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Factors Required to Sustain Pastoral Farming Systems and Forage Supply in Winter-Cold Zones in Canada

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캐나다의 동계한냉지역에 있어서 초지개발과 조사료 공급의 활성화에 필요한 요인

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적 요

캐나다에서 화본과와 두과목초 및 사료작물은 가축사양에 있어서 주된 에너지 공급원이다. 캐나다에는 약 1,100만 ha의 개량초지와 조사료 생산은 가능하지만 환경조건이 다소 불량한 방대한 면적의 아직 개발되지 않은 3,000만 ha가 넘는 일반초지가 있다. 캐나다는 약 1,240만두의 육우와 약 150만두의 젖소를 가지고 있다.

캐나다 남부지역에서는 짧은 생육기간이 초지농업을 제한한다. 겨울은 길며, 대부분 지역은 저온, 결빙, 해빙 및 질병 등으로 사초의 월동은 큰 피해를 입고 있다. 따라서 적응력 높은 품종의 개발은 양호한 초생유지를 위해 필수적이며, 특히 생육기간이 짧은 불량 환경지대에서 그러하다.

건물생산은 초여름의 높은 생육에 비해 늦여름과 가을의 낮은 건물축적 양상으로 계절성을 나타낸다. 이러한 불균형적 생산형태를 극복하고 방목기간을 효과적으로 연장시키기 위해서는 혁신적인 관리기술과 재생력이 우수한 품종개발이 필요하다. 초지의 생산성증대는 가축사육에 있어서 생산비를 절감시키고 경쟁력을 갖추기 위한 중요한 부문을 차지한다. 유용한 기술의 적용은 초지의 생산성을 증진시키고 사내에서의 저장사료 사양의존도를 낮추며 소규모 농가들을 경제적으로 유리하게 해 준다. 수확과 저장 및 사양과정에서 영양분 손실의 방지는 생산효율을 높이는데 필수적이다. 사일리지 조제시에도 생산비 절감과 생력관리기술 개발은 조사료 위주 낙농업의 생산효율을 높이고 순수익을 높이는데 큰 역할을 하고 있다.

축산업은 저지방이나 저콜레스테롤 식품 같은 소비자의 기호성을 충족시키는 데에 지속적인 관심을 기울여야 하며, 연구와 교육 및 농민지도에 있어서 많은 어려움은 있으나 협력과 공동연구를 확대시켜 조사료 위주의 축산업을 발전시켜야 한다.

Ⅰ. INTRODUCTION

Pastures and forage crops are a main component of farming systems on which ruminant livestock industry is based in Canada. The total area used for pasture, range, and conserved forages in Canada is approximately 41 million ha. About 11 million ha of this forage area is on improved land which involves cultivation, fertilization, drainage and other improvements. The remaining area includes land which is unsuitable for cropping due to factors such as poor drainage, salinity and fringe areas with short growing season. The total number of beef cattle is approximately 12.4 million including 4.5 million beef cows. There are 1.5 million dairy cattle.

In this paper, winter-cold zones include agricultural regions with an average January temperature of −7℃ or colder. There are five distinct agricul-

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tural regions in the winter cold zones of Canada.

The Atlantic Region has relatively fertile soils developed under forest cover. The climate is modified by the Atlantic Ocean, but it is also affected by cold currents from the coast of Labrador and by northern winds. Precipitation averages 760 to 1,500 mm annually and it is evenly distributed throughout the year. The conditions in summer are frequently unfavourable for field curing of hay due to rain and humidity. The growing season ranges from 100 to 180 days. Mixed farming is most common, with forage crops and pastures supporting a strong livestock industry.

The Central Region includes lowlands bordering the St. Lawrence River. Fertile soils, mostly formed by glacial deposits and lake sediments, and a mild climate modified by the Great Lakes and the St. Lawrence River allow for varied farming. Precipitation averages from 760 to 1140 mm a year. Ontario's agricultural sector is Canada's largest and most diverse. Forage crops and pasture are the most common use of cultivated land. The dairy industry in Quebec is the largest in Canada.

