ATLANTIC CANADA FORAGE RESEARCH REVIEW

FINAL REPORT

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CHAPTER 1

INTRODUCTION

1.1 Importance of Forages in Atlantic Canada

The Atlantic Provinces are particularly well adapted to the production of forage crops. Abundant rainfall, well-distributed throughout the growing season and moderate temperatures in both summer and winter are favourable for forage production. Soils, in addition to some physical constraints, are generally low in natural fertility, but they respond well to applications of lime and fertilizer, and conditioning. Pastures, which are the most economical means of supporting livestock, typically produce high levels of herbage for grazing livestock in late spring and early summer. Supplementary pasture species extend the grazing season by providing herbage when regular pasture growth is slow, and conserved forages such as hay and silage support livestock operations throughout the winter months.

Climate in the region is moderated by the Atlantic Ocean, cold Labrador currents and northern winds. Precipitation averages 760 to 1500 mm annually and is evenly distributed throughout the year; the growing season can vary from 100-210 d depending on geographic location, proximity to the sea, and year (Dzikowski et al., 1984). July is the warmest month of the growing season with average temperatures ranging from 11°C-19°C and highest extreme temperatures ranging from 25°C-35°C. The growing season is characterized by a wet, cool spring and autumn, and a warm, moist summer with occasional periods of drought. Growing conditions in this region are optimal for production of adapted cool season grasses and forage legumes. Principal grass species in this region include timothy (Phleum
pratense L.), the most winterhardy species, bromegrass (Bromus inermis Leyss.), meadow fescue (Festuca pratensis Huds.), bluegrasses (Poa spp.), reed canarygrass (Phalaris arundinacea L.) and, orchardgrass (Dactylis glomerata L.). Red clover (Trifolium pratense L.) is the most common legume species grown. Other major species include white clover (T. repens L.), alfalfa (Medicago sativa L.), and birdsfoot trefoil (Lotus corniculatus L.).

Dry matter production of cultivated grasses in primary growth can exceed 100 kg/ha/day (Kunelius, 1990a). Yields can be maximized by incorporating existing technology into fertilization practices, intensive management and improved utilization. Increased persistence of perennial forage species may be accomplished through the identification and development of new species and cultivars that are better adapted to the region's climate and soils. Sown pastures, for example, are most productive during the first year after seeding (Suzuki, 1991), while post-seeding years show rapid and marked decline. Improved persistence would increase productivity of these pastures. Improvements in forage species management and employment of minimum tillage systems have also been investigated as means of improving productivity (Kunelius and Campbell, 1984).

### 1.2 Limiting Factors of Forage Production In Atlantic Canada

Agricultural soils (classes 2, 3 and 4) in Atlantic Canada cover 5.6 million ha or 24% of the land area (Nowland, 1975). 2.6 million ha have immediate potential for commercial agriculture while only 0.6 million ha, or 2.6% of the region, can be considered prime agricultural land (class 2 soils). Several distinctive soil types, including peatlands in Newfoundland and reclaimed tidal marshlands surrounding the Bay of Fundy, have special problems associated with forage production. Two major inherent soil factors that limit agricultural productivity in the region are low fertility and poor soil structure (Nowland, 1975). Other limiting soil factors include
undesirable soil structure and/or low permeability, excessive stoniness, excess water, steep topography, low moisture-holding capacity, bedrock near to the surface, subjection to flooding and occasional combinations of several of these factors.

While the region's cool, humid climate favours growth and production of forage crops, it also causes problems in their harvesting and utilization. The low probability of sufficient, consecutive fine days, and the high levels of humidity and relatively low temperatures make hay drying difficult. Seasonal growth patterns result in reduced production after early summer and make pasture management crucial, and the short growing season results in increased reliance on conserved forages. The region's high rainfall pattern promotes heavy infestation of gastrointestinal parasites on grazing livestock. Severe winters often result in frequent winterkilling, particularly in legume crops.

Availability of adapted cultivars is another factor which limits forage production in Atlantic Canada. Lack of persistent legumes results in rapid disappearance from mixed stands, which reduces forage quality and necessitates frequent reseeding. Legumes are important in mixtures as they decrease the requirement for costly N fertilization. The improvement of soil conditions through drainage, tillage, fertilization, liming and crop management, and the continuation of breeding programs to produce more persistent cultivars, are important steps that must be taken to maintain optimal forage production.

1.3 Purpose of a Comprehensive Review

Forage research in Atlantic Canada has been conducted since before the turn of the century and consequently, a great deal of knowledge pertinent to improving the agricultural capability of the
region has been acquired. A comprehensive review of all forage-related research would provide a useful reference for researchers and extension personnel as well as reduce duplication of research and promote transfer of existing technologies that are relevant to producers at this time. An associated computer database of published and unpublished research will facilitate access to information.

