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EXTENDING THE GRAZING SEASON

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SUMMARY

It is accepted that grazed grass of high quality is the cheapest feed resource for ruminant animal production. Thus, maximizing its use aids the economic viability of grassland farming systems, this objective being increasingly necessary in light of the highly competitive marketplace. This review deals with the forage production and utilization strategies which have been developed, some of which were developed in the past and others of more recent vintage. Choosing suitable plant species for the specific growing conditions which pertain is a key element and such species can range from annual forage crops to perennial grasses and legumes. The time of application of fertilizers, particularly nitrogen, is another strategy particularly important for the provision of early or late season grazing. In semi-arid regions irrigation is an obvious option provided water is available and inexpensive. However, in such regions sight should not be lost of drought resistant plant species including shrubs and trees that can be grazed. Allowing grass to accumulate (the grass 'wedge' or 'bank', deferred grazing, stockpiling) can provide forage for utilization in dry summer periods or late season. In utilizing growing or saved grass efficiently, techniques can vary from limited short-period grazing or rationing to full-time grazing, and in method from strip grazing to continuous stocking with the use of optimal sward surface heights as a guide to controlling intensity of use. Experimental work has proven the case for the various strategies of extending the grazing season and improving animal output in a range of environments. The challenge on individual farms is to achieve year-round integration of selected management practices suitable for the specific farm environment.

Key words: Forage species, fertilizer nitrogen, maximizing grazing, management strategies, animal performance.

INTRODUCTION

Direct payments from the EU and agricultural production are in the process of being decoupled due to the agreement between the Council of Agricultural Ministers of the EU on Common Agricultural Policy (CAP) reform in 2003. As a result it is anticipated that prices for some ruminant products, including milk, will decline. To maintain margins per farm an obvious remedy would be to increase stocking rates where biologically possible. However, increasingly restrictive environmental legislation, e.g. widespread designation of Nitrate Vulnerable Zones (NVZs), is imposing limits on stocking rates and so the alternative is to reduce costs without jeopardising output.

Grazed grass is the cheapest form of high quality feed. Although recent estimates of its cost relative to grass silage and concentrates in dairy production suggest that it is not as cheap as originally calculated, it is still one quarter to one third cheaper than grass silage to produce (Keady and Anderson, 2000). Further, due to often less than optimal grass for conservation, poor fermentation or high nutrient losses during ensiling, grass silage quality is more variable than that of grass at a stage suitable for grazing. Therefore, any management practice which increases reliance on the use of grazed grass has potential to reduce costs and increase animal performance.

Environmental legislation is restricting the months during which slurry can be spread, necessitating an increase in slurry-holding capacity. Such legislation also is increasing penalties for and public awareness of point source pollution of watercourses by silage effluent. Reducing the amount of time animals spend indoors outside the conventional grazing season should have a positive impact on both of these issues.

One approach to increasing reliance on grazed grass and hence alleviate these problems is to extend the grazing season. In cooler temperate regions this will be to increase the use of grazed grass in late autumn and early spring. In areas with a midseason drought, irrigation of pastures is an option if cost effective, while grazing of short term summer forage crops offers a cheaper alternative than zero grazing (González Rodríguez *et al.*, 1996).

The relatively recent interest in extended grazing in the UK and Ireland was stimulated by New Zealand Grassland Advisers, while working with farmers in the SW of Ireland; in particular, they introduced the concept which in the early 1990s had become well established in New Zealand. In effect the concept of extended grazing is a reworking of past individual practices such as 'early bite', 'late bite' and 'deferred grazing'. However, the difference now is the year-round interdependent integration of all these extended grazing practices in order to achieve maximum use of grazed grass. Good forward planning is the key element.

FACTORS INFLUENCING SWARD GROWTH

A complex of weather and management factors influences grass growth for extended grazing in both early and late season. In cool temperate environments, at temperatures less than 11 °C, growth is more directly influenced by temperature than by solar radiation. In contrast, at higher temperatures, solar radiation tends to be more limiting and so as it increases for a given temperature so does growth, unless soil moisture becomes restrictive. Thus the main factor limiting grass growth during these extended grazing periods is temperature. For example, during the low temperatures of winter and early spring (November to March) in the United Kingdom (UK) and Ireland the average daily growth rate of grass ranges from about 3 kg DM ha^{-1} in north-east Scotland to 11 kg DM ha^{-1} in SW Ireland (Brereton *et al.*, 1996). These values represent about 6 per cent and 14 per cent, respectively, of total annual production for these areas. Consequently as the daily rate of growth will not produce sufficient herbage to sustain a herd, especially at more northerly latitudes, it is necessary to defer the utilization of some of the grass grown earlier in the season and save it for later use or carry over grass grown late in autumn for use in early spring. Due to the interaction between environment and grass physiology, limits are placed on the amount and timing of herbage deferment in autumn and spring. As grass accumulates in autumn, there is declining solar radiation and slow leaf appearance rates but with senescence rates being less temperature dependent a maximum herbage mass is reached which declines with progress of autumn into winter (Frame, 1972; Laidlaw and Mayne, 2000). Lengthening the regrowth period beyond the stage at which the ceiling yield is reached results in a net loss of green leaf material (Fig. 1 from Laidlaw and Mayne, 2000). This imposes a maximum limit on the length of period over which herbage can be deferred and this also applies to herbage over the winter. In contrast grass growth in late winter-early spring is strongly influenced by rising temperature and radiation levels and the 'ceiling' yield attainable becomes progressively higher particularly with lengthening rest interval prior to utilization. This is enhanced by the changing physiology of tillers (at least with perennial ryegrass (*Lolium perenne* L.)) as in spring leaf extension rate can be 2 to 3 times faster than in autumn for the same temperature and irradiance conditions (Peacock, 1975). However early season growth is also influenced by the previous late autumn-early winter management, particularly N fertilizer application or soil N reserves, and intensity of defoliation whether by cutting or grazing. For example, in Ireland, meaned over 3 years, yield of herbage harvested in April was reduced by 31 % when deferred herbage had been grazed on 20 December compared to 20 November in County Cork (Hennessy *et al.*, 2004a). However, from a comparable study in County Meath, where the grass growing season is about 40 days less, April yields were not affected by the different grazing dates earlier in winter.

