FACTORS INFLUENCING PASTURE PRODUCTIVITY IN ATLANTIC CANADA

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ABSTRACT

Most pastures in Atlantic Canada are classified as permanent and contain primarily native species. Well-managed native swards have the potential of supporting profitable animal output. Productive cultivars of cool-season perennial grass species such as timothy (*Phleum pratense* L.), orchardgrass (*Dactylis glomerata* L.), tall fescue (*Festuca arundinacea* Schreb.), reed canarygrass (*Phalaris arundinacea* L.) and legumes such as white clover can increase pasture productivity in the region and ameliorate seasonal fluctuations in dry matter yield associated with native swards. Improved swards gradually revert to native species, partly because forage cultivars and mixtures are not assessed for persistence under grazing.

Soil acidity and deficiencies in soil nutrients were shown to reduce herbage yield, legume content of the grazed swards and mineral content of the herbage, all of which may adversely affect livestock performance. High concentrations of K, observed in swards heavily fertilized with N, are likely to cause problems in the metabolism of Ca and Mg in lactating ruminant livestock grazing such swards.

Supplemental pasture crops, including annual ryegrass (*Lolium multiflorum* Lam.) and *Brassica* species, extend the productive grazing season from approximately 4-7 mo, and permit the production of large quantities of biomass close to the barn.

Rotational grazing and forward creep-grazing techniques at high stocking rates can improve the number of animal grazing days and average daily gains. Previous experience with grazing and exposure to pasture species before and during weaning appear to influence grazing behaviour and species preference of newly weaned livestock. The use of previous grazing experience may help create the desired pasture sward or improve the efficiency of sward utilization by the grazing animal.

The high rainfall climate of the Atlantic region, which promotes good herbage production, also encourages heavy and prolonged infestations of infective free-living stages of gastrointestinal parasites on pastures. Permanent pasture is the main source of initial herd infection, which then spreads to newly seeded pastures. Strategic treatments of grazing livestock with anthelmintic drugs are recommended to minimize the impact of these parasites on the productivity of grazing livestock in this region.

Key words: Pasture, Atlantic Canada, productivity, grazing management, fertility management, *Brassica* spp., grasses, legumes
INTRODUCTION

The productivity of most pastures in Atlantic Canada is limited by soil fertility and management of forage and grazing livestock. Understanding the role of each factor affecting pasture productivity offers considerable opportunity for improving the profitability of livestock production. The present paper summarizes available research data on factors influencing pasture productivity in Atlantic Canada.

SOIL AGRICULTURAL CAPABILITY

Pasture is probably the most important advantage of ruminant livestock enterprises in Atlantic Canada. Approximately 80,000 ha are currently utilized as pastures (Table 1). Much of the pasture area utilizes land unsuitable for other crops; soils ranked as class 3 or lower agricultural capability. In addition to the general cropping constraints in the Atlantic region, a short growing season and low natural soil fertility, pasture lands are subject to a number of other limitations which depress their productivity and increase production cost (Nowland 1975). These include one or more of the following: undesirable soil structure and/or low permeability, excessive stoniness, excess water, steep topography, low moisture holding capacity, bedrock near the surface, and flooding.

CLIMATE AND WEATHER

Despite soil limitations, pasture production in the Atlantic region has two natural advantages for the production of forage crops; namely, a well distributed high rainfall pattern and moderate temperatures throughout the growing season. The growing season can range in length from 100-200 d and is characterized by the prevalence of moderate temperatures providing near optimal growing conditions for cool season grasses and forage legumes. The warmest average temperature during the growing season occurs during the month of July and ranges from 11-19EC, and the highest extreme July temperature ranges from 25-35EC (Dzikowski et al. 1984). In general, agricultural areas in Atlantic Canada do not experience temperatures high enough to interfere with good pasture species growth. Annual total precipitation ranges from 760-1500 mm with 400-500 mm of precipitation distributed evenly throughout the growing season (Dzikowski et al. 1984).

TYPES OF PASTURES AND SWARD COMPOSITION

Permanent Pastures

Most pastures in Atlantic Canada are classified as permanent and include unimproved native swards (grass and legume species introduced by early settlers) not included in a regular crop rotation sequence, or unploughed hayland which has been invaded by native species (Roland and Smith 1969; Kunelius and Narasimhalu 1993). Bluegrass (Poa spp.), bentgrass (Agrostis spp.), red fescue (Festuca rubra L.), quackgrass (Elytrigia repens (L.) Nevski) and white clover (Trifolium repens L.) are the predominant species in these pastures. The productivity of permanent pasture is often limited by: 1) its soil agricultural capability, and 2) previous and current management. Permanent pastures with poor soil structure (shallow soils or imperfect drainage) result in very variable herbage production (Bélanger and Winch 1985). Native and naturalized plant species adapted to such soils become semi-dormant in mid-summer (July and August) resulting in severe shortage of forage and poor animal performance (Calder 1970; Kunelius and Dickson 1989). Properly managed permanent pastures with few soil limitations are capable of producing acceptable animal output (Table 2). Work in PEI and NS on rotationally...
grazed permanent pastures indicated that a reasonable target for herbage and animal production was 16 t DM ha$^{-1}$ and 700 kg ha$^{-1}$ live weight gains respectively with application of 50 kg N ha$^{-1}$ (Winter and Black 1975; Neary 1991; Kunelius and Narasimhalu 1993).