CHAPTER 2

AN HISTORICAL PERSPECTIVE ON FORAGE RESEARCH IN ATLANTIC CANADA

Forage research in Atlantic Canada is carried out by the Research Branch of Agriculture
Canada, which operates research stations in Charlottetown, P.E.I., Fredericton, N.B., Kentville, N.S., and St. John's, Nfld, and experimental farms in Nappan, N.S. and Bouctouche, N.B. Each research facility has a mandate for specific research needs of the region. The major forage-related research activities of each facility are listed in Table 1. Forage research is also conducted by the Provincial agriculture departments; and the Nova Scotia Agricultural College.

2.1 Research Stations and Forage Research

2.1.1 Nappan Experimental Farm

The selection of Nappan as the preferred site for the Experimental Farm for the Maritime provinces was made in 1887 (Weaver, 1986). Forage research at the farm began as early as 1889 when a wide selection of grasses and legumes were sown. In 1893, corn and beans were grown for silage. Hemp (Cannabis sativa L.), winter rye (Secale cereale L.), cauliflower (Brassica oleracea L. botrystis) and other crops were introduced to determine their value for livestock feed. Work began on alfalfa (Medicago sativa L.) in 1902 but experiments were not very successful in these early years. Researchers found that liming the soil was beneficial and that alfalfa performed well with clover (Trifolium spp.). In 1910, good yields were finally realized.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Charlottetown</th>
<th>Fredericton</th>
<th>Nappan</th>
<th>St. John's</th>
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<tbody>
<tr>
<td>Breeding</td>
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<tr>
<td>Pastures</td>
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<tr>
<td>Person years, Prof.</td>
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<td>1.0</td>
<td>2.1</td>
<td>1.0</td>
</tr>
<tr>
<td>Scientists</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>1</td>
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Research on alfalfa has continued through the entire life of the Experimental Farm (Weaver, 1986).

By 1897, work was being done on root crops for fodder (Weaver, 1986). Swede-turnips (Brassica campestris L.), mangels, carrots (Daucus carota L.) and sugar beets (Beta vulgaris L.) were considered a valuable, high yielding component of cattle feed and were tested extensively.
until the 1950s. Root crops eventually gave way to high quality hay and silage although in the 1980s interest in the crops as a means of extending grazing in late fall was renewed. Variety trials of root crops were carried out extensively in the early years of the Farm to select for high yield, keeping quality and resistance to clubroot, a fungal disease (Weaver, 1986).

In 1921, beef cattle fed corn (Zea mays L.) silage and hay had better gain than cattle fed root crops and hay (Baird, 1922). Grasses (Graminae spp.) and clovers were sown alone and in mixtures to determine the best combinations for hay and pasture use. The 1922 season found the best yields from red clover (Trifolium pratense L.)/meadow fescue (Festuca pratensis L.) and red clover/orchardgrass (Dactylis glomerata L.) mixtures. Corn and sunflower (Helianthus annuus L.) were being grown for silage and in particular, dates of planting and plant spacing were examined (Baird, 1923). It was determined that sunflowers did best with late seeding and when planted with one meter between plants. "Longfellow" corn was considered the best variety for ensiling. Early and late maturing red clover were compared and preliminary results showed late red clover to have superior performance. Nurse crops were found to be detrimental to alfalfa and broadcast seeding was considered a necessity to enable alfalfa to survive the winter (Baird, 1924). The best yielding grass/clover mixture at this time was timothy/red clover/alsike clover (Trifolium hybridum L.; Baird, 1925).

Pasture investigations in the 1930s dealt chiefly with rotational vs. continuous grazing; fertilizing; liming; and the effects of cultural treatment (Weaver, 1986). Sheep were initially used for grazing but were replaced by dairy cows and heifers in 1929. Results indicated that rotational grazing gave slightly more forage but considering the extra cost of fencing, this type of grazing was not recommended. Fertilization methods around 1930 involved applying 336 kg/ha of superphosphate and 84 kg/ha of muriate of potash every 4 years, and 112 kg/ha of sulphate of ammonia every year (Weaver, 1986). Slightly higher yields were realized in fertilized pastures.
An experiment was conducted to determine the value of complete fertilizer on pastured area and ground limestone only as a top dressing on old sod. The complete fertilizer gave superior herbage. The limestone was slow in showing any effect; it depressed yield slightly for the first 2 years following application then eventually stimulated the growth of clover. A combination of the treatments was considered to be a better choice (Weaver, 1986).