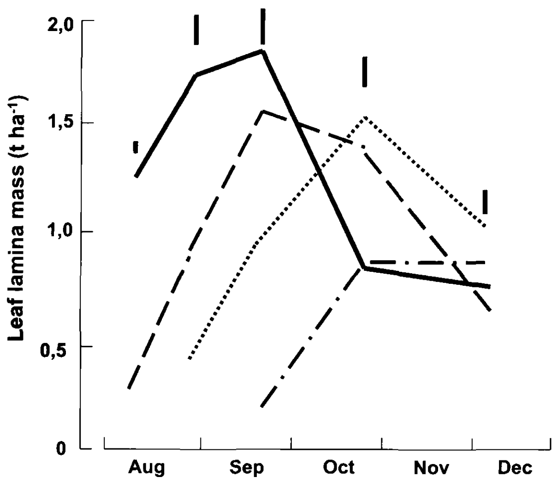

FIGURE 1

Leaf lamina mass in swards at intervals during autumn and winter subsequent to a range of autumn defoliation dates: —— 19 July, - - - - 8 August, ·········· 30 August, — · — 20 September. Standard errors of the mean (s.e.m.) are represented by vertical bars.

Masa de hojas durante el otoño y el invierno, después de una serie de fechas de defoliación: —— 19 Julio, - - - - 8 Agosto, ·········· 30 Agosto, — · — 20 Septiembre.

Los errores normales de la media (s.e.m.) se representan en barras verticales

It was noted that the length of leaf senescing per tiller daily was directly related to the length of autumn regrowth interval (Carton *et al.*, 1988). Although the average number of live leaves per perennial ryegrass tiller has been estimated to be about 3 for most of the year (summer and winter) (Davies, 1977), these observations were made on spaced plants. In swards, the mean number of complete live leaves per tiller declines with progress into the winter. Therefore, senescence per tiller in swards where 3 or more leaves have been produced during regrowth is faster than appearance of new material from October into December (Hennessy *et al.*, 2004b) and so the number of live leaves per tiller declines. Also, the greater the amount of herbage accumulated during autumn for deferred grazing, the greater is the amount and proportion of senescent leaf material (Davies and Simons, 1979; O'Kiely and O'Riordan, 1994; Roche *et al.*, 1994). To minimise these adverse effects Laidlaw *et al.* (2000) suggested that the herbage accumulation target in autumn be no more than 2.5 t DM ha^{-1} prior to utilization.

In the British Isles late winter-early spring grass production is most attainable in the moist and warm south west (Down *et al.*, 1981; Lazenby and Down, 1982). Rising soil and air temperatures increase the rates of leaf appearance and extension, duration of the extension and production of sites for new tillers (Parsons and Chapman, 2000). Perennial ryegrass tillers produced over the autumn-winter period can contribute more than 60 % of ryegrass growth in spring (Fulkerson and Michell, 1987).

With the rise in late winter-early spring soil and air temperatures, swards on free draining, light textured and friable loam soils are the first to respond and grow, especially when sheltered and south-facing. There is also less risk of trampling damage on these swards than on those later growing swards based on heavy textured clays and silts which are highly retentive of water (Wilkins and Garwood, 1986).

HISTORICAL PRACTICES

Commonly in the UK, those spring-born ewe lambs on hill and upland farms that are to be kept as replacements for the flocks, are transhumed to lowland grasslands from the early autumn to the start of spring (1 October to 31 March) to ensure a satisfactory growth rate. This has both positive and negative effects on lowland swards, positive since surplus grass that shades the sward tiller base is grazed off and negative since the late winter-early spring grazing delays the turn-out date for housed stock due to insufficient grass being available.

Past research assessing the effects of the sheep grazing showed that it depressed herbage yield in early season, the depression being greatest from January - March grazing, particularly from later dates of cessation during this period (Frame, 1970; Wilman and Griffiths, 1978). The adverse effect on yield increased with increasing grazing intensity (Black, 1969; Lockhart *et al.*, 1969), an effect attributed to trampling damage (poaching) of the sward in addition to defoliation. Apart from a yield depression *per se*, swards were later in attaining a target level of yield for grazing. Nitrogen fertilizer applied in late winter / early spring can compensate for yield loss by accelerating the growth rate of the previously grazed sward (Edwards and Morgan, 1962; Lockhart *et al.*, 1969; Frame, 1970) and in practice can be done by shutting off selected fields from winter grazing. Following these trials many lowland dairy farmers only permit sheep grazing until December.

In the earlier work it was also found that building up a bank of lush autumn growth by deferring utilization increased the likelihood of winter kill which in turn led to reduced late winter / early spring growth from the weakened sward. Cocksfoot *(Dactylis glomerata* L.) and timothy (*Phleum pratense* L.) proved more winter hardy than perennial ryegrass swards which were particularly susceptible and more so if N fertilizer was applied in the autumn (Baker, 1956; Hunt *et al.*, 1976). Various reasons put forward included reduced tillering due to the prolonged autumn cover, the diversion of water-soluble carbohydrates to respiration and the sudden exposure of the stubble remaining after defoliation to low temperatures. One major effect resulting from such experiences was the development by plant breeders of winter-hardy varieties. It may be added that in recent years severe winters have become less common.