The Prairie Region contains 80% of farmland in Canada. The prairie's long sunny summer days and generally reliable precipitation produce quality grains. Grasslands, cultivated forage crops, and feed grains support a large beef cattle industry. Rangelands are comprised of a number of unique ecosystems with native species endemic to the prairies. Alberta is Canada's chief producer of feed grains, beef cattle and is the leading forage producing province in the country.

In the Pacific Region, farming is concentrated in river valleys, southwestern mainland, and southern Vancouver Island. Only 2 percent of land in British Columbia is used for farming, with dairy and beef cattle and horticulture predominating.

In the northern Boreal Forest Region, north of the Prairie Region, the harsh climate and long distances to markets limit commercial agriculture. It is estimated that in these fringe areas of the prairies there are up to 15.5 million ha of agricultural land suitable for forage production (Nickel and Pringle, 1983). Climate is the major limiting factor ($<$1300 growing degree days, $>$5℃) to agricultural production and perennial forage species offer the best option for farming. Much of this land needs to be cleared from bush and trees and drainage improved.

Overall, the southern rather than the northern parts of Canada are suitable for farming due to climatic limitations. The growing season ranges from 80 days in the northern regions to over 200 days in southern Ontario. The winter season is long and in most parts of Canada, cold temperatures, freezing and thawing, and diseases exert severe stress on overwintering forage plants. In the northern fringe areas of the agricultural zone, forages are the most reliable species as cropping is severely limited by the short growing season.

II. PRODUCTION POTENTIAL

Dry matter yields of forages can be increased significantly by intensifying existing forage and pasture production. This can be accomplished readily through application of existing technology including fertilization, management and utilization. Overcoming production-related problems offer opportunities for greater utilization of grasslands in animal production.

The forage and pasture species adapted to the winter-cold northern conditions produce a large dry matter yield in the primary growth. Typically, the dry matter production of cultivated species in the primary growth exceeds 100 kg ha^{-1} day^{-1} (Table 1) (Kunelius 1990) and in some instances 200 kg ha^{-1} day^{-1} have been exceeded (Deinum et al., 1981). Natural grasslands in the prairies have relatively low dry matter yields (Smoliak et al., 1990). Although the incoming net radiation is relatively low in the north, the net potential photosynthesis is high during the long days of summer. Under these conditions plant development is very fast which

Table 1. Cold hardiness, water soluble carbohydrates (WSC) concentration, and daily dry matter accumulation of forage grasses in Charlottetown, Prince Edward Island

Species	LT_{50}[1] ℃	WSC[1] % of DM		Daily DM accumulation[2] kg/ha/day		
	23 Nov.	5 Aug.	13 Oct.	19 June[3]	1 Aug.	19 Oct.
Phleum pratense	−16.5	7.0	15.5	121	71	33
Lolium perenne × Festuca pratensis	−14.0	10.3	16.2	77	72	44
Dactylis glomerata	−14.0	9.2	11.9	99	84	50
Lolium multiflorum × Festuca arundinacea	−14.0	8.8	15.7	116	64	48

[1] Data from Suzuki (1989).

[2] Data from Kunelius (1990).

[3] Growth period from 1 May.

results in a skewed distribution of the dry matter production of north-temperate grasslands (Hay 1989). Reproductive tillers are usually numerous which is partly responsible for the reduced nutritional quality of herbage in the primary growth (Kunelius 1990).

The productivity of sown swards is usually the greatest in the first production year (Suzuki 1991). This instability of sown swards leads to decreased production in post-seeding years and occurs even when the winter survival has been adequate. Fertility management of stands may be partly responsible for this decline. The regrowth of most herbage species is slow which reduces the dry matter production and carrying capacity later in the season. Winterhardiness tends to be inversely related to the dry matter production of herbage grass and legume species with hardy cultivars entering dormancy earlier than less hardy ones.