5 Sown Pastures

Sown pastures, lands seeded for pasture use, are becoming more prominent in the Atlantic region (Calder and Nicholson 1970; Bosveld 1990a,b; Cummings 1992; Thomas 1990a). Despite the fact that timothy (*Phleum pratense* L.) is not considered a pasture species, it is a commonly used component in pasture mixtures because it is the most winterhardy species (Thomas 1991; Kunelius and Narasimhalu 1993). However, rotationally grazed timothy-based swards were shown to be very productive (Rodd et al. 1992). Tall fescue (*Festuca arundinacea* Schreb), meadow fescue (*Festuca pratensis* Huds.), and reed canarygrass (*Phalaris arundinacea* L.) are hardy and suitable for pasture use (Winter and Black 1975; Laflamme and Papadopoulos 1987; Kunelius and Narasimhalu 1993). Orchardgrass (*Dactylis glomerata* L.) is a productive pasture species and commonly used in pasture mixtures even though it suffers substantial winter injury some years (Suzuki 1989; Thomas 1991a; Papadopoulos et al. 1993b). The identification of white clover cultivars adapted to climatic conditions in Atlantic Canada will increase the utilization of this species in seed mixtures for new pastures (Fraser 1988; Kunelius and Narasimhalu 1993). Perennial ryegrass (*Lolium perenne* L.) is included in some commercial mixtures but the current cultivars are highly susceptible to winter injury in the Atlantic region (Thomas 1991; Rodd et al. 1992). Alfalfa (*Medicago sativa* L.) cultivars adapted to this region do not withstand grazing (Rodd et al. 1992). Other species such as bromegrass (*Bromus inermis* Lyss.) and birdsfoot trefoil (*Lotus corniculatus* L.) are adapted to climatic conditions in the Atlantic region and are known to be valuable species for pasture use, but are not normally used for establishing or renovating new pastures.

Annual forage species such as Italian ryegrass (*Lolium multiflorum* Lam.), kale (*Brassica oleracea* L.), rape (*Brassica napus* L.) and stubble turnips (*Brassica rapa* L.) are recommended for mid- to late-season pastures to supplement permanent pastures (Burgess and Kunelius 1986; Winter 1987).

Newly established pastures seeded to productive forage species are capable of producing up to 10 t DM ha$^{-1}$ (Papadopoulos et al. 1993a) and over 1000 kg ha$^{-1}$ live weight over a 3-yr period (Kunelius and Narasimhalu 1993; Papadopoulos et al. 1993b). However, newly seeded swards gradually revert to unsown native species (Table 3), and consequently may not sustain a level of improved productivity necessary to recoup the increased input cost (Kunelius and Narasimhalu 1993; Rodd et al. 1992). Kunelius and Narasimhalu (1993) concluded that unless newer varieties of improved species are developed or identified to persist under grazing pressure in Atlantic Canada, properly managed natural swards are the most profitable for beef production in Atlantic Canada.
AGRONOMIC FACTORS AFFECTING PRODUCTIVITY

Soil Fertility
The growth of unamended permanent pasture or permanent hayland swards is extremely slow and results in poor herbage seasonal distribution and low quality herbage yield because of soil acidity and lack of available nutrients, particularly N, P and K (Tables 4 and 5). These limiting effects can be ameliorated by surface application of lime and fertilizers. The response to surface application of lime, N, P and K is long-term in nature (MacLeod et al. 1960, 1965). Nonetheless, the application of lime above (4.5 t ha\(^{-1}\)) can eventually result in the elimination of soil acidity but has no impact on DM yield (MacLeod et al. 1960). A significant increase in DM yield occurred when either P or K was applied, but the response to P alone was greater than K alone, and when P and K were applied together higher DM yield was obtained than with either of the two nutrients alone (MacLeod et al. 1965).