Following the early work there was a hiatus during which silage production and use burgeoned, fuelled by advances in equipment and in the technology of making and utilizing it efficiently. However from the mid-eighties onwards there was an increased focus on maximizing the use of grazed swards stimulated by advances in grazing technology (Hodgson, 1990). Adapting the rotational grazing system on dairy farms by increasing rotation length when growth rates were slow, New Zealand grassland technologists developed a system of extended grazing which allowed a 'wedge' of herbage to be built up in early winter. This ensured some herbage was available for grazing and start of lactation at calving in early spring. This was the link to the reintroduction of extended grazing in early and late season into western and north eastern Europe.

In northern European countries grass growth curves tend to show maximum growth in the spring and a minimum in winter (Corrall, 1984). In contrast growth curves in southern European countries show a bimodal shape with minimum growth in summer, due to drought, as well as in winter, due to low temperatures; this scenario is typical whether in semiarid Mediterranean climates (Olea *et al.*, 1990), or in the wetter areas with an annual rainfall of near or well over 1000 mm (Piñeiro and Pérez, 1977). This high rainfall is mainly concentrated in spring, autumn and winter but with a marked summer deficit as in the northern region of Spain (Diaz-Fierros, 1971). Historically this led to the concentration of permanent pastures on the soils with a high water table or with summer irrigation in some of the wetter regions such as Galicia, NW Spain. Also, summer growing forage was traditionally used - maize (*Zea mays* L.), for example- as a whole plant densely sown in some areas and cut at the vegetative stage through the summer to meet animal needs. In some farms the maize was sown with grass and the part of the plant above the cob cut and fed to stock. Later, in the autumn, the grain was harvested and the remaining straw used as a low quality feed to complement the grass from the irrigated permanent pastures. This system fell into disuse because of the economic disbenefits, especially high labour costs, and so modern economically viable grassland farms are based on swards developed mainly on arable lands and on rainfed lands reclaimed from shrublands in the second half of the twentieth century

GRASS SPECIES AND VARIETIES

Early and late season

The good late winter / early spring production of Italian ryegrass (*Lolium multiflorum* Lam.) whether diploid or tetraploid is well documented. This production is particularly notable in the first full harvest year following a sowing in the previous late summer rather than in the previous spring. Most varieties head at the same time as intermediate-heading perennial ryegrass varieties and so an early grazing can be taken before resting the sward for a conservation cut. Italian ryegrass persists for two to three years but with declining production; hence the strategy of including it in seed mixtures with more persistent hybrid ryegrass (*Lolium* x *hybridum* Hausskn) or even perennial ryegrass in order to improve sward longevity. Italian-type hybrids are more productive in late winter-early spring than perennial-type hybrids but form less dense swards, though still denser and more resistant to poaching during grazing than pure-sown Italian swards. Most hybrids developed in the UK are tetraploids.

In the past some grass species and varieties capable of growth at low temperatures did not prove to be cold hardy and so were unsuitable for early season growth. However, plant breeders succeeded in combining those characters, for example, in perennial ryegrass varieties (Wilkins, 1995). In north western Spain, local winter-active ecotypes of perennial ryegrass were used to develop early growing varieties (Piñeiro and Pérez, 1981).

Among perennial species early heading ryegrass varieties exhibit good late winter-early spring production characteristics (Davies *et al.*, 1985; Davies and Morgan, 1988; Brereton and McGilloway, 1999) and within the early heading group - and later heading groups - there are differences among varieties (Wilkins *et al.*, 2000). Where the information is available, on country Recommended Lists for example, the seasonal distribution of production and herbage quality aspects of individual varieties should be studied by farmers in order to identify those with the best early season growth characteristics; these can then be used in special-purpose seed mixtures. Unfortunately, early heading perennial ryegrasses are perceived to be difficult to manage in rotational grazing systems as the later grazed paddocks during the flowering stage tend to have a particularly high content of flowering heads, compared with later heading types at a comparable development stage. This seems to be due to a high proportion of tillers which flower in this heading category and so the leaf content is particularly low and quality falls (O'Donovan, 2001). This can be difficult to overcome and so in many grazing mixtures sown, early heading types tend to be excluded. The range in growth rates among varieties of perennial ryegrass in autumn is narrow, at least among recommended varieties in Ireland (Brereton and McGilloway, 1999; Laidlaw, 2004), and so there appears not to be much opportunity to select a variety for deferring herbage for grazing into early winter.

While tall fescue (*Festuca arundinacea* Schreb.) is also an early growing and winter hardy species (Baker *et al.*, 1965; Frame *et al.*, 1970; Frame, 1972) its slow establishment and coarse leaf characteristics, make it less acceptable to stock than perennial ryegrass, and militate against its use in north-west Europe. Nevertheless its tolerance to heat, drought and to heavy grazing has led to its wide use in southern Europe and the United States of America (Wilkins and Humphreys, 2003). Attempts have been made to hybridise it or other fescue species such as *Festuca gigantea* (L.) Will. with Italian ryegrass to produce early growing productive hybrids; however, there are no commercial varieties as yet - though there are stable tetraploid hybrids between meadow fescue (*Festuca pratensis* Huds.) and perennial ryegrass in central eastern Europe for example (Wilkins and Humphreys, 2003).

Cocksfoot was a constituent of the two main pasture mixtures used in the late fifties to early seventies of the 20th Century in the humid temperate and summer dry Cantabric-Atlantic region of Spain because of its well known adaptation to drought and its high persistency. But despite the evidence that it grows slightly better in summer than perennial ryegrass (Martínez and Piñeiro, 1994), the use of cocksfoot declined from the early seventies onwards due to its low acceptability and digestibility and tufted growth habit. Cocksfoot represented only 2 % of the total seed used to sow pastures in the nineties, being replaced mainly by hybrid and perennial ryegrasses (Piñeiro and González, 2001). Although cocksfoot may confer a benefit of an increase of 50 % in summer yield, this represents only about 0.6 t ha^{-1} DM during July to September and so does not compensate for the above-mentioned disadvantages.