In 1929, small areas of land were set aside to compare: ploughing and reseeding old pasture areas; diskng and harrowing the sod without ploughing; and a check area receiving no cultivation treatment, (Baird, 1949). The results did not indicate sufficient differences between these treatments to warrant the expense of ploughing and reseeding, provided the sod was good to begin with. The possibility of improving permanent pasture without ploughing was investigated by applying several fertilizer materials to 0.4 and 0.8 ha pasture fields which were in sod for an extended period prior to the start of the experiment in 1937. Response was measured by the live weight gains of dairy heifers and in the yields of herbage. The field which received superphosphate and potash had higher live weight gain (246 kg/ha) than the check field (Baird, 1949). The same trend was apparent in the herbage yield.

Timing of nitrogen (N) fertilization was also investigated and researchers found that spring application provided heavy spring growth but only very light growth during summer and early fall (Weaver, 1986). Early summer application more than doubled the amount of herbage available for late summer and fall grazing, a time when the grazing problem is most acute in this area.

In the 1930s, corn was considered the most satisfactory crop for ensilage purposes, where yields of 22.4 t/ha or more could be attained (Baird, 1938). In addition to making high quality silage, corn was also suited for use as green feed as it remained in a succulent condition for a
long period. Several commercial varieties, Longfellow, "Golden Glow", "Wisconsin No. 7", "Compton's Early" and "Salzer's North Dakota", were recommended by researchers (Baird, 1938).

Root crops were extremely popular as livestock feed at this time because they were well suited to Maritime climatic and soil conditions (Baird, 1938). A great deal of work was done to select the best yielding and most disease resistant varieties. Tests showed that the half-long and intermediate classes of mangels were superior, however, other classes, particularly shallow-rooting ones, were often recommended depending on a farmers' soil type. Swedes were evaluated chiefly for yield and disease resistance. As early as 1922, a clubroot resistant variety, known as "Bangholm", was introduced, multiplied and distributed to farmers by the Experimental Farm. Its inability to produce consistently good yields, however, initiated a cooperative project among Maritime Experimental Stations, Illustration Stations and several private farms. "Wilhelmsburger" proved to be the most resistant variety with a better yield than Bangholm. Another cooperative project was conducted to solve the problem of brown heart, a deficiency disease in swedes.

Roots affected with the disease were shown to have a lower feed value than normal roots. Researchers found that borax applied to the soil was effective in controlling the disease under most conditions (Baird, 1938).

Trials on field carrots showed no great yield differences between varieties although short and intermediate types were recommended due to the difficulty in harvesting the long types. The fleshy annuals kale and rape were tested during the 1930s (Baird, 1938). Dwarf Essex rape was the best yielder of the two crops and also required less labour. Recommended kale varieties were "Green Marrow Stem" and "Purple Marrow Stem" (Baird, 1938).
Annual crops were tested from 1927 to 1941 to determine their suitability for hay production (Baird, 1949). These crops were seeded and harvested for one season and were also used as green feed or annual pasture. Oats (Avena sativa L.), sown alone or in combination with peas (Pisum sativum L.) and common vetch (Vicia sativa L.), provided the best yields. Millets (Echinochloa crusgalli Roxb.), sorghum (Sorghum bicolor Moench), sudangrass (S. bicolor sudanese Moench) and soybeans (Glycine max L.) were tested but did not compete well with weeds (Baird, 1949).

Field trials to determine the best mixtures for hay production were conducted from 1922 until 1934 (Baird, 1938). These 12 years of data are summarized in the 1932-1936 Station Report (Baird, 1938). In general, timothy was much more productive and adaptable than any other grass species. Red and alsike clover were found to be basically interchangeable in mixtures. It was also recommended that 2.2 kg/ha of alfalfa be added to any mixture, provided the soil was well drained and contained sufficient lime (Baird, 1938).

By 1947 timothy (Phleum pratense L.) was still considered the most valuable grass component of seed mixtures for the province and researchers recommended it be included in every hay and pasture mixture (Baird, 1949). "Medon", "Milton", "Boon", "Drummond", "Huron", "Swallow" and "Svalof M.S." varieties all performed well. Bromegrass (Bromus inermis Leyss.) was established in mixtures with alfalfa at Nappan with excellent results. This popular western grass was just becoming of interest in eastern Canada. Trials indicated that "Parkland" was slightly superior to common brome. Alfalfa was still of limited use in the province at this time. The Experimental Farm began a selection program to produce lines which would be adapted to Nova Scotia conditions. "Grimm", "Ladak" and "Ontario Variegated" gave the best results. Red clover seed obtained from southern sources were not sufficiently hardy for Nova
Scotia winter conditions and it was recommended that only Canadian-grown seed be used. Researchers also recommended single-cut varieties for use in the province. The white clover (Trifolium repens L.) "Morso" was considered the most hardy and productive, although "Ladino", with plentiful rainfall, yielded very well (Baird, 1949).