Response to fertilizer N, additional to other fertilizer, was shown to be dependent on sward composition. Calder and Nicholson (1970) in their study showed that N fertilization resulted in 3% DM yield increase when applied to legume swards, 16% DM yield increase when applied to grass/legume sward and 59% DM yield increase when applied to grass swards (Table 6). Grass/legume swards without any N fertilizer produced 90% of DM of grass swards fertilized with 140 kg N ha\(^{-1}\) (Calder and Nicholson 1970). Papadopoulos et al. (1993b) demonstrated that an equitable orchardgrass/white clover (O/W; each species represents 50% of botanical composition) sward without N fertilizer produced 20% less DM than orchardgrass swards plus 160 kg N ha\(^{-1}\) (O+N), but O/W swards produced higher lamb live weight gains per ha (Fig. 1). Orchardgrass/white clover swards produced herbage containing less ADF or NDF and higher CP than that of orchardgrass plus N fertilizer (Papadopoulos et al. 1993b).

Timing of application and amount of N fertilizer were examined on permanent pastures. Black (1978) concluded that neither irrigation (during dry periods) nor N fertilization can eliminate the characteristic mid-summer decline in yield of permanent pasture swards, although total DM yield increased in response to N fertilizer application (MacLeod et al. 1965; Black 1978). Total DM yield was not affected whether N was applied in spring or summer (MacLeod et al. 1965) or split into four applications throughout the season (Black 1978), but the herbage distribution over the growing season was enhanced with strategic applications of N (MacLeod et al. 1965; Black 1978). Black (1978) concluded that the application of N at a rate of 63 kg ha\(^{-1}\) early in the spring followed by 94 kg ha\(^{-1}\) in mid-June, 94 kg ha\(^{-1}\) in early August and 63 kg ha\(^{-1}\) in September was the most effective strategy for applying high levels of N fertilizer to permanent pastures when compared to six other strategies with rates ranging from 0-280 kg/ha.

Choice of Plant Species and Varieties
Numerous investigations on different soil types in the Atlantic region demonstrated that the productivity of native pasture species is relatively low and up to 70% of their annual yield occurs before mid-July (Calder 1970; Kunelius and Dickson 1989).

Studies assessing newly developed Kentucky bluegrass varieties, the main species found in native pastures, failed to identify cultivars with improved DM yield and DM yield distribution (Calder 1983). Adapted forage species such as orchardgrass, meadow fescue, tall fescue, fescue x ryegrass hybrids, reed canarygrass, perennial ryegrass, timothy, alfalfa, birdsfoot trefoil and white clover were shown to have the potential of ameliorating seasonal fluctuations in DM yield (reduced
DM production in mid-summer and early fall) associated with native swards (Calder et al. 1970; Fraser et al. 1993; Kunelius and Narasimhalu 1993; Papadopoulos et al. 1993b; Rodd et al. 1992). However, as previously discussed, currently available cultivars lack the needed persistence (tolerance to intensive pasture management systems and harsh winter conditions) and this consequently prevents the successful utilization of such species in the region (Kunelius and Narasimhalu 1993; Papadopoulos et al. 1993a; Rodd et al. 1992).

Traditionally the performance of grass and legume varieties has not been assessed for compatibility in mixtures and under pasture management (Papadopoulos et al. 1993b). Forage cultivars are developed and recommended on the basis of DM production under clipping management regimes. Recent studies have demonstrated that clipping management does not accurately reflect sward performance (DM yield, herbage quality and animal output) under grazing (Calder et al. 1970; Papadopoulos et al. 1993a; Rodd et al. 1992). Grazing trials in combination with clipping management have been proposed for identifying superior pasture or dual purpose (conserved feed and pasture) cultivars. The feasibility and the effectiveness of such research needs to be determined.

Mixtures

It has long been established that livestock performance improves significantly when pasture swards contain a legume component (Calder and Nicholson 1970; Calder et al. 1970; Papadopoulos et al. 1993b). White clover is a widely adapted perennial forage legume and interest in this species has increased in the Atlantic Provinces with the availability of adapted cultivars (Fraser 1988; Kunelius and Narasimhalu 1993). Papadopoulos et al. (1993b) examined the benefit of including white clover in pasture mixtures. In this study, the contribution of white clover to lamb production in Atlantic Canada was assessed by comparing the relative DM yield, yield distribution, herbage quality, gain and carcass quality of lambs grazing grass monocrop (orchardgrass) fertilized with 160 kg N ha⁻¹ (O+N) and an equitable grass/legume mixture (orchardgrass/white clover) without N fertilization (O/W). Despite the fact that the grass/legume sward yielded approximately 2 t ha⁻¹ less DM than grass monocrop, it supported higher average lamb gain; 960 vs. 819 kg ha⁻¹ for grass/legume and grass monocrop, respectively (Fig. 1). The O/W swards had slightly less stocking rates early in the grazing season than the O+N swards, but animals grazing O/W throughout the growing season had higher average daily gains as well as higher total gain ha⁻¹ than O+N swards. Lamb carcass quality at the end of the growing season was also improved by incorporating white clover in the mixture (Papadopoulos et al. 1993b). Based on a 3-yr average, 93% of the lambs from the grass/legume swards were rated as grade A, while 83% of lambs raised on grass monocrop were assessed as grade A at slaughter. Forage quality assessment showed that grass/legume swards had higher crude protein (CP), lower nitrate (NO₃⁻), and lower fiber content (ADF and NDF) than grass swards; average CP, NO₃⁻, ADF and NDF values for O/W swards were 22.1, 0, 26.4 and 43.2%, respectively, while for the O+N swards the values were 20.2, 0.7, 29.5 and 59.1%, respectively.