Development of models for estimating herbage production in winter-cold regions is complicated by the risk factor in the production of forages (Bootsma and Boisvert 1991). New modelling efforts are underway which will develop the capability of estimating forage yields on annual basis and thereby provide the required risk data.

1. Species

In the winter-cold regions, grasses are more dependable than legumes and for this reason grasses are grown for pasture and conserved feed in these areas. The further north the grasslands are located, the more limited becomes the selection of adapted species and cultivars. Local forage breeding programs are essential for developing adapted cultivars for specific winter-cold environments (Knipfel and Howarth, 1989).

In eastern Canada, the principal herbage species include *Phleum pratense* L. which is the most winterhardy species. *Festuca pratensis* Huds., Poa spp., *Bromus inermis* Leyss., and *Phalaris arundinacea* L. are also hardy species (Suzuki, 1989). *Trifolium pratense* L., *T. repens* L., *Medicago sativa* L., *Lotus corniculatus* L., and *Dactylis glomerata* L. may be grown in less demanding environments. On the west coast in lower mainland of British Columbia *D. glomerata* is an important species for making hay and silage.

In the arid and semi-arid regions of Western Canada (prairies) common cultivated forage species include *Medicago* spp., *Onobrychis viciaefolia* Scop., *Melilotus spp., B. inermis, Festuca* spp., *Elymus* spp., and *Agropyron* spp., *B. inermis* is commonly grown with *Medicago* spp. for hay. *Agropyron cristatum* L., and *Elymus juncea* L. are the best adapted pasture species for dry soils. *B. inermis* and *Agrostis intermedium* [(Host) Beauv.] are well adapted and hardy under mesic conditions. Efforts to improve these species for drought tolerance, disease and pest resistance, quality and winterhardiness have produced several improved cultivars. Species such as *P. arundinancea* have desirable agronomic characteristics in winter-cold regions but the quality does not support adequate animal performance. Efforts need to continue to improve the nutritional quality of *Phalaris* such as further reduction of alkaloids in new cultivars. Development of bloat-safe alfalfa (*M. sativa*) will improve the value of this species in animal feeding programs.

Seed production of grasses and legumes is practiced in the central and particularly in the western regions of Canada. Forage seed production is important for diversification and information on new and changing markets is essential to the producers (Knipfel and Howarth, 1989). A thorough knowledge of physiological processes leading to seed production of the cultivar coupled with an understanding of the climate-management variables in the seed-producing area should lead to higher seed yields and quality (Steppler, 1983).

2. Persistence

Persistent perennial forage species are essential for dependable forage production in the winter-cold regions of Canada where winter conditions last up to 6 months. Total snowfall ranges from 100 to 450 cm a year. Overwintering plants may be exposed to severe conditions which influence the survival of perennial forages (Suzuki, 1989). Cold (−10 to −40℃) and fluctuating temperatures (freeze-thaw cycles), excessively wet conditions in poorly drained soils, ice encasement, soil heaving, and disease can cause winter injury and winterkill. New cultivars and species capable of with standing such adverse conditions remain a high priority for forages to be grown in severe winter climates (Buxton, 1989; Steppler, 1983). Severe water deficits during the growing season reduces stands particularly those weakened by diseases and insects.

3. Management

Traditionally forage crops and pastures, with the exception of *M. sativa* and *Zea mais* L. have been considered low-value crops. Yet forages have very unique features that other crops cannot match. Implementing proper management of forage crops and pastures increases the productivity, quality, and carrying capacity. Technology developed through research would increase grassland productivity significantly upon application of such technology on the farm. Such transfer of technology involves close collaboration between research and extension personnel. Irrigating grassland in low rainfall areas of the prairies will increase herbage production and animal gains manyfold (Wilson and Rode, 1991).