Tests were conducted from 1941 to 1943 to determine the feasibility of producing sugar beet seed in Nova Scotia (Baird, 1949). Average yield was 2.8 tlha which compared favourably with yields obtained in the more important seed production areas. A number of soybean varieties and strains were tested with "Manitoba Brown" showing the most satisfactory maturity and yields (Baird, 1949).

From 1937 to 1947 corn continued to be tested for suitability for ensiling (Baird, 1949). Researchers recommended ensiling the crop when the kernels were in the "early" or "medium dough" stage. Longfellow was considered to be the most consistent, good yielding, open pollinating variety. Even though climatic conditions in Nova Scotia are well suited to root crop production, interest in them as livestock feed had dramatically decreased by 1947. Only 4400 ha were grown annually and the decrease was attributed to the high cost of labour and the damage caused by clubroot. Experiments at the Farm showed that it cost approximately 2-1/2 times as much to produce a tonne of digestible nutrients from a root crop as from a hay crop (Baird, 1949).

The Nappan Experimental Farm, in addition to its upland soils, also contains a considerable acreage of dikeland soil. Problems associated with the protection, drainage, cultivation, fertilization and cropping of these soils have been studied for 100 years (Weaver, 1986). Marshland hay, which is comprised mainly of timothy, was usually harvested after upland crops and hence was normally past the most nutritive stage when cut. In 1947, an extensive
breeding program was designed to develop later maturing varieties to overcome this problem (Baird, 1949). A number of selections were made which matured 2 to 3 weeks later than commercial timothy. New timothy trials were established in 1951 and 1952 to include a large number of varieties. At the time, "Climax" and "Milton" varieties were superior (Sterling and Langille, 1954).

In the early 1950s, a considerable amount of red clover seed was still being imported from other countries (Sterling and Langille, 1954). Samples of seed imported in 1949 were studied during 1950 and 1951. The average winterkilling of crops from imported seed was found to be 66% while Canadian-produced seed had an average of only 15% winterkill. Researchers recommended purchasing seed only from areas that were known to have climatic conditions very similar to the producers' area (Sterling and Langille, 1954).

Alfalfa was becoming more popular in Nova Scotia due to improvements in drainage and the increased use of lime. Alfalfa research at the Experimental Farm increased and dealt chiefly with developing varieties that were capable of long term, high productivity on the acid soils of the Maritime Provinces (Sterling and Langille, 1954). The variety "Rhizoma" was the highest yielding variety and was also relatively hardy (Table 2). Researchers also recommended using Canadian-grown alfalfa seed after finding only a 5% winterkill from this seed as compared to a 49% winterkill from foreign seed (Sterling and Langille, 1954).

In 1951, the following grass and legume species were seeded in various combinations to determine their usefulness for hay and pasture production: timothy, bromegrass, meadow fescue, Kentucky bluegrass (Poa pratensis L.), reed canarygrass (Phalaris arundinacea L.), red top (Agrostis alba L.), single-cut and double-cut red clover, alsike clover, Grimm and Rhizoma alfalfa, birdsfoot trefoil (Lotus corniculatus L.), "Dutch" white clover and Ladino clover (Sterling
Eighteen mixtures were planted and studied under 3 management regimes: 2 years as hay followed by 1 year as pasture; 1 year as hay followed by 2 years as pasture; and 3 years as pasture. General conclusions drawn from this study were: simple mixtures were as good as or better than complex mixtures; mixtures containing alfalfa regularly outyielded those without; and the same mixtures generally yielded best whether grown for hay or pasture or on upland or dikeland soil (Warren and Langille, 1957). One of the best mixtures was made up of: timothy, 9.0 kg; double-cut red clover, 4.5 kg; Rhizoma alfalfa, 3.4 kg; and alsike clover, 2.2 kg per hectare.

Root crops had by now been largely replaced by grass/legume silage in the Maritime provinces though many farmers still found swede crops profitable (Sterling and Langille, 1954). Experiments at Nappan concentrated on breeding varieties that combined quality and resistance

Table 2. Average yield in tonnes of dry matter per hectare of alfalfa varieties in Nova Scotia, 1950-52, inclusive

<table>
<thead>
<tr>
<th>Variety</th>
<th>Tonnes dry matter per hectare</th>
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<tbody>
<tr>
<td>Rhizoma</td>
<td>5.2</td>
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<tr>
<td>Ladak</td>
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<td>Grimm</td>
<td>4.5</td>
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<td>Canauto</td>
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<tr>
<td>Ranger</td>
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<td>Ferax</td>
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*Reproduced from Sterling and Langille (1954). II*
to clubroot. Between 1914 and 1950 approximately 30 corn varieties and 40 corn hybrids had been studied at Nappan. "Dekalb 65" and "Pioneer 355" provided superior yields but Canada 240 had the most satisfactory maturity. Testing of corn for ensilage was discontinued in 1950. The crop was utilized only on a very limited scale in Nova Scotia and with the increasing popularity of grass/legume silage, many stockmen were no longer growing corn (Sterling and Langille, 1954).