Extending The Grazing Season

In Atlantic Canada, perennial forage growth normally starts in early May with peak DM yield occurring in June, followed by a steady decline and low DM production in mid-July and early August. A small increase in pasture growth begins in mid-August, producing a relatively small DM yield peak before cessation of growth in early October (Kunelius and Narasimhalu 1993;
Due to this characteristic pattern of forage growth, ruminant livestock producers in this region require stored forages up to 8 mo of the year. Nicholson (1984) demonstrated that the cost of feeding stored feed to growing steers was two times greater than that of using pasture in NB. Harvesting, storage, and labour costs accounted for the difference. Research studies and farm trials have shown that annual forages such as annual ryegrass, kale, rape, stubble turnips and even fodder beets (*Beta vulgaris* L.) can be used successfully to supplement perennial pastures during the declining production period of mid-summer (Kunelius and Coulson 1983; Kunelius 1984; Goit 1986; Kunelius and Sanderson 1990), and extend the length of effective pasturing in Atlantic Canada by at least 2 mo into fall. Winter and Kunelius (1987) investigated two cropping options in an attempt to extend the pasture season for growing and finishing Holstein steers. They compared animal performance on a permanent pasture supplemented with Italian ryegrass and fodder beets vs. performance on a permanent pasture supplemented with Italian ryegrass and kale. Animals gained well throughout four grazing seasons, 1984-1987, in which grazing was successfully extended into mid-December. Average daily gains ranged from 0.54-1.0 kg steer\(^{-1}\). Poorer average growth rates obtained during two of the four grazing seasons (1985 and 1986) were attributed to restricted kale and fodder beet intake. Improved growth rates were obtained in 1987 when daily allotment of these crops was increased to 1.5% of live weight from early October to mid-November and to 1.2% for the remainder of the grazing season. In the same study, Winter and Kunelius noted that care in management must be exercised to obtain high rates of gain. The timing and gradual access by steers to the supplementary annual pastures were found to be the most important factors responsible for the maintenance of high daily gain (Fig. 2). Despite the fact that these animals achieved high daily gains once provided access to supplementary annual pastures, they could not achieve desired finished weights on pasture alone and required an additional 6 wk on a high-grain ration to achieve desired finish. On-farm trials between 1984 and 1986 demonstrated that such cropping options are effective in reducing the cost of beef, dairy and sheep production (Goit 1985a,b and 1986). The results of the above trials were used to develop a guide to an extended season (7 mo) pasture system for Nova Scotia (Thomas and Goit 1987). Numerous experiments evaluating annual forage cultivars reported DM herbage yields ranging from 3-13 t ha\(^{-1}\) (Kunelius and Coulson 1982,1983). Yields varied depending on seeding date, grazing frequency and prevailing growing conditions during the seeding year. Peak production of high quality herbage occurred in mid-summer or early fall when perennial pastures declined in productivity (Burgess and Kunelius 1984; Nicholson et al. 1984; Kunelius et al. 1987; Kunelius and Sanderson 1990).

**Pasture Renovation**

Renovation of pastures has received limited attention in the Atlantic region; some research and on-farm studies conducted in PEI. Reduced tillage techniques such as sod-seeding were shown to be effective in establishing timothy, orchardgrass, tall fescue and white clover (Kunelius and Campbell 1984). Sod-seeding of alfalfa and trefoil had erratic establishment (Kunelius et al. 1982; Kunelius 41 and Campbell 1984).

**PLANT/ANIMAL FACTORS AFFECTING PRODUCTIVITY**
Grazing systems are management plans utilized by livestock producers to coordinate plant and animal growth and productivity during the pasture season (PS). The time interval allowed between grazing periods and sward height at the end of grazing is the primary factor distinguishing the various gazing systems. Grazing systems currently utilized in Atlantic Canada can be divided into two major types: continuous and intermittent.