Alfalfa (*Medicago sativa* L.) and red clover (*Trifolium pratense* L.), in this order, are more productive than white clover (*Trifolium repens* L.) in summer (Piñeiro and Pérez, 1984, 1988). White clover summer yield, ranging from 0.8 to 2 t DM ha^{-1}, is very dependent on rainfall during this season, while alfalfa yields are more stable, ranging from 4.5 to 5 t DM ha^{-1}, and red clover yield is intermediate. However, in the Cantabric-Atlantic region of Spain, soils are acidic and the water table high in the deepest soils, features which can limit alfalfa performance. Provided soil acidity is corrected and suitable free-draining soils are chosen alfalfa is an option. Red clover mixed with prairie grass (*Bromus catharticus* Vahl.) had better growth in the summer than when mixed with Italian ryegrass due to the more aggressive behaviour of Italian ryegrass in the establishing phase when red clover could not express its potential (Martínez and Piñeiro, 1996) but alfalfa, sown as monoculture in the same trial, yielded better in the summer than both mixtures.

White clover, as a component of the sward, can also play a role in extending the grazing season in the summer. The yield of pure-sown perennial ryegrass, heavily fertilized with N throughout the season, was slightly lower than that of the ryegrass-white clover mixture without irrigation in wet summers (Martínez and Piñeiro, 1994). In summer-dry regions within the temperate humid area of Spain, when a mixture of perennial ryegrass, cocksfoot and white clover was compared with a mixture of perennial ryegrass and cocksfoot, summer growth under irrigation was clearly higher in the mixture with clover (González, 1990). Similar results were obtained by Besnard *et al.* (1983) when comparing a rainfed monoculture of perennial ryegrass with its association with white clover without irrigation in more northern regions.

Systems based on annual forage crops play a role in intensification with double cropping in Spain increasing production by 139 to 166 % (Lloveras, 1987) compared with long-term sown pastures. This practice is of use in humid areas which suffer a marked annual drought but have good quality soils which enable crops such as maize to be grown for forage without irrigation. Results from a forage crop rotation trial, located in northwestern Spain, which comprised of Westerwold ryegrass (*Lolium multiflorum* Lam. ssp. *westerwoldicum*), for late autumn-winter-early spring green feed and silage in May, and sorghum (*Sorghum bicolor* (L.) Moench) x sudan grass (*Sorghum sudanense* (Piper) Stapf), for summer, showed that they can be a good complement for a mixture of Italian ryegrass with red clover which provides most of the yield in spring, early summer and autumn (Piñeiro and Pérez, 1997). Nevertheless, as happened in a trial sited in the Rhône Valley (France), sorghum x sudan grass was not able to supply enough green forage for the summer gap because regrowths were dependent on the climatic conditions and their use had to be delayed for the forage to reach the aimed development stage (Billot, 1986). Both sorghum trials were conducted under cutting conditions, with an early harvest (plants were at least 50 cm high), to simulate grazing. However, sorghum grew very rapidly after this stage and the high heights reached would probably affect grazing efficiency in practice though showing suitability for zero grazing.

Other examples of annual forage crops available for out-of-season use include forage rye (*Secale cereale* L.), vetches (*Vicia* spp.) forage pea (*Pisum sativum* L.), rape (*Brassica napus* L. ssp. *oleifera*), kale (*Brassica oleracea* L. convar. *acephala* (DC).) and stubble turnip (*Brassica rapa* L. var. *rapa* (L) Thell.). While they can be highly beneficial as complements to the grass crop their selection and subsequent production and utilization will depend on factors such as soil type, climate and farming system (Pollott, 1990; Fraser *et al.*, 2000).

A number of species of trees and leguminous shrubs are being utilized for animal fodder in a range of environments, including Mediterranean and temperate. One notable shrub is tagasaste (*Chamaecytisus proliferus* ssp. *proliferus* var. *palmensis*) which belongs to the taxonomic complex *Chamaecytisus proliferus* (L. fil) Link (*Fabaceae: Genisteae*). Tagasaste can be developed as a tree from which branches are cut or as a shrub maintained as such by a suitable grazing regime (Frame *et al.*, 1998). Noteworthy trees which provide fodder via trimmings include willows (*Salix* spp.) and poplars (*Populus* spp.); their use together with that of tagasaste was recently the subject of a workshop in New Zealand indicating increased interest (Charlton, 2003). Similarly a number of woody plant species, particularly leguminous shrubs such as black locust (*Robinia pseudoacacia* L.) and amorpha (*Amorpha fruticosa* L.) are being researched in Mediterranean regions, the findings of which were reported at a recent symposium in Greece (Dupraz, 1999; Papanastasis, 1999; Talamucci and Pardini, 1999).

NITROGEN FERTILIZER ON SWARDS FOR EXTENDED GRAZING

The nitrogen economy of grass swards is of interest both for production and environmental reasons. Soil mineral N levels are high in autumn and low in early spring and so response to applied N will generally be higher in early spring than late autumn. However due to concern about N leaching from highly fertilized swards and N fertilizer application being restricted to only certain months in the year in NVZs, the usefulness in relying on N fertilizer to ensure sufficient herbage is available for out-of-season use may be limited in some regions. Nevertheless, where there are no restrictions in the application of N fertilizer, it is a useful, and sometimes necessary, means of aiding the production of out-of-season herbage.

Response to N fertilizer applied early and late in the season

Response to N in autumn declines with delay in application (Whitehead, 1995; Binnie *et al.*, 2001). A general response to N applied in autumn to produce herbage for late autumn/early winter utilization specifically is about 12 kg DM kg^{-1} N. (Baker *et al.*, 1961; Skinner and Allen, 1991; Binnie *et al.*, 2001). Response to autumn-applied N declines if herbage is not utilized by early December (Binnie *et al.*, 2001).