Grassland renovation techniques for improving productivity have been developed for various conditions (Kunelius and Campbell, 1984). Reduced tillage or no till techniques provide an alternate method of rejuvenating pastures and hayland instead of the conventional method of cultivating and reseeding. More importantly, no-till seeding reduces soil erosion and time required for renovation. A relatively high level of knowledge is essential for successful no-till renovation. The critical factor for the adoption of this technique is the cost of grassland renovators. Producers with limited resources are able to access this technology through contractors or rental arrangement.

Ⅲ. PASTURES

The role of pastures in small livestock operations in particular is being reassessed in various parts of Canada (Clark and Christie, 1988). Season-long grazing is seen as an essential part of staying competitive in changing economic and market environment. The need of improved cultivars and species, grazing systems, extended pasture season, and animal health are the key factors in intensifying the utiliz ation of pastures. The introduction of high voltage electric fencing from New Zealand has changed the management of grazing animals. Marked seasonality of pasture production is a major weakness which influences animal production in temperate regions (Reid and Jung, 1982).

Ⅳ. MECHANIZATION

Harvesting and storing forages require machinery and storage facilities which are costly to acquire and operate. North American forage equipment is generally designed for large operations found in the prairie region of Canada. Such equipment may not be suitable for smaller farms of eastern Canada where maneuverable equipment is required. Silage systems can require large investments which are beyond the means of small, part time farmers.

Systems that reduce costs and labor requirements are essential for remaining competitive. The popularity of big round bales is related to the low labor requirement and high capacity of handling forage. Both fully dried hay or silage can be made with these units. Securing good silage and hay quality involves new techniques to overcome problems related to inappropriate moisture levels of forage in round bales. Wrapping large bales with plastic provides adequate cover for desirable fermentation of wet herbage to occur but associated environmental concerns regarding the disposal of used plastic need to be addressed.

Ⅴ. CONSERVATION

In regions with short growing seasons, feed must be stored for the confinement feeding period which lasts up to eight months. Year-round confinement feeding is practiced by dairy and some beef farmers who depend on highly mechanized storage and handling systems.

A large proportion of forages is stored as hay although silage is made on many farms. A major limitation in hay and silage making is unfavorable drying conditions due to rain, high humidity, low temperatures, and costs associated with machinery, storage facilities and energy. It is estimated that field losses of rain damaged hay average 32% compared with 17% loss for field cured hay without rain damage (Ewing, 1972). Harvest, storage and feeding losses are usually too high and developing technology that will reduce these losses are required. Multidisciplinary teams are needed to solve problems associated with forage conservation.

Ensuring good fermentation during ensiling is critical for producing stable silages. Many of the forage species adapted to winter-cold regions contain low concentrations of sugars (Table 1) essential for desirable fermentation. These concentrations are further reduced by delays in harvesting cut material which leads to an inadequate fermentation of ensiled grasses and legumes. Fermentation may be improved by adding sugar substrate, chopped potatoes, inoculant and enzyme alone or in combination. It is clear that the use of such additives improves silage quality and animal performance (Steen, 1991). Further development of such additives is warranted to secure desired fermentation and quality of silages under undesirable conditions; for example, ensiling forage species with low fermentable carbohydrates.

Development of affordable ensiling systems is essential. Capital costs of sophisticated silos and matching machinery put strain on finances. The popularity of big bale systems demonstrates the need for high capacity and labor saving harvest and storage systems. More efficient methods of feeding and reliable ways of covering high moisture material for ensiling are required.

1. Feed quality

Low legume content, harvesting at late maturity and weather damage during the harvest lower the quality of stored forages. Utilization of the low quality forages requires considerable skills by cattle feeder in knowing what forage to give to various classes of livestock for optimum results and in devising adequate supplementation. Improper use of low quality forages can be a limiting factor in milk production or can require expensive (depending on global markets) grain supplementation, or both (Nicholson, 1983).