In the continuous grazing system livestock are allowed unrestricted access to all pasture fields for a long period of time (greater than 2 wk and up to the entire growing season). The majority of pastures in Atlantic Canada are grazed continuously for the entire pasture season. These pastures are usually poorly managed, overgrazed and receive little or no fertilizer which results in sparse regrowth, weedy swards and low nutritive value herbage. In comparison with rotational grazing, well-managed continuous grazing on permanent pasture produced approximately 30% less beef calf gain ha⁻¹ PS⁻¹ (Neary 1991), and 11-17% less Holstein steer gain ha⁻¹ PS⁻¹ (Kunelius et al. 1989). Reduced animal productivity was associated with low DM production between mid-July and early October and poor persistence of improved forage species, particularly legumes in successive years (Calder 1970; Kunelius and Dickson 1989).

Intermittent grazing systems include management plans where livestock are moved between pastures or restricted segments of the field (strip grazing) to facilitate periods of undisturbed regrowth. Periods of grazing on each pasture or segment of these grazing systems ranges from 2 d to 1 wk. Over the last 10 yr, various forms of intermittent grazing have provided the major source of roughage on many livestock farms in the Atlantic region. In addition to improved animal performance (relative to continuous) these systems were found to improve pasture utilization by allowing the growth and maintenance of productive forage species in permanent and established pastures (Calder 1970; Kunelius and Dickson 1989). Compared with conventional grazing over a 2-yr experiment, researchers at the Charlottetown Research Station of Agriculture Canada concluded that both rotational and daily strip intermittent grazing systems produced excellent livestock gain while permitting the harvest of forage in excess of herd requirements; 2.2 and 1.2 t ha⁻¹ of excess forage production was recorded for each system respectively (Winter 1985; Winter and Kunelius 1986).

Rotational grazing can be modified to support two or more animal groups with varying nutritional requirements. Examples of such modifications utilized in the Atlantic region include forward grazing and creep grazing. Theoretically, in such systems, livestock that require and respond to high nutrition (high producing dairy cattle and growing lambs in a ewe-lamb flock) have first access to the best quality forage. Calder et al. (1962) concluded that under low stocking rates lambs raised on a creep graze and creep concentrate pasture system reached market weight sooner than those raised on creep-grazed or rotationally grazed pasture, but differences in total seasonal lamb or ewe gain were not significant among the three systems. At high stocking rates creep grazing resulted in superior lamb performance than ordinary rotational grazing but the combined values of lamb-ewe daily gains, carrying capacity and total seasonal gains per ha appeared to be identical for both systems. They also confirmed in their study that continuous grazing is inferior to the other rotational grazing systems evaluated under high stocking rates and creep grazing is an effective management tool to reduce internal parasite buildup in growing lambs.

Effects of Grazing on Animal Health

Parasites. Smith and Calder (1972) observed that irrigation of pastures (used to generate wet...
conditions to enhance the survival and dispersal of parasites) did not consistently increase the parasitism by *Ostertagia ostertagia* and *Cooperia oncophora* in grazing steers under Maritime conditions in a "put and take" grazing management system. Untreated steers were more heavily infected with parasites and gained significantly less (0.55 kg less daily) than those treated with an anthelmintic. Development of clinical symptoms of parasitism developed rapidly (4-6 wk) in untreated steers after turnout to pasture, indicating the important effect of residual contamination of pastures in the Maritimes. The build-up of infections in all permanent pastures, despite relatively low numbers of eggs shed by the treated animals, indicated that fencing and use of anthelmintics may not be effective in preventing parasitic infection of pastures in Atlantic Canada.

**Herbage quality.** Fertility management of pasture swards improves their productivity (Calder and Nicholson 1970), but N fertilization increases the concentrations of soluble N, and K in herbage, which may have deleterious effects on animal health and productivity. Swards fertilized with N resulted in reduced feed efficiency (increased F:G ratio) (Table 6). The nitrate concentration of pasture herbage is also elevated after N fertilizer is applied, and it is generally higher in grass than in mixed swards (Papadopoulos et al. 1993b). High intake of soluble N elevates concentrations of serum urea which is a risk factor for reproductive failure (Ferguson et al. 1988). Nitrogen fertilization has been shown to increase the concentration of K and reduce that of Mg in herbage (Mayland and Wilkinson 1989), increasing the risk of hypomagnesemia (Fontenot et al. 1989). The hypomagnesemia and high intake of K may also affect Ca metabolism in a way that could precipitate parturient hypocalcemia (Fredeen 1992). Although the extent of hypomagnesemia or parturient hypocalcemia caused by a high concentration of K in pasture herbage in Atlantic Canada is unknown, it is presumed to be a major cause (Beede 1992).

