocked swards. The relative inflexibility of grazing time means that the rate of intake (rate of biting x bite size) is the major factor determining daily intake. Bite size is the component of rate of intake most sensitive to sward changes. The following equation describes the relationship between herbage intake (HI) (kg DM/d) and bite size (IB) (g DM) for 1 set of data (Leaver, 1986a):

$$HI = 45\ IB - 34\ IB^2 + 6IB^3$$

The contrast between the rate of intake of forage and of grazed herbage (Table 1) emphasises the problems associated with achieving high intakes at pasture. A clear conclusion from behaviour studies therefore is that for high intakes of DM, swards allowing a large bite size are required.

TABLE 1 Rate of intake (kg DM/h) of forages and grazed herbage.

Forage	3.0
Grazing - spring	2.2
early season	1.8
mid season	1.3
late season	1.0

Increasing Bite Size

As bite size appears to be the dominant factor influencing intake, an examination of the relationship between sward structure and bite size would appear to be a rewarding area of research. Herbage allowance (Hodgson, 1986) and season (Leaver, 1986a) are 2 factors which have been shown to affect bite size and intake.

The relationship between herbage allowance and bite size appears to be positive and linear. With sheep the depth of the leafy canopy and the bulk density of herbage within the leafy layer are critical factors (Black and Kenny, 1984, Burlison and Hodgson, 1985). Similar investigations with grazing cattle have not been carried out.

Bite size is high in spring, but declines thereafter (Table 2). The result is a decline in rate of intake (Table 1) and in herbage intake as the season progresses. There are several causal factors. Herbage availability measured as residual herbage mass or height, in rotational systems, or sward height in set-stocked systems, often overestimates the amount of herbage available to the cow due to the inclusion of rejected areas in the assessment. These rejected areas increase as the season progresses. Gibb *et al.* (1985) have highlighted this variation by demonstrating double normal distribution curves for herbage mass in grazed and rejected areas. The rejected herbage is not only less attractive to the grazing animal because of dung contamination, but also because of the reduced quality of herbage in these patches (a greater proportion of stem to leaf, and dead to live matter).

TABLE 2 Season of grazing and herbage intake.

Season	Bite size (gDM)	Herbage intake[1] (kg DM/d)	Herbage ME (MJ/kgDM)	ME intake (MJ/d)
Spring	0.60	16.1	12.2	196
Early	0.50	14.8	11.8	175
Mid	0.35	11.8	11.2	132
Late	0.25	9.2	11.0	101

[1] cows of 550 kg live weight

The digestibility of herbage declines after the spring period. This is due initially to a decreased leaf to stem ratio during the reproductive phase of growth, and then by a decrease in the live to dead ratio. This adversely affects intake and probably bite size. The decline in intake as the season progresses is therefore due to a combination of herbage availability and quality.

Thus at any particular residual mass or height under rotational grazing, or sward height under set-stocking, intakes are greater in spring than later in the season (Holmes, 1987). Conversely, to maintain high intakes, sward mass or height requires to be increased as the season progresses. This practice is detrimental to sward utilisation, and highlights the problems of combining high levels of pasture utilisation with high DM intakes.

Cow Potential

High yielding cows are more efficient producers of milk than low yielding cows due to their maintenance requirements being a smaller proportion of their total energy intake and their energy output in milk. Studies on high (HBI) and low (LBI) breeding index cows (Bryant and Trigg, 1981; Grainger *et al.*, 1985a, b) have shown that the higher production of HBI cows is associated with a greater intake per unit of live weight than for LBI cows. The ability of HBI and LBI cows to digest and metabolize food is similar.

Cows with a higher genetic potential to produce milk fat and protein therefore need to eat more feed over the lactation cycle to express this potential. Under grazing conditions this means either grazing for longer per day and/or having a faster rate of intake (rate of biting x bite size). There is evidence that cows of higher potential have an increased grazing time. Journet and Demarquilly (1979) reported an increase of 12 min grazing time /kg milk. This represents an extra intake of about 0.44 kg DM/kg milk for a bite size of 0.65 g DM, but only 0.19 kg DM/kg milk for a bite size of 0.25 g DM. This suggests at bite sizes associated with spring grazing (Table 2), that grazed pasture presents few limits to increased cow performance. However, at the lower bite sizes seen in summer and autumn, high potential cows are unlikely to meet their requirements, and accelerated declines in milk yield will occur.

The rationing of pasture to HBI cows prevents them from achieving their potential intake and performance. Daily requirements for feed DM remain relatively constant for at least the first 20 weeks of lactation (Leaver, 1986b), and management should endeavour to exploit the efficiency of such cows by not restricting the availability of feed in mid to late lactation.

A recent assessment of changes in seasonal production in New Zealand (Macmillan and Henderson, 1987) confirms that although the increased genetic potential of cows over 25 years has allowed production levels to increase substantially in spring, restriction of pasture has limited increases in summer and autumn.

If the use of bovine growth hormone (Peel *et al.*, 1985) becomes commercial practice, it will have the effect of increasing cow potential (probably by 15-20%). The greater intake drive of these cows will lead to longer grazing times and possibly to higher rates of intake. Nevertheless, the appropriate sward management will be necessary to allow this higher potential to be expressed.

GRAZING MANAGEMENT

There is little doubt that the view of McMeekan (1956) concerning the importance of stocking rate relative to other aspects of grazing management is still valid. The better understanding we now have of the influences of the animal on herbage utilisation, and of herbage availability on animal intake should lead to the development of more efficient systems of production.