Herbage production responses in late winter-early spring are variable on account of different site conditions but a key factor is the date of first utilization following N application. Thus the response and available DM yield is less at very early dates of utilization, for example when turning out stock for a few hours rather than a later day or day plus night grazings when there is a greater sufficiency of herbage. Baker (1961) and Baker *et al.* (1965) emphasized the importance of early season application of N fertilizer. For instance, from N applied in late winter Stevens *et al.* (1989) obtained a mean response of 14.5 kg DM kg^{-1} N (range 6 to 22.4 kg DM kg^{-1} N) from four sites over a 3-year period in Northern Ireland. However only a small response to N was detected in a series of trials in which the fertilizer was applied in very early spring to swards which had been previously grazed (Laidlaw *et al.*, 2000). This lack of response could be attributable to a build-up of soil N emanating from the excretal return during the autumn grazing (Ball and Ryden, 1984), a build-up which would not take place in cut swards.

There is some evidence that residual N from autumn-applied N fertilizer can stimulate sward growth in spring (Corbett, 1957; Baker, 1960; Culleton and Lemaire, 1981) an effect possibly due to increased tiller production during the winter. Conversely tiller density in late winter / early spring decreased with increasing amount of herbage accumulation in late autumn, while herbage quality was adversely affected because of leaf senescence (Laidlaw *et al.*, 2000).

Forecasting time of N application

A number of indicators to predict the optimum time for N fertilizer to be applied in early spring has been suggested. These include when soil temperatures are high enough for grass growth to respond to the N, namely, prolonged soil temperatures of 5-6 °C and above at 10 cm depth (Wilman, 1980) and adequate soil moisture in the rooting zone. Another method based on air temperatures is the T-sum 200 system, which originated in The Netherlands. In this system, maximum and minimum temperatures in °C are recorded daily from 1 January and the daily means are cumulatively summed, though negative values are ignored. The claimed optimum time to apply nitrogen fertilizer to the sward is when the total sum of 'day degrees' reaches 200 (Jagtenberg, 1970; Van Burg *et al.*, 1981).

The system can be implemented from data recorded on farms, in grassland research stations or on sites controlled by official or commercial advisory services. Trials in the UK have shown that 200 °C is not a rigid target and that N application during a period of 10-14 days before and after will give 90 per cent of the optimum production response (Baker, 1986; Harkess and Frame, 1986). This gives some flexibility of management in light of soil and weather conditions. However, from trials in Northern Ireland, neither the T-200 system nor the soil temperature method were more successful at predicting the optimal time for first N application than a date range of 4-5 weeks based on local experience (Stevens *et al.*, 1989).

Work in NW Spain, which has a mild winter climate, showed that the safest date to apply N fertilizer was mid February even though in some years T-sum 200 was reached by late January (González Rodríguez *et al.*, 1996). In the same region, but at an altitude of 650 m, the safest date was mid March, when the T-sum value was well above 200 (Mosquera and González, 1992).

Specialised equipment with low ground pressure tyres is available for situations where early season conditions for grass growth are satisfactory but wet soil conditions preclude the use of standard fertilizer spreading equipment; however, forecast weather conditions for the near future should be favourable.

Type of nitrogen fertilizer

Straight N fertilizer, e.g. ammonium nitrate, is mainly used to stimulate early grass production. Urea N fertilizer has proved a suitable alternative though herbage production response has often been lower than that from ammonium nitrate (Swift *et al.*, 1988a) mainly because of volatilisation of ammonia which is highest in dry conditions and which increases with increasing rate of N application (Ryden *et al.,* 1987; Watson *et al.*, 1990). Nonetheless, in a review of 20 comparisons of urea *versus* calcium ammonium nitrate in spring the relative herbage production from urea was more than 95 per cent in 17 of the comparisons (Watson *et al.*, 1990). On soils with very low P status (0-9 mg P litre^{-1} air dry soil) spring herbage DM was increased by 29 per cent when N fertilizer was supplemented with P fertilizer and a further 23 per cent when the two fertilizers were applied as a compound rather than separately (Swift *et al.*, 1988b); smaller increases in herbage production were obtained on soils with a low P status (10-15 mg P litre^{-1} air dry soil). The advantage of NP over N + P is explained by enhanced P availability since the release of P from low soil reserves is normally slow at low temperatures, grass root extension is encouraged by both the N and the P, and both nutrients reach the root rhizosphere together rather than the N first followed by the slower moving P. Following this research, proprietary NP compound fertilizers were manufactured for the market.

Environmental considerations of N in extended grazing

Nitrogen may be lost from grassland through hydrolysis of ammonium to ammonia, denitrification of nitrate to N_2 and N_2O or leaching of nitrate. Webb *et al.* (2002) cited by Jewkes *et al.* (2003) have calculated that up to 9 % less ammonia may be lost by extending the grazing season by one month as ammonia losses are particularly high when dairy cows are housed. Losses by denitrification would not be expected to be particularly high in the period late autumn to early spring as soil temperatures are generally low. However, if N was applied late in a mild wet autumn and soils were to be waterlogged, high denitrification losses could be expected (Watson *et al.*, 1992). Indeed monitoring soil mineral N concentrations through the profile of soils of swards receiving N fertilizer at various times through autumn suggests that losses are high, only 30 kg N ha^{-1} of 90 kg N ha^{-1} applied in autumn being detected in the top 1 m of soil by mid-November and only 16 kg N ha^{-1} by mid-December (Laidlaw *et al.*, 2000). During this time there had been considerable NO_3^- movement below the rooting zone suggesting that leaching may have been a significant source of loss.