The 1950s saw a considerable increase in forage research at Nappan, reflecting the rising popularity of grassland agriculture in the Atlantic region (Warren and Langille, 1957). Emphasis at Nappan was shifted from varietal testing to plant breeding in timothy, alfalfa, and swedes; evaluation of introductions and new varieties; and physiology and management for hay and pasture production. A single major problem in each of 3 important forage crops was studied at this time: clubroot resistance in swede turnips; later maturing in timothy; and tolerance to acid
soils in alfalfa. Most of these projects, especially those in plant breeding, were part of a long-term program (Warren and Langille, 1957).

From 1953 to 1957, 400 swede hybrid lines were rated for disease resistance, type and appearance (Warren and Langille, 1957). Eight hybrids that were superior following several levels of selection were then compared with standard varieties to determine their suitability as table stock. Work on alfalfa concentrated on producing a better adapted variety. Many thousands of plants were grown under adverse conditions and 180 vigorous plants were selected and multiplied for further study. 15,000 plants collected from 10 countries were added to the program. Eight superior individual timothy plants were isolated after an extensive selection program. These plants were intercrossed in various combinations and the resulting synthetic varieties were compared with standard varieties over a 3 year period. Results indicated that the best of the synthetic varieties equalled Climax in performance but surpassed it in protein and fiber. All synthetics averaged 2 weeks later in maturity than Climax. The synthetics were then sent to other locations in Canada and the United States for further testing (Warren and Langille, 1957).

Investigation of several hay and pasture management problems were initiated at Nappan at this time (Warren and Langille, 1957). The effect of method, date and rates of seeding of certain species and mixtures on establishment and persistence; and the influence of grazing intensity on yield and composition of herbage were examined. Up to this time the majority of pasture research focused on liming and fertilizing but by the 1950s, more work was done on measuring animal productivity (Warren and Langille, 1957).

Varietal tests during this period showed "Vernal" alfalfa to be a good substitute for
Rhizoma. It exhibited greater disease resistance and seed was more readily available. "Lasalle" red clover, a double-cut variety, outyielded all varieties for hay production but was a poorer seed producer than the more common varieties. Twenty-one varieties and strains from other institutions as well as those already involved in trials at Nappan were compared. Climax was superior in spring vigour and production of aftermath. Twenty-two varieties and strains of orchardgrass were tested and "Avon", with a yield of 5.8 t of dry matter/ha and 70% winter survival, was considered the best variety (Warren and Langille, 1957).

After extensive testing, "Chignecto", a clubroot-resistant swede, was released in 1961 (MacIntyre, 1963). Seed production was increased for general distribution. Between 1958 and 1961, a large number of alfalfa varieties were tested for acid soil tolerance and 25 hybrids were developed. A breeding program for birdsfoot trefoil was started in 1960 to develop a productive, winter-hardy variety that would grow rapidly in early spring. More than 35 strains were tested and preliminary hybrids were produced. Most birdsfoot trefoil planting had been unsuccessful in the Maritimes to date. Field experiments with birdsfoot trefoil showed improved germination, growth and weed control if seeding was delayed until the ground warmed up. Effect of seeding date and the performance of various grasses and legumes in mixtures was also investigated in the early 1960s (MacIntyre, 1963).

Pasture research from 1958-1961 showed that continuous grazing was best for Ladino clover pasture and lambs did better with creep grazing than with strip, rotation or free grazing (MacIntyre, 1963). Researchers examined four methods of seeding bromegrass and compared various annual crops and fall rye (Secale cereale L.) for pasture production.

Forage research over the next few decades increased significantly and focused on improving production, quality and utilization for the beef and sheep industry (Weaver, 1986).
Forage quality was evaluated in the laboratory as well as with animal feeding experiments. Frank Calder established the first in vitro digestion facility in the region in the early 1960s. Evaluation of cold hardiness in forages, breeding for selection of late-maturing timothy varieties and acid tolerant alfalfa, and management of birdsfoot trefoil were also important at this time. The effects of formic acid on silage quality and animal performance and aspects of pasture management were investigated (Weaver, 1986).

Current research is concerned with the role of forages in cow-calf beef systems. Areas of interest include pasture studies on the management of white clover/grass mixtures and the development of suitable systems for dikelands including flood tolerant species and cultivars, and fertility and harvest management.