It is imperative that close attention is paid to the forage quality for maximum benefits from forages in livestock diets. Accurate and quick methods of analyzing forages for their nutritional quality would allow precise formulation of diets and full utilization of forage nutrients. Technologies such as near infra-red reflectance spectroscopy and inductively coupled argon plasma emission spectrometry show promise for analyzing the forage quality enabling timely adjustments in diets. The nutritional needs of most classes of livestock can be met to a large extent by timely harvesting of forages to attain proper levels of protein, energy, and minerals.

VI. ANIMAL SYSTEMS

Dairy cattle are concentrated in Quebec, Ontario, and southwestern British Columbia. The land base on these farms supports production of adapted, high producing species such as *M. sativa* and *Z. mais*. In large operations, confined feeding is practiced year-round. In contrast, smaller dairy farms depend on pastures for summer feeding which reduces inputs. Kaffka (1989) noted that the adoption of grassland based management systems offered farmers with small-sized dairy operations a largely unanticipated opportunity to remain financially competitive.

Beef operations range in size and type. Large feedlot operations involve stored forages and heavy feeding of low cost small grains. At the other end of the scale, small part-time farmers may have 10 to 30 cows and low cost housing with limited machinery for operating the farm. These farmers depend heavily on pastures and hay for feeding the cattle. Low cost opportunity feeds such as cull potatoes can constitute a significant portion of diets. Intensified grazing management including adapted species, fertilization, and controlled grazing with the help of electric fencing are factors that need to be considered for improved profitability.

Traditional dairy and beef breeds are dominant in most livestock enterprises. Exotic breeds are gaining popularity and their role requires further research. For extreme conditions breeds well adapted to the rigorous environment are necessary for successful animal production (Polyakov and Ivanov, 1986).

Sheep population is modest (0.7 million) in Canada but sheep are well adapted to the rugged conditions of winter-cold regions. The performance of sheep during the brief summer grazing period is adequate on improved pastures (Syrjala-Qvist, 1985).

Consumer preferences for low fat and cholesterol food is a significant factor to be considered in developing ruminant systems. Conveying a healthy image of dairy products and red meats is necessary to maintain market share. Innovative advertising and product promotion are proving successful in reducing misunderstanding about cholesterol and fat in dairy and beef products.

VII. FORAGES IN ROTATIONS

Forages have played an important role in rotations throughout the ages. The benefits from forages in rotations include improved soil structure, residual nitrogen, increased organic matter, protection against erosion, and break in disease and pest cycles (Campbell et al., 1990). Cash crop farmers in particular have experienced problems due to continuous cropping, and they recognize again the benefits of forages in such rotations and integrating livestock in cropping programs (Clark and Christie, 1988). In southern Alberta and Saskatchewan, soil salinity has increased as a result of applying summer fallow in rotation with cereal crops. Forage grasses, which can withstand moderate to high salinity, can serve as an alternate to grains in salt-affected areas (Howarth and Goplen, 1987).

The residual effects of *Trifolium* spp. and *M. sativa* on succeeding crops are well known and significant savings in nitrogen fertilizer costs can be realized with proper management. It is important to understand the nitrogen cycle in winter cold regions to avoid losses and to gain full benefit from organic nitrogen source in crop production.

Ⅷ. HAY MARKETING

Production of hay for domestic and export market has increased steadily in recent years. This segment offers opportunities for producers to market their forage and augment their income. Total Canadian *M. sativa* processed pellet and cube production exceeds 600,000 tonnes annually. Alberta is the leading province in hay products manufacture and marketing.

Key factors influencing the forage processing industry include access to raw materials, energy and transportation costs, climatic conditions, availability of containers, and price and availability of competing products (Industry, Science and Technology Canada 1988). Fluctuations in demand and price result in uncertainty in this sector. There is also a need for identifiable quality standards to be established by buyers which would assist in developing constant and consistent supplies (Love Rolheiser and Barrie, 1990). These markets require specific forage species and quality standards. Meeting niche markets offers opportunities for specialized market development.