The loss of N via the grazing animal, other than by ammonia volatilization as already mentioned, has been considered. Jewkes *et al.* (2003) did not find any increase in soil mineral N as a result of extended grazing in autumn in four dairy farms in which cows were not housed until November at the earliest. This confirms findings from earlier work which showed no effect on soil mineral N of dairy cows grazing for 2-3 hours per day in strips throughout November (Laidlaw *et al.*, 2000).

These limited studies suggest that out-of-season grazing *per se* may not be a source of major loss of N, but application of N fertilizer to provide herbage for out-of season grazing, especially in autumn, may be a potential problem.

IRRIGATION

Irrigation of grassland is not widespread in northern Europe but may be used in some intensive livestock enterprises where there is a satisfactory water source and economic viability is assured. Irrigation in semi-arid countries increases forage yield 5- to 8-fold, reaching annual yields of 14-16 t DM ha^{-1} (Olea *et al.*, 1990), and was traditionally used in several regions to increase production of different crops, pastures included.

A comparison among different binary grass-legume mixtures with three grasses (perennial ryegrass, cocksfoot and tall fescue) and legumes (white clover and alfalfa in Granada (S Spain), combined with other studies on variety evaluation and on NPK fertilization, under irrigation, demonstrated that tall fescue was the only grass that persisted for three years. The tall fescue/alfalfa mixture was clearly more productive than tall fescue/white clover, while the alfalfa monoculture was even more productive than the tall fescue-alfalfa mixture (Ratera *et al.*, 1977). This explains why most of the irrigated land devoted to forage production based on pluri-annual species in Spanish semi-arid climates is sown on arable land to alfalfa (MAPA, 2003), which is mainly used to make hay or dehydrated and sold mainly to dairy farmers in the wetter regions.

Using the best adapted varieties of Mediterranean type alfalfa, the growing season under irrigation extends from February to November near Sevilla (S Spain) with a maximum of 160 kg DM ha^{-1} day^{-1} in July. Annual yields of about 20 t DM ha^{-1} are achieved from 8-10 cuts $year^{-1}$ with intervals between cuts varying from 50 days in February-April to 21 days in July, the average interval between the last cut in November and the first in February extending for 90 days (Muslera *et al.*, 1975). Measurements made in the more continental and northern region of Aragón (NE Spain) showed that the growth of alfalfa under irrigation lasted from early March to the end of October with a maximum of 90.2 kg DM $ha^{-1}day^{-1}$ in June and an annual yield of 11.5 t DM ha^{-1}. Under rainfed conditions the growth curve was bimodal with two maxima of 42.5 and 15.3 kg ha^{-1} day^{-1} DM on April and October, respectively, and two minima in summer and winter, the annual yield being 4.6 t DM ha^{-1} (Delgado *et al.*, 2004). Although alfalfa was shown to grow successfully without irrigation in good soils in semiarid climates more than 30 years ago (Hidalgo Maynar, 1973), the area cultivated under rainfed conditions did not increase and remained around 30 % of the total area sown to alfalfa. The rainfed alfalfa is concentrated mainly in sub-humid climates although it is grown in some semiarid regions using a native well adapted ecotype, such as the 'Tierra de Campos' ecotype in Central-North Spain (Hidalgo Maynar, 1973). It can be concluded that alfalfa will be productive from spring to autumn with summer irrigation in semiarid regions thus extending the grazing season. Therefore the growing season can extend from February to November in southern Spain and from March to October in the northern continental Spanish regions.

In the Cantabric-Atlantic region with dry summers but high annual rainfall, irrigation can provide growth to fill the summer forage gap. Martínez and Piñeiro (1994) found a five-year annual average increase of 37 % due to irrigation at a coastal site in Asturias (N Spain) with an average annual rainfall of 1000 mm but with a pronounced drought in the summer. The growth curve of the irrigated pastures was higher than the rainfed pastures from May to October but slightly lower in early spring, probably due to the adverse effect of irrigation on plant reserves as previously observed by Meriaux (1971). The curve was the average of the different pastures sown as monocultures in the experiment: grasses (perennial ryegrass, timothy and cocksfoot) or legume (white clover) and of the binary mixture of perennial ryegrass-white clover, with and without N. Irrigation favoured clover persistency in mixed pastures, making them less dependent on fertilizer nitrogen. A high growth response to summer irrigation was also found in the Ulzama Valley (Navarra, Spain) in the east of the Cantabric-Atlantic region, where an annual increase of 5.3 t DM ha^{-1} was achieved on permanent pastures, an increase equivalent to 45 % of the yield of the rainfed pastures treatment (RNSA and ITGV, 1986).

In experiments in the more northern countries of Europe an improvement in summer and annual production from irrigation has been recorded. Corrall (1984) reported a clear increase in summer growth with a 19-year average annual yield increase of 24% in southeast England. Irrigation of pastures is also needed in most years for intensive production from sandy soils in Denmark (Søegaard, 1991). In the Goms Valley, Switzerland, annual yield increases of 13-50%, depending on year and site, were measured on natural pastures in response to irrigation (Troxler *et al.*, 1992). In northern Italy, Parente (1991) measured annual yield increases of 0-20 % and Mansat (1977) stated that, in general, yield of French grasslands is mainly limited due to water availability between late spring and the autumn.

The water is free in Spain in the traditional irrigation areas (Delgado *et al.*, 1999), but nevertheless the farmers have to pay a given sum per ha or per m^3 to cover the maintenance expenses of the reservoirs, channels and administration. The average cost of irrigation per ha ranged from €48 (flood irrigation) to €137 (sprinkler irrigation) in 1991-92 (DAGM, 1993). With these costs and if the response to irrigation is of the order of 7 t DM ha^{-1} as measured by Delgado *et al.* (2004), the practice of irrigation is clearly cost effective. The problem is that it is probably not feasible for the area of irrigated grassland to increase as the necessary investment capital is very high and decision making is difficult due to the social and environmental issues raised. This was the case of the project to irrigate the Ulzama Valley in Navarra despite the fact that the increase in the grass value was estimated at €600 ha^{-1} (RNSA and ITGV, 1986). Also, there is a further conflict between agriculture and other commercial activities that can afford to pay a higher price.