2.1.2 Charlottetown Research Station

The Experimental Station for Prince Edward Island was established in Charlottetown in August, 1909 (Bourdon, 1984). The Farm was bought by the provincial government and leased to the Federal Department of Agriculture. Corn, clovers and grasses were initially investigated to determine which varieties would be best suited to P.E.I.'s cool, moist climate and various soil types. Suitable varieties were multiplied and seed distributed to farmers throughout the province. In 1910, corn was first grown for silage at the farm and variety trials were conducted. Annual forages such as mangels, sugar beets, turnips and carrots were also tested. Trials were conducted on "Gay" and "Chandler" timothy, which yielded 6.7 and 4.5 t/ha respectively (Bourdon, 1984). Alfalfa was grown in P.E.I. beginning in 1910. Three seedings were made that year and an average yield of 4.0 t/ha was reported. One acre of alfalfa was grown in plots to test its persistence when seeded with other crops. Results showed that 14.5 L seed/ha of wheat (Triticum
spp.), barley (Hordeum vulgare L.) and oats as nurse crops were all detrimental to alfalfa (Bourdon, 1984).

1911 saw the beginning of beef, dairy and sheep production studies, particularly comparing mixed hay and alfalfa feeding costs (Clark, J.A., 1912). Alfalfa field trials showed the variety "Hungarian" had twice the yield of "Turkestan" and "Northern Michigan". Work with clover found that alsike clover had equivalent yields with red clover from half the seeding rate (Clark, J.A., 1912). In 1912, the Experimental Station sent out small lots of alfalfa seed for use in almost every township on the Island. Grimm alfalfa was planted again on the Station, over the next few years, producing average yields of 2.3 t/ha and all plots overwintered well (Bourdon, 1984).

Thirteen different grasses were established in 1912 with red top (6.7 t/ha) and Kentucky bluegrass (4.5 t/ha) performing best (Clark, J.A., 1916). Alfalfa trials again found that a nurse crop was not recommended. Alfalfa averaged 2.3 t/ha and red clover, 4.5 t/ha. Seed production from Grimm alfalfa was attempted in 1915 but although there were adequate blooms, the flowers failed to set seed (Clark, J.A., 1916).

Despite the onset of World War 1, with the loss of labour and budget cuts, research continued at the Charlottetown Research Station. A plant pathology lab was established in 1915 to conduct a program on plant disease (Bourdon, 1984). 1916 saw the beginning of a study on cutting dates in timothy and clover. Researchers found that it was best to cut timothy-.before bloom and best to cut clovers when in full bloom. During the next few years, research continued in alfalfa and grass/clover mixtures. In 1920, after 4 years of field trials on 28 grass/clover mixtures, researchers concluded that timothy performed best as a standard grass hay; orchardgrass and meadow fescue were promising grasses; ryegrass (Lolium perenne L.), Kentucky bluegrass
and tall oat grass (Arrhenatherum elatius (L.) Presl.) were unsuitable due to their inability to compete with natural grasses; and red top was recommended as a pasture "bottom grass". Work on corn at this time showed that the growing season was not long enough for available corn varieties to mature for use in silage (Clark, J.A., 1921).

In 1921, alsike and white clover trials demonstrated the inability of the two species to persist for longer than one or two winters (Clark, J.A., 1922). Sunflowers were tested for use in silage, and combined with corn, they produced an excellent quality silage. More work was done on root crops such as turnips, mangels -and sugar beets. Continuing research on grasses and legumes showed that timothy was best suited for hay on the Island and orchardgrass was the best species for pasture grass (Clark, J.A., 1923). Variety trials with red and sweet clovers (Melilotus alba L.) were begun in 1923 as well as trials on white clover, timothy and other grasses. Ladino white clover was recommended as a good pasture species. Trials on root crops showed that early seeding was beneficial to increase yields (Clark, J.A., 1924).

Red clover plots did not survive the winter of 1923/24 and were not recommended for use by Island farmers (Clark, J.A., 1925). Trials were begun that spring to compare forage yields with and without nurse crops. In 1924 the Station began to measure and record dry matter yields for forages because of a very wet summer that year. Samples were heated to 212°F for 24 hours and hay yields were calculated from the dry matter yields (Clark, J.A., 1925).

In the early 1930s, forage research at Charlottetown underwent expansion in the number of crops and varieties tested (Clark, J.A., 1937). New crops introduced included soybean, millet, lupine (Lupinus spp.), lespedeza (Lespedeza spp.),' sudangrass, crested wheatgrass (Agropyron desertorum (Fisch. ex Link) Schult) and reed canarygrass. Research on Swedes and mangels, which had been carried on for many years, was reduced to include only the most promising
species. Results to date indicated that there was no one Swede variety that was universally superior for Island farms, although the best varieties were thought to be "Halls Westbury", "Ditmars", "Purple Top", "Acadia", "Metts Bangholm", "Millpond" and "Hazards Improved" with Wilhelmsburgther being the most clubroot resistant. Work on mangels showed that they should 'be planted as early in the spring as possible and that "Giant White Sugar" and strains of "Half Sugar White", "Long Red" and "Danish Sludstrup" were the best varieties for the Island (Clark, J.A., 1937).