**Toxic Elements.** Fodder brassicas including kale, stubble turnip and rape, are recommended to extend the grazing season into the fall (Kunelius and Sanderson 1990). Brassicas contain glucosinolates, which depress the synthesis of thyroid hormones. Hypothyroidism may occur in livestock and their fetuses grazing brassicas, especially where I intake is marginal, and this may result in retained placenta, infertility and abortion (Wilson 1975). Hemolytic anemia and hemoglobinuria have also been reported in livestock grazing brassicas (Clegg 1963). Feeding cows brassicas in late gestation has been associated with higher perinatal calf mortality in France (Barnouin et al. 1992). Hepatic dysfunction is prevalent in cows fed fresh rape, suggesting that fetal liver may also be damaged when the dam consumes brassicas (Barnouin and Paccard 1988). Consequently, supplementation with trace-mineral salt and strip-grazing brassicas, allowing animals access to other roughages, are recommended where brassica pastures are used.

Estrogenic compounds including coumestrol (leaves) and isoflavones (stems) found in clovers (Price and Fenwick 1985), and whose concentrations are correlated positively with that of crude protein (Kallela et al. 1987), cause concern about reduced reproductive performance of breeding females grazing it. Clovers are also associated with a greater risk of pasture bloat, consequently, grass/clover mixtures are preferred.

**Animal Factors Affecting Productivity**

**Nutritional Supplementation**

Ryegrass has been associated with a deficiency in effective fiber, resulting in a high rate of digesta
passage. Supplemental fiber is recommended to reduce digesta passage rate and alleviate milk fat
depression in dairy cows.

The crude protein in pastures (ryegrass more than clover) can be high in soluble and
degradable fractions, resulting in a need to supplement grazing ruminants, that are highly productive,
with a source of undegradable intake protein (Beever et al. 1986).

The mineral composition of orchardgrass swards was examined after rapidly growing lambs
grazing them experienced some mineral-deficiency symptoms in a previous growing season. The
effects of orchardgrass cultivar and of including white clover in the sward were examined (Fredeen
et al. 1993). No differences were observed among cultivars of orchardgrass and results indicated
that animals grazing orchardgrass swards require supplements of Ca and trace elements, particularly
Cu. Orchardgrass swards contained dangerously high levels of K (in excess of 3.5%, DM basis).
Adding white clover to the sward improved its Ca content and lowered the K concentration. The
K:(Ca+Mg) ratio averaged 6.24 in orchardgrass and 4.15 in the orchardgrass-white clover swards.
A ratio of 2.2 is generally considered a safe upper limit to reduce the risk of hypomagnesemia in
grazing animals (Grunes and Welch 1989).

Nicholson (1980) observed that the rate of gain during the winter feeding program and body
condition at turnout to pasture in spring influenced the performance of beef steers on pasture. Steers
lose 5-15% of body weight initially, due to approximately equal losses in gut fill and carcass
content. Supplementation of grazing steers with K did not prevent the weight loss that occurred, and
that was particularly severe in heavy steers that gained faster in the feedlot during the previous
winter. Consequently, it is not economical to pasture heavy steers. Presumably they require
supplementary energy and/or protein in combination with good pasture management. In
comparison, lighter Holstein steers are capable of gaining more than 1 kg daily over the grazing
season when pastures are grazed intermittently.

**Behaviour**

Initial acceptance of pasture and species preference while grazing a mixed sward can be influenced
by previous grazing experience. Ramos and Tennessen (1991) showed that lambs introduced to
pasture with their dams before weaning spent significantly more time grazing after weaning than
those who were not previously introduced to pasture, and that lambs introduced to either white
clover or ryegrass pasture before or during weaning preferred that species over the other after
weaning. The extent to which previous exposure to pasture can be used as a management tool to
control pasture weeds or improve the initial acceptance of pasture under practical conditions is not
known. In a comparison of 11 pasture mixes over 2 yr, Thomas (1989a and 1990a) observed that
sheep preferred swards containing timothy or white clover as the principal species, even though
orchardgrass swards yielded more.

Animal preference for various plant species can influence the short-term and long-term
species composition and productivity of the swards. Sheep are more selective and graze more
closely than cattle (Calder 1970). Calder (1970) demonstrated clearly that the impact of grazing
behaviour on sward dynamics is unique for cattle and sheep on rotational or continuously grazed
systems. Based on the above results, the use of previous grazing experience and the different classes
of livestock may prove to be effective management tools to create the desired pasture sward or
improve the efficiency of sward utilization by the grazing animal.
CURRENT AND FUTURE RESEARCH NEEDS

Pasture productivity in Atlantic Canada can be maximized through careful consideration of the factors discussed in this review. However, the benefits can only be realized when each becomes a component of a delicately balanced and dynamic management system. Further studies should be attempted with commercial livestock operations to assess the combined effects of these factors in maximizing the economic and environmental benefits of grazed swards in the region.