GRAZING MANAGEMENTS

The guidelines for early and late season grazing are similar but some adjustment is needed because of the different patterns of grass growth at these times. In early season, grazing pressure has to be increased in order to utilize the increasing grass growth efficiently. In Ireland and the UK this is done by strip grazing progressively smaller areas for the allocated grazing periods, whether ultra early (2-3 hours daily), whole day and eventually day and night grazing. The use of sward surface height (SSH) is a useful means of controlling grazing pressure. For dairy cows, a target post-grazing height of 5-6 cm is suitable for early season grazing since this level of grazing intensity encourages the subsequent development of densely tillered, leafy swards of high nutritive value. This high quality grass is especially important for summer calving dairy cows and also for the setting up of a grass bank or 'wedge' in early autumn for utilization later. However to budget grass effectively, some estimate of the amount of herbage the cows will eat for the period in which they are in the paddock and the amount of herbage available needs to be known. Available herbage can be calibrated with a rising plate meter. It can be assumed that when cows have access to fresh grass for only part of a day (e.g. 2-3 hours) they will consume up to 1.5 kg DM head^{-1} h^{-1} (Mayne and Laidlaw, 1995).

The following guidelines were drawn up when extended grazing technology was being developed in New Zealand in the late 1980s but is relevant to any dairy farm:

- Use a strip grazing system to match stocking density and available grass.
- Use front and back electric fencing - grazing from back of field in wet conditions.
- Adjust daily grazing periods in line with available grass.
- Provide farm access tracks and several gateways in the grazing area to alleviate any poaching problems.
- Have adequate drinking water available in the fields and in the cowshed.
- Assess ground conditions daily and postpone grazing in excessively wet or stormy conditions.
- Adjust supplementary silage and concentrate feeding.

The simplest way to introduce extended grazing in a temperate region in which the grazing season extends from spring to autumn is to begin planning in August when grass growth is beginning to slow down. Assuming a 24-day rotation has been used up to this point, the rotation length is gradually increased, bringing in second cut silage ground, possibly removing dry stock from the normal grazed ground and gradually reducing the time cows are outside. By October, the rotation length may be as long as 5 weeks extending to 6 or 7 weeks for November-grazed paddocks by which time cows will be fully housed. This leaves paddocks with a range of regrowths from those which were recently grazed in November to those were last grazed in late September. The latter will be the first to be grazed early in the following spring when the rotation is again initiated.

Set stocking or continuous stocking are more prevalent in the UK than New Zealand and so the practice of taking paddocks out of rotation has to be adapted to this system. Bax (1995) has described how the principles can be adapted to continuously stocked grass/white clover swards. Fields (accounting for about 38 % of the grazing area, some after 3rd cut silage and the balance from the summer grazed area) can be shut off from grazing in late August, achieved by tightening up the area allocated to dry cows. The deferred area was strip grazed for 3 hours per day from 1 October to 6 December commencing with 45 cows per 0.2 ha strip gradually declining to 50 cows per 0.25 ha strip. Estimated saving in silage was approximately 4 kg DM head^{-1} d^{-1}.

In subclover (*Trifolium subterraneum* L.) and other annual legume-based pastures of the Dehesa ecosystem (SW Spain) the management recommendation is hard grazing in the winter followed by lenient grazing in the spring to allow the plants to produce seeds in order to maintain and increase, if needed, the bank of legume seeds in the soil. This technique ensures the persistency of the pastures and provides feed for the animals as straw and seeds to be grazed during the summer and autumn (Olea *et al.*, 1990).

In the Cantabric-Atlantic pastures (NW Spain), a system of deferred grazing or stockpiling by saving pastures in spring to be grazed in the summer was tried in an area developed by minimum cultivation in late eighties on shrublands. After several years of good rotational grazing by beef suckler cows first and sheep later, the pastures were lightly grazed in spring in order to save some of the growth to be used through the summer and thus overcome the summer deficit due to drought. The result was a pasture dominated by bent grass (*Agrostis capillaris* L.) with sparse white clover. In 1998 the whole area was topped to remove the dead accumulated material and divided to establish two contrasting grazing regimes: 1) lightly grazed in spring and 2) well grazed in spring to avoid accumulation of herbage. After two years, the average white clover ground cover of the lightly grazed area was 10 % compared with the 24.5 % for the better grazed pastures (Piñeiro *et al.*, 2002a). Lamb growth up to weaning, at the end of June, was similar in both managements (Piñeiro *et al.*, 2002b) but the ewes from the well grazed treatment recovered better because it had a higher clover content through the summer and early autumn.

Several forage species are suitable for stockpiling spring growth for summer utilization by grazing; one example, perhaps more typically used in North America, is the use of birdsfoot trefoil (*Lotus corniculatus* L.) (Collins, 1982).

ANIMAL PERFORMANCE

In trials in Northern Ireland, short-time access by dairy cows to grazing in late October - late November or in late winter / early spring resulted in a bonus of 2.2 litres cow^{-1} d^{-1} and 3.2 kg DM cow^{-1} d^{-1} less silage consumed compared with indoor-fed cows (Table 1).