Alfalfa research at this time concentrated on using the species in hay mixtures, particularly as a replacement for red clover which had failed repeatedly for several years. Experiments with seed inoculation showed marked benefits for crops grown on land not previously seeded to alfalfa nor with above average fertility (Clark, J.A., 1937). Sweet clover was looked at as a supplement to the red clover crop on the Island. Nine varieties were tested for hardiness and yield with "Common White Blossom" and the yellow blossom varieties, "Erector", "Albatrea" and "Zouave" being the most promising. Soybeans and millet were tested for usefulness as a hay crop but not enough was known to make any recommendations (Clark, J.A., 1937).

A number of strains of timothy were tested but none showed any marked superiority (Clark, J.A., 1937). Kentucky and Canada bluegrasses (Poa compressa L.) were shown to be hardy and persistent species for pasture but orchardgrass was not hardy enough to provide consistently good yields. Reed canarygrass had been grown for the past 3 years and looked promising as both a hay and pasture grass. Crested wheat grass, though very hardy, did not yield a good hay crop and sudangrass did not compete well with weeds and produced low yields. Lupins performed well under test and were expected to be a good crop for green manure (Clark, J.A., 1937).
Investigational work on various crop rotations, cultural and cropping methods, experiments with manure and commercial fertilizer and studies of production costs, weed control and pasture improvement, was also conducted at this time (Clark, J.A., 1937). Three, four, five and seven year rotations were compared to determine their value and effect on soil fertility and crop yields under Prince Edward Island conditions. The results of these and other experiments on the depth of ploughing timothy sod for root crops and oats; the best seeding rates and mixtures of red and alsike clover and timothy; the role of crop rotation in weed control; and observations on pasture management were published in the Station's 1932-1936 Annual Report (Clark, J.A., 1937).

Between 1937 and 1946, forage crop research at Charlottetown dealt chiefly with grasses for hay and pasture, swedes, mangels and corn (Schurman, 1949). Bromegrass was investigated as a replacement for timothy on land which was light and dry. The variety Parkland was determined to be as hardy as common brome and quite persistent in competition with other cultivated and natural grasses. Reed canarygrass and orchardgrass were tested as pasture grass. Both yielded well although orchardgrass did not winter well (Schurman, 1949).

Field trials with swedes showed "Ditmars" and "Laurentian" to be the best yielding with good roots, but neither showed any resistance to clubroot (Schurman, 1949). Wilhemsburger and Bangholm displayed the highest resistance to clubroot although they were inferior in yield to Ditmars and Laurentian. All varieties of mangels except "Frontenac", "Prince" and "Tip Top" were eventually eliminated from field trials. Corn trials conducted over many years determined the standard varieties that were most suited to Prince Edward Island conditions. Work now concentrated on testing of hybrid corn with Canada 240 and "Algonquin" being the most promising (Schurman, 1949).
The increasing popularity of alfalfa as part of hay mixtures at this time was reflected in the research conducted at Charlottetown (Schurman, 1949). Studies showed that growing alfalfa as part of the leguminous hay mixture was better than attempting to grow it as a pure stand and inoculated seed produced better crops than did un-inoculated seed. In variety tests, Ladak had the highest yield in the first season but was slow to recover in subsequent years. Grimm and "Cossack" were the hardiest varieties, being the last to die out in old stands (Schurman, 1949).

Testing grasses and legumes for hay and pasture and corn for silage continued over the next 5 years (LeLacheur, 1954). Meadow fescue was tested and found to be fairly drought resistant and hardy but it was not recommended because of its unpalatability with livestock. Reed canarygrass, orchardgrass and meadow fescue all had the same problem when seeded. The seeds were too large and light to be seeded with a regular grass seeder and although special seeders solved this problem, legumes could not be seeded with them and still be evenly distributed (LeLacheur, 1954).

Considerable work was done at the Charlottetown Station from 1948 to 1952 on the use of alfalfa as a legume in hay mixtures (LeLacheur, 1954). It was recommended that both alfalfa and red clover be sown into a hay mixture because during some winters, one or the other would be winterkilled. Rhizoma alfalfa outyields other varieties at this time, although Ladak and "Viking" performed well. Researchers found that double-cut red clover was best suited to the local conditions. These types produced a crop that was ready to cut at about the same time that timothy was ready to cut. The double-cut clovers also produced the most aftermath for pasture or green manure. Birdsfoot trefoil performed well in 1952 but not enough work had been done at this point to make recommendations (LeLacheur, 1954).
Field trials with corn showed the hybrid Algonquin to outyield all other varieties in most years of test (LeLacheur, 1954). Algonquin was favoured for its habit of reaching the stage desired for ensiling within the range of the Maritime growing season. Longfellow was found to mature a little too late to be considered a good ensilage variety. "Canada 531" and "Canada 275" were good performers over the test years (LeLacheur, 1954).