Improvements in persistence of productive forage species is required to insure the economical viability of pasture renovation efforts. Research emphasis should be placed on identifying and/or developing locally adapted varieties which can persist under grazing as well as possess superior seedling vigour characteristics to facilitate successful establishment when frost or sod-seeded. Additional research efforts should be channelled: 1) to resolve current limitation of weed control in grass/legume pasture swards, and 2) to develop management recommendations for general purpose, multi-species swards, as well as precise formulation of seed mixtures for such swards.

As discussed previously, recent research findings in the Atlantic region identified problems when following current fertility recommendations for forage crops. Research is needed to investigate alternative fertility management practices that have the potential to supply the requirements of pasture swards while avoiding nutrient imbalances which have been shown to result in poor animal performance.

Pasture provides an ecological and economic advantage to animal agriculture in Atlantic Canada. Continued research effort must be directed towards pasture systems appropriate for the region. Pastures have been deemphasized by nutritionists in much of the dairy industry with year-round feeding of stored forages. However, permanent pasture may be more profitable, and provide a repository for animal manures. Research is needed in the areas of nutritional management of grazing dairy cows, and in the use and management of supplemental and permanent pasture in Atlantic Canada. Animal breeds have not been selected for grazing efficiency in Atlantic Canada, although selection within and among breeds could improve grazing efficiency (Kronberg et al. 1986).

Retailers currently obtain quantities of beef and lamb from outside the region that could be produced locally. A current constraint in the beef industry of Atlantic Canada is that of yellow fat in carcasses of pasture-finished beef. Studies are currently underway at the Nappan Experimental Farm of Agriculture Canada and the N.S.A.C. evaluating this constraint. Finishing beef on pasture is possible in Atlantic Canada, but to become an economic reality, further research in the areas of product marketing and feeding management using locally generated feeds is needed.

Use of extensive sheep grazing systems is often hampered by coyote predation. Development of appropriate protection mechanisms are evolving.

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<table>
<thead>
<tr>
<th></th>
<th>NS</th>
<th>PEI</th>
<th>NB</th>
<th>NF</th>
<th>Atlantic Provinces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thousand hectares</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total land</td>
<td>5,284</td>
<td>566</td>
<td>7,157</td>
<td>37,164</td>
<td>50,171</td>
</tr>
<tr>
<td>Cropped land</td>
<td>106</td>
<td>154</td>
<td>122</td>
<td>6</td>
<td>388</td>
</tr>
<tr>
<td>Pasture land</td>
<td>31</td>
<td>19</td>
<td>25</td>
<td>5</td>
<td>80</td>
</tr>
</tbody>
</table>

3z Adapted from Statistics Canada (1991).
Table 2. Dry matter (DM) yield and grazing animal performance on seeded perennial grasses and permanent pasture, 2-yr means $^{z}$

<table>
<thead>
<tr>
<th>Pasture</th>
<th>DM yield (t ha$^{-1}$)</th>
<th>Gain kg d$^{-1}$</th>
<th>Carrying capacity kg ha$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timothy</td>
<td>5.5</td>
<td>0.90</td>
<td>629</td>
</tr>
<tr>
<td>Orchardgrass</td>
<td>5.5</td>
<td>0.85</td>
<td>604</td>
</tr>
<tr>
<td>Meadow fescue</td>
<td>5.3</td>
<td>0.94</td>
<td>540</td>
</tr>
<tr>
<td>Permanent pasture</td>
<td>5.9</td>
<td>0.76</td>
<td>606</td>
</tr>
</tbody>
</table>

$^{z}$Adapted from Winter and Black (1975).
$^{y}$SD = Steer-day.
Table 3. Dry matter (DM) yield of alfalfa-based binary forage mixtures as influenced by management systems during the first three production years.

<table>
<thead>
<tr>
<th>Forage type</th>
<th>DM yield (t ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass</td>
<td></td>
</tr>
<tr>
<td>Pasture</td>
<td>2.69 (53%)(^{y})</td>
</tr>
<tr>
<td>Hay (2 cut)</td>
<td>3.41 (50%)</td>
</tr>
<tr>
<td>Alfalfa</td>
<td></td>
</tr>
<tr>
<td>Pasture</td>
<td>0.94 (18%)</td>
</tr>
<tr>
<td>Hay (2 cut)</td>
<td>1.96 (29%)</td>
</tr>
<tr>
<td>Weed + native species</td>
<td></td>
</tr>
<tr>
<td>Pasture</td>
<td>1.39 (28%)</td>
</tr>
<tr>
<td>Hay (2 cut)</td>
<td>1.51 (22%)</td>
</tr>
</tbody>
</table>