Grazing at these times also increased milk protein (by 0.17 % units) and butterfat (0.33 % units). A 2.6 litre advantage in milk yield was maintained by cows given access to grazing part of the day in early spring but receiving only 0.8 of the *ad libitum* consumption by other cows which also had access to grazing for the same time (Sayers and Mayne, 2001). Intake of the feed-restricted cows was presumably maintained by more efficient grazing. In addition to savings in silage, concentrates may also be saved by allowing cows access to grass in early season. In Ireland, Dillon and Cross (1994) found a saving of 4 kg concentrate cow^{-1} d^{-1} in addition to less silage being consumed by giving cows access to grazing for up to 6 h d^{-1}. However, these studies were conducted with dairy cows on moderate planes of nutrition and producing modest yields. When conducted with dairy cows of high genetic merit on high planes of nutrition, access to pasture for short periods had no significant effect on milk yield or quality although silage intake was reduced (Ferris *et al.*, 2001).

TABLE 1

Effects of a short period of grazing per day in early winter or late winter/early spring on silage intake and milk yield and quality (Mayne and Laidlaw, 1995).

Efecto de un corto período diario de pastoreo al final del invierno/principio de la primavera sobre el consumo de forraje ensilado y la producción y calidad de la leche.

	Access to grazing in:			
	Late Oct to Late Nov.		Late Feb. to Mid Mar.	
Grazing h day^{-1}	0	3	0	2.5
Silage intake (kg DM d^{-1})	10.9	6.8	10.9	8.3
Concentrates fed (kg d^{-1})	4.0	4.0	4.0	4.0
Milk yield (litres d^{-1})	17.7	19.9	18.4	20.6
Butterfat (%)	4.15	4.29	3.99	4.40
Protein (%)	3.18	3.37	2.75	2.89

Higher total DM intake, higher ME content of grass than silage and improved rumen function may contribute to improvements in performance of cows which have access to out-of-season grazing, particularly in late winter / early spring . However, the influence of weather has also to be taken into account in these studies as cold wet conditions are a disincentive to animals grazing and may be a factor in the variable response of cows to out-of-season grazing.

In a beef production experiment conducted at Mabegondo (NW Spain) on alfalfa pastures, grazed by young bulls of 300 kg liveweight in spring and of 160 kg in summer, the grazing season lasted from April to October (Laranjo *et al.*, 1993), although daily alfalfa growth decreased steadily from June to October. Contrastingly, in conventional pastures of perennial ryegrass, cocksfoot and white clover the animals had to be withdrawn from the second half of July to the second half of October in the same farm, due to drought (Zea and Díaz, 1979; Zea *et al.*, 1980).

CONCLUSIONS

Governments of EU countries are responding to official policies, legislation and subsidies. Increasingly these are based on de-intensification, environmentally friendly production systems, accredited food products (as 'natural' as possible), landscape enhancement and nature conservation. Nevertheless, production *per se* is at the heart of agricultural systems and to be sustainable overall, economic viability necessitates an internationally competitive cutting edge. In the battle for efficiency there has to be strong containment of production costs and in the face of the different pressures above, swift yet sensible and flexible responses and adaptations require to be made by grassland farmers.

Grazing has long been accepted as the cheapest method of utilizing the forage resource yet more expensive technology involving forage conservation and attendant indoor feeding has often been adopted at the expense of shortening the grazing season. However, in recent years there has been a resurgence of interest, experimental work and uptake by farmers of the concept of maximizing the grazing of forages. In particular, this has involved extending the grazing season at both the beginning and end of the normally used period and additionally in summer dry regions by grazing irrigated pastures (where viable) and specially grown annual forages. Strategies available, which are discussed above in this review, include choosing suitable forage species, judicious application of nitrogen fertilizer, forage budgeting, irrigation, deferred grazing of accumulated herbage, e.g. the grass 'wedge', and efficient grazing systems. Experimental work has proven the case for the various strategies in a range of environments. The challenge to the farmer lies in the attainment of year-round integration on-farm of selected practices for his circumstances in order to achieve the maximum use of grazed forages, for which a key element is effective forward planning.

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AMPLIANDO LA ESTACIÓN DE PASTOREO

RESUMEN

Se acepta que la hierba de alta calidad aprovechada en pastoreo es el recurso más barato para la alimentación de rumiantes. Por tanto, maximizar su uso ayudaría a mejorar la viabilidad económica de los sistemas basados en pastos, objetivo de creciente interés, dada la alta competitividad del mercado. En este artículo se revisan estrategias de producción y utilización de pastos, algunas desarrolladas en el pasado y otras en épocas recientes. La elección de las especies más adecuadas para cada situación concreta es el

elemento clave, existiendo una amplia gama que va desde forrajes anuales a especies perennes de gramíneas y leguminosas. El momento de aplicar los fertilizantes, especialmente nitrógeno, es otra estrategia de gran importancia para disponer de pasto al principio o al final de la temporada de crecimiento. El riego es una opción en regiones de clima semiárido siempre que el agua esté disponible y sea barata. En tales regiones no deben olvidarse las plantas resistentes a la sequía, incluidos los árboles y arbustos forrajeros que pueden aprovecharse pastoreo. La acumulación de hierba por retraso en su utilización (pastos diferidos, pastos reservados) puede proporcionar pasto tanto en la época seca del verano como en el otoño. Para una utilización eficiente del pasto reservado, las técnicas pueden variar desde cortos intervalos de pastoreo hasta pastoreos a tiempo completo, y los modos de pastoreo desde el pastoreo en franjas hasta el pastoreo continuo, usando la altura óptima de la superficie del pasto como guía para controlar la intensidad del aprovechamiento. Las distintas estrategias para ampliar la estación de pastoreo y mejorar la producción animal en diferentes ambientes se han probado experimentalmente. El reto para las explotaciones es conseguir integrar las distintas prácticas de manejo a lo largo del año, y lograr que resulten adecuadas para el ambiente específico de las explotación

Palabras clave: Especies forrajeras, fertilizante nitrogenado, maximización del pastoreo, estrategias de manejo, producción animal.