High density baling reduces the volume of baled hay significantly and makes long distance shipment of hay feasible. Exported hay must meet stringent quality standards including low tolerance levels for insects such Hessian fly (*Mayetiola destructor*) for the Japanese market. Developmental work on the processing and packaging of hay is essential to meet the quality standards.

Ⅸ. FORESTRY/GRASSLAND INTEGRATION

In regions where clear-cut logging takes place, there is potential for seeding large areas to forage species while reforestation takes place. Adapted legumes in these areas would reduce N fertilizer costs. Forage potential of these clearcuts exceeds 2.6 t ha^{-1} of dry matter compared with about 0.2 t/ha in unimproved areas (Zacharias and Holl, 1983). In British Columbia clearcut areas seeded to forages make a significant contribution to meeting pasture needs of beef enterprises. Resolving potential conflicts between forestry and agricultural land use is essential in such collaborative efforts.

Sheep have been used successfully in reforested areas for grazing vegetation and thus reducing competition from volunteer species. In plantations of conifer trees sheep will remove herbaceous species and strip leaves of deciduous tree seedlings (Syrjala-Qvist 1985). This technique is environmentally sound and it may be used during periods when there is limited damage to the planted species.

Ⅹ. PRIORITIES FOR RESEARCH AND EDUCATION

Forages are part of a complex production and land use system in which they play a key role. It is essential that animals, forages, soils, environment and all the factors influencing profitability and sustainability are studied collaboratively (Clark and Christie, 1988). A systems approach is essential to bring various components together in developing viable enterprises. The development of grazing systems for beef and sheep enterprises is required to take full advantage of season-long pasture season.

The following breeding goals for the Northeastern United States and Eastern Canada were identified in the Regional Research Project NE-144 on Forage Crop Genetics and Breeding to Improve Yield and Quality (1992). Changes in forage production strategies, such as reduced nitrogen fertiliz ation and increased use of forage mixtures and pastures, will require changes in breeding strategies for continued development of improved cultivars and germplasm. Involving public institutions in the development of grass cultivars and forage legumes other than *M. sativa* is becoming important because private interests are abandoning this activity. Close collaboration among researchers in geographic zones with similar conditions is essential to develop cultivars with broad adaptation. Producers will have greater access to the improved cultivars which in turn enhances their commercial success.

Development of persistent cultivars with good nutritional quality for all regions remains a high priority (Knipfel and Howarth, 1989). Since suitable breeding material is limited, ecotypes are an important gene resource in breeding programs in winter cold zones (Simonsen, 1985). Introducing material from regions with milder climates is of little help if such material is not persistent. Biotechnology offers opportunities in developing new cold-tolerant, disease resistant plant material. Speedy and accurate forage quality determination for producers and hay trade need further development. Improved ensiling technology is a key factor for producing quality stored feed.

New harvest and storage techniques need to be developed that reduce dependence on climatic conitions, are energy efficient and give a quality product suitable for export market. Seed producers need new techniques to ensure condsistent yields and competitiveness.

Fertility management including biological nitrogen fixation and manure disposal need added attention to develop environmentally acceptable systems in grassland farming. The short growing season and long periods when soils are frozen present challenges for developing environmentally acceptable methods of manure disposal and other management practices under social, political, and economic pressures. Improved manure management practices are being adopted by farmers under government incentive programs. Such practices include the use of holding tanks to store manure from dairy barns and feedlots until it can be recycled as fertilizer.

Climatic change, real and predicted, will challenge the forage producer and research community to respond to anticipated impacts and responses. The entire forage production system will face dramatic changes if the anticipated global warming will occur. Accompanying changes in growing season and overwintering period will require better fundamental understanding of plant, soil, and animal system (Stoddart, 1991).

Finally, concerns are raised regarding the allocation of resources to research, education, and extension activities in support of forage based livestock systems. In many countries, the farming sector comprises a very low percentage of the entire population and it will be increasingly difficult to secure adequate resources for traditional research on pastoral farming systems. National and international policies have the potential to dominate farm structure and activity in spite of best management practices. With severe financial constraints, alliances and cooperation must expand between agencies with common goals to foster better communication (Estes and Lucey, 1989).