4\(^{z}\)Adapted from Rodd et al. (1992).
5\(^{y}\)Percent of total dry matter yield.
Table 4. Effect of long-term fertility management (1937-1956) on dry matter (DM) yield and herbage composition of permanent haylandz

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Average DM yield (t ha(^{-1}))</th>
<th>Composition in 1956</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Grass (%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clover (%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weeds (%)</td>
</tr>
<tr>
<td>No fertilizer or lime</td>
<td>1.8</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>92.2</td>
</tr>
<tr>
<td>Lime</td>
<td>1.4</td>
<td>12.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>79.2</td>
</tr>
<tr>
<td>N P</td>
<td>3.0</td>
<td>17.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>78.2</td>
</tr>
<tr>
<td>N K</td>
<td>2.0</td>
<td>12.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>83.6</td>
</tr>
<tr>
<td>P K</td>
<td>2.8</td>
<td>8.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>82.5</td>
</tr>
<tr>
<td>N P K</td>
<td>3.6</td>
<td>12.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>74.1</td>
</tr>
<tr>
<td>N P K + Lime</td>
<td>3.1</td>
<td>16.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>69.0</td>
</tr>
</tbody>
</table>

3 Adapted from MacLeod et al. (1960).
Table 5. Effect of fertilizer application on herbage dry matter (DM) yield and yield distribution on permanent pasture\(^z\)

<table>
<thead>
<tr>
<th>Fertility treatment (kg N ha(^{-1}))</th>
<th>DM yield (6-yr means) (t ha(^{-1}))</th>
<th>Yield distribution (3-yr means)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>June (%)</td>
</tr>
<tr>
<td>No fertilizer</td>
<td>4.4</td>
<td>61</td>
</tr>
<tr>
<td>Spring (120)</td>
<td>7.4</td>
<td>74</td>
</tr>
<tr>
<td>Spring (240)</td>
<td>8.6</td>
<td>69</td>
</tr>
<tr>
<td>Summer (120)</td>
<td>7.4</td>
<td>47</td>
</tr>
<tr>
<td>Summer (240)</td>
<td>8.9</td>
<td>43</td>
</tr>
<tr>
<td>P and K (0)</td>
<td>8.4</td>
<td>ND(^y)</td>
</tr>
<tr>
<td>P and K (240)</td>
<td>11.8</td>
<td>ND</td>
</tr>
</tbody>
</table>

\(^z\)Adapted from MacLeod et al. (1965).

\(^y\)ND = no data.
Table 6. Effect of sward composition and nitrogen fertilization on dry matter (DM) yield and animal performance under grazing; means of 3 yr and two replications

<table>
<thead>
<tr>
<th>Treatment</th>
<th>N level (kg ha(^{-1}))</th>
<th>DM yield (t ha(^{-1}))</th>
<th>AGD(^x) ha(^{-1})</th>
<th>Gain (kg ha(^{-1}))</th>
<th>F:G(^w)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SGR(^z)</td>
<td>GR(^y)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grass (G)</td>
<td>0</td>
<td>3.2</td>
<td>5.0</td>
<td>527</td>
<td>327</td>
</tr>
<tr>
<td></td>
<td>140</td>
<td>4.4</td>
<td>8.0</td>
<td>676</td>
<td>404</td>
</tr>
<tr>
<td>Legume (L)</td>
<td>0</td>
<td>4.2</td>
<td>6.8</td>
<td>553</td>
<td>404</td>
</tr>
<tr>
<td></td>
<td>140</td>
<td>4.5</td>
<td>7.0</td>
<td>590</td>
<td>404</td>
</tr>
<tr>
<td>G + L</td>
<td>0</td>
<td>4.8</td>
<td>7.3</td>
<td>601</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td>140</td>
<td>5.4</td>
<td>8.5</td>
<td>688</td>
<td>450</td>
</tr>
<tr>
<td>Mean</td>
<td>0</td>
<td>4.1</td>
<td>6.4</td>
<td>560</td>
<td>377</td>
</tr>
<tr>
<td></td>
<td>140</td>
<td>4.8</td>
<td>7.8</td>
<td>651</td>
<td>419</td>
</tr>
</tbody>
</table>

\(^3\)SGR = Simulated grazing (frequent clipping); Calder et al. (1970).
\(^4\)GR = Grazing; Calder and Nicholson (1970).
\(^5\)AGD = Animal grazing days.
\(^6\)F:G = kg sward DM yield:kg live weight gain.
Fig. 1 Seasonal DM distribution and cumulative lamb gain of pure orchard and orchardgrass/white clover pastures.
Fig. 2 Productivity of two cropping options (permanent pasture supplemented with fodder beets or kale) for an extended grazing management system and a control treatment (feedlot); data represents means of 2 yr (1985 and 1986 growing seasons).