Season Trends

In temperate grassland, management of the grazed sward during the reproductive phase in spring is critical to the seasonal production of the sward and to animal performance.

High stocking rates at that time are essential in predominantly perennial ryegrass swards. This practice prevents stem elongation and develops a high digestibility sward with a higher tiller density and fewer rejected areas for the remainder of the summer. The outcome is a greater output of milk fat and protein and an increase in UME/ha (Table 3).

The practice of topping pastures (Bryant, 1982) following understocking in the spring is wasteful, and conservation of surplus pasture generated by high grazing stocking rates (Bryant, 1980; Thompson *et al.*, 1984) is a more efficient approach. There is a critical balance between maintaining high DM intakes in early lactation, controlling pasture growth and quality, and conserving ample amounts of silage or hay to meet subsequent deficits (Thomson *et al.*, 1984).

TABLE 3 Stocking rate in spring and dairy cow performance (Baker and Leaver, 1986).

Performance	Early season stocking rate (cows/ha) 4.7	5.6	6.4
Fat + protein yield (kg/d)			
Early season (7 weeks)	1.77	1.74	1.75
Remaining season (14 weeks)[1]	1.34	1.44	1.47
Fat + protein yield (kg/ha) over 21 weeks	894	999	1081
UME (GJ/ha)	77	82	87

[1] All groups on same stocking rate

Grazing System

The large uptake of intensive set-stocking in the U.K. has been stimulated by the results of trials which suggest little difference in output between set-stocking and rotational grazing systems (Ernst *et al.*, 1980). The set-stocking system is nevertheless dependent on the availability of supplementary feed to maintain intakes when sward heights fall below 5-7cm (sward surface height). This is possible in countries where the milk price:purchased feed price ratio is favourable. In countries where grazed herbage supplies the year round basal feed, as in New Zealand, the lack of control of pasture availability with set-stocking makes the system less attractive than rotational systems where greater control of herbage allowance is possible. This is particularly true in winter when a rationed approach to grazing is desirable. There may however be periods where set-stocking may be beneficial for tiller population density and sward longevity.

Rotational systems may have an added advantage in clover-based swards. There is evidence that continuous hard grazing of clover, as with intensive set-stocking, leads to a reduced proportion in the sward (Frame, 1984). In the classical study of McMeekan and Walsh (1963) rotational grazing was superior to set-stocking at the high stocking rate. Where a large proportion of the pasture is conserved for winter feeding, as in the U.K. within season alternation of areas for set-stocking and harvesting for silage has been shown to be successful in maintaining white clover-perennial ryegrass swards (Younie *et al.*, 1986).

It may be concluded that the choice of grazing systems should be made according to the likely benefits in farm organisation and management rather than for potential increases in output.

Supplementation with Forage

Dairy cattle on indoor feeding on a flat-rate of concentrate and *ad libitum* grass silage, show rates of decline in milk solids yield of less than 2% per week (Leaver , 1986b). When grazing provides the sole feed, however, milk yields often exhibit declines of over 3% per week. This is due to inadequate herbage intakes in summer and autumn as discussed earlier.

Offering a forage such as silage as a supplement has little benefit to performance in early season as it substitutes for grazed herbage of higher quality (Phillips and Leaver, 1985); but from late summer onwards the limitations of bite size on herbage intake stimulates good responses in total DM intake to forage supplementation (Table 4). The increased DM and total ME intake achieved can alleviate the decline in milk yield, providing the forage supplement has high intake characteristics (an ME of over 10.5 MJ/kg DM and in the case of silage a good fermentation). Additive responses in total DM intake to forage supplementation will ensue at any time during the year, if herbage availability is restricted.

Estimates of utilisation from swards cut for silage compared with grazed swards indicates an increased gross utilisation/ha of about 30% for cut swards (Richards, 1977). After subtracting conservation losses, the net advantage of cutting in well managed systems is likely to be 10-15% DM/ha. A grazing system based on high stocking rates in spring will therefore lead to better utilisation of grazed areas and the development of a highly digestible regrowth and to the release of more land for conservation with a higher UME/ha level. The conserved surplus can then be used for tactical supplementation when herbage availability and intake is restricted later in the season. The extent to which this practice is followed depends on the cost of the conservation system but in most cases this should be cost beneficial.

SUPPLYING THE MARKET

In New Zealand the majority of the production from dairy farms is destined for export. The seasonability of pasture production dictates milk output, and as a result there are large variations between and within years in production. This appears to be an inefficient use of milk processing plant. Also the variations in milk production dictated by pasture output could lead to marketing problems. In a world market saturated with dairy products, the marketing objective of having available the right product, in the right amount, at the right price and at the right time will be increasingly important. A greater flexibility in the present rigid systems of milk production to even out production over the year seems to be a likely future development.

TABLE 4 Grass silage supplementation for grazing dairy cows (Phillips and Leaver, 1985).

Performance	Feeding system	
	Grazing	Grazing plus silage[1]
Early season (12 weeks)		
Silage DM intake (kg/d)	0	1.7
Total ME intake (MJ/d)	174	166
Fat + protein yield (kg/d)	1.40	1.41
Liveweight gain (kg/d)	0.29	0.06
Late season (9 weeks)		
Silage DM intake (kg/d)	0	4.1
Total ME intake (MJ/d)	147	162
Fat + protein yield (kg/d)	1.08	1.13
Liveweight gain (kg/d)	0.31	0.65

[1] Available for up to 1 h after morning milking

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