XI. CONCLUSIONS

There are thousands of farmers in Canada who have the potential for utilizing forages in livestock and cash farming enterprises more to their benefit. Decreasing price margins for livestock products will necessitate the use of low cost forages in animal diets for producers to remain competitive. It will be essential to develop and plan sustainable systems including forages, animals, environment, soils and climate. In Canada there is a large land base in fringe areas suitable for increased forage production but this is possible only if there are markets for additional beef and other animal products from this kind of expansion. Prospects for such expansion are not promising due to overproduction and changing consumer preferences. Sustaining production levels in cropping systems will require sound agronomic practices including proper crop sequences. Forages can play an important role in these areas.

XII. SUMMARY

Forage grasses and legumes are the main component of livestock diets in Canada. There are over 30 million ha of grassland in Canada and there is a large, undeveloped land base in fringe areas suitable for forage production. The short growing season limits the grassland farming to the southern parts of Canada. The winter season is long and in most parts of Canada cold temperatures, freezing, and thawing, and diseases exert severe stress on overwintering forage plants. The development of persistent cultivars is essential for sustained production particularly in the fringe areas with short growing season. The seasonality of dry matter production is a result of high growth rates in early summer and low dry matter accumulation in late summer and fall. Innovative management practices and cultivars with improved regrowth capacity are necessary to overcome such skewed production pattern and to extend effective grazing season. Improved pasture production is an important part of reducing costs in livestock operations and remaining competitive. It is suggested that applying available technology would increase pasture productivity and reduce dependence on stored feeds thus improving profitability of small producers in particular. Reducing nutrient losses during harvesting, storage, and feeding is essential for improved production efficiency during confinement. The development of low cost and labor saving methods of ensiling is critical for improved efficiency and profitability of forage based enterprises. Livestock industries must respond to consumer preferences for low fat and cholesterol foods. Research and development of entire production systems is emphasized for developing viable enterprises. It is increasingly difficult to secure resources for research, education, and extension, and alliances and cooperation must expand among organizations with interests in forage based livestock systems.

XIII. REFERENCES

1. Bootsma, A. and J.B. Boisvert. 1991. Modelling methodology for estimating forage yield potential in Canada. Agriculture Canada, Ottawa, Ont. Tech. Bull. 1991-6E, 33 pp.
2. Buxton, D.R. 1989. Major climatic and edaphic stresses in the United States. pp. 271-232. *In:* Persistence of forage legumes, Marten, G.C. ed., Wisconsin, USA, American Society of Agronomy.
3. Campbell, C.A., R.P. Zentner, H.H. Janzen and K.E. Bowren. 1990. Crop rotation studies on the Canadian Prairies. Agriculture Canada, Ottawa, Ont. Publ 1841/E, 133 pp.
4. Deinum, B., J. De Beyer, J., A. Nordfeldt, A. Kornher, O. Ostgard and G. van Bogaert. 19 81. Quality of herbage at different latitudes. *Netherlands journal of agricultural science* 29: 141-150.
5. Estes, G.O. and R.F. Lucey. 1989. Crop and soil management for a low-input agriculture. *Proceedings of Northeastern Branch Meetings, American Society of Agronomy*: 3-5.
6. Ewing, S.A. 1972. Harvesting, storing processed feeds for beef cattle (Tables 11-19). Iowa State University, Iowa City, Iowa. PM-535. 59 pp.
7. Hay, R.K.M. 1989. The performance of high-latitude grass varieties under Scottish conditions: seasonal distribution of dry-matter production. *Grass and forage science* 44:405-410.
8. Howarth, R.E. and B.P. Goplen. 1987. Forages on the Prairies. *Agrologist*, fall issue:15-16.
9. Industry, Science and Technology Canada 19 88. Processed Forage. Industry Profile. Industry,

Science & Technology Canada, Ottawa, Ontario, pp. 7.

10. Kaffka, S.R. 1989. Prospects for the survival of the small dairy farm in the northeastern US. *in: Sustaining the Smaller Dairy Farm in the Northeast,* Kaffka, S.R. *ed.* The sunny Valley Foundation, Inc., CT, USA.
11. Knipfel, J.E. and R. E. Howarth. 1989. Summary of group reports and discussions. pp. 378-380. *in: Proceedings of the Western Region Workshop on Forage Crops,* B.P. Goplen. *ed.* Agriculture Canada, Ottawa, Canada. 383 pp.
12. Kunelius, H.T. 1990. Dry matter production, fibre composition and plant characteristics of cool-season grasses under two harvest systems. *Journal of agricultural science, Cambridge* 115 :321-326.
13. Kunelius, H.T. and A.J. Campbell 1984. Performance of sod-seeded temperate legumes in grass dominant swards. *Canadian journal of plant science* 64:643-650.
14. Love Rolheiser, C. and A. Barrie 1990. Industry development issues. Forage to Asia, Summary Report, Alberta Agriculture. pp. 7.
15. Nicholson, J.W.G. 1983. Forage utilization in Eastern Canada. pp 19-23 *in: Proceedings of the National Forage Symposium 1981, Agriculture Canada:* 197 pp.
16. Nickel, J.G. and Pringle, W.L. 1983. Forage production and potential from fringe areas of the prairie provinces. pp 40-48 *in: Proceedings of the National Forage Symposium 1981, Agriculture Canada:* 197 pp.
17. Polyakov, V.A. and Ivanov, V.G. 1986. Dairy cattle pasture use in the extreme northern USSR. pp. 153-155 *in*: Grazing Research at Northern Latitudes. Gudmundsson, O. *ed.* New York, Plenum Press.
18. Reid, J.L. and Jung, G.A. 1982. Problems of animal production from temperate pastures. pp. 21-43 *in*: Nutritional limits to animal production from pastures, Hacker, J.B. *ed.* UK, Commonwealth Agricultural Bureaux. 536 pp.
19. Simonsen, O. 1985. Herbage breeding in northern areas. pp. 277-295. *in:* Plant Production in the North, Kaurin, A; Junttila, O.; Nilsen, J. *ed.* Tromso, Norway, Norwegian University Press.
20. Smoliak, S., W.D. Willms and N.W. Holt. 19 90. Management of the prairie rangeland. Publ. 1589/E, Agriculture Canada, Ottawa, Ont., pp. 37.
21. Steen, R.W.J. 1991. Recent advances in the use of silage additives for dairy cattle. pp. 87-101. *in*: Management issues for the grassland farmer in the 1990's, Mayne, C.S. *ed.* Hurley, UK, British Grassland Society.
22. Steppler, H.A. 1983. Summary. pp 171-174. *in:* Proceedings of the National Forage Symposium 1981, Agriculture Canada: 197 pp.
23. Stoddart, J. 1991. IGER and the future of UK grassland agriculture. pp. 7-12. *in:* 1990 IGER Report, Robson, M. *ed.* AFRC Inst. Grassland and Environmental Res., Aberystwyth, UK.
24. Wilson, D.B. and L.M. Rode. 1991. Irrigated pastures in Western Canada. Agriculture Canada, Ottawa, Ont. Publ. 1862/E, 26 pp.
25. Suzuki, M. 1991. Effects of stand age on agronomic, morphological and chemical characteristics of alfalfa. *Canadian journal of plant science* 71: 445-452.
26. Syrjala-Qvist, L. 1985. Improvement of natural pasture utilization by sheep. pp. 157-165. *in*: Grazing Research at Northern Latitudes, Gudmundsson, O. *ed.* Plenum Press, New York.
27. Zacharias, J.V. and F.B. Holl. 1983. Forage crops in British Columbia. pp. 49-56. *in:* Proceedings of the national forage symposium 19 81, Agriculture Canada. 197 pp.