Over the next 5 years, research-concentrated on variety testing. A 3 year test of double-cut red clover varieties was completed in 1956 (LeLacheur, 1957). The best yielding varieties were "Dollard", "Lasalle", "Ottawa" and "Redon". Studies to determine the effects of molybdenum on red clover growth were initiated in 1954 and 1955. Molybdenum, a trace element, had been known to be a limiting factor in legume growth. These studies showed an increase in yield of red clover when seed was treated with molybdenum. Further study was recommended to address problems of toxicity to livestock of treated forage and the relationship of soil pH and herbage increases and the balance that must be attained when working on land rotated with potatoes (Solanum tuberosum L.) (LeLacheur, 1957).

In greenhouse tests from 1959 to 1961, red clover, birdsfoot trefoil, alsike clover and alfalfa were examined for the effects of excess manganese (Parent, 1963). Birdsfoot trefoil, still a relatively new crop in Prince Edward Island, was being tested in an effort to select more competitive strains with high seedling vigour. In particular, researchers were looking at rates of fertilizer, dates of seeding and competitiveness. Pasture work continued on the timing of fertilization application. Long-term studies indicated that late-fall or early-spring applications produced surplus amounts of forage early in the grazing season. Delaying application until mid-summer was found to eliminate much of the excess growth and production was better sustained throughout the grazing season (Parent, 1963).
A three year survey of diseases of forage legumes and grasses in P.E.I. was completed in 1964 (Parent, 1966). Common leaf spot (Pseudopeziza trifolii) was the most destructive leaf spot disease on red clover and alfalfa, and sooty blotch (Cymadothea trifolii) on alsike clover. Crown rot (Sclerotinia trifoliorum) caused a 10% loss in clover stands in 1964. The root rot complex in forage legumes was considered to be the most important deterrent to forage production. None of the diseases observed on forage grasses were considered to be of economic importance at the time (Parent, 1966).

The Charlottetown Research Station currently has the mandate in the Atlantic region for forage research and conducts cultivar evaluations on a wide number of forage species. Recent emphasis is on improving yield and persistence of forage species including red clover breeding and determination of the physiological and biochemical characteristics responsible for winter hardiness and the metabolism of carbohydrates (Willis and Kunelius, 1991). Pasture management and renovation studies, grazing trials, silage quality, and establishment of feed values of local forages are also of interest. A great deal of work has been conducted on the effects of forages on nematode populations, and in particular, their effect on crop rotations (Willis and Kunelius, 1991).

2.1.3 Kentville Research Station

The Kentville Experimental Station was established in 1911 at the behest of the Nova Scotia Fruit Growers Association (Smeltzer and McKenzie, 1986). The station was mainly concerned with solving horticultural problems, particularly those of the apple industry, but from the beginning it was felt that part of the Station should be devoted to general agriculture, especially vegetable research. The research program at Kentville was broadened to include experimentation and
demonstration in support of horticulture, general agriculture, home gardening and rural beautification (Smeltzer and McKenzie, 1986).

During the early years of the Kentville Experimental Station, cereal, field and vegetable crops were grown between the rows of fruit trees, with cow manure as the main source of added fertility (Smeltzer and McKenzie, 1986). The rate of planting of these crops depended upon the speed with which the land could be cleared and the Station was encouraged by Ottawa to start four- and five-year crop rotations. A long-term experiment was set up in 1914 to determine the value of ground limestone and commercial fertilizer in a three-year rotation with cereals, hay and root crops. After 30 years limestone was considered a valuable soil amendment for cereals, hay and mangel crops but of lesser importance to the production of swedes and potatoes (Solanum tuberosum L.) (Smeltzer and McKenzie, 1986).

Root crops were planted in 1914 and good yields over the next few years led to an increase in the number of varieties tested (Blair, 1915). Alfalfa was first grown in 1915 to look at fertility, seed inoculation and liming. These plots failed by the following spring and researchers concluded that the soil must be well manured and free from weeds (Blair, 1916). Grimm alfalfa was seeded again in 1916 but on less than 0.5 ha. A small amount of grasses and clovers were grown with red top and alsike clover performing best (Blair, 1917). With adequate soil fertility and soil acidity levels, Grimm alfalfa had good yields in 1917 (Blair, 1921).

Hay was produced on marshland from 1915 with good results and in 1919 hay yield was compared between dikeland and upland fields (Blair, 1921). Dikeland yielded 8.1 t/ha while upland yielded only 3.5 t/ha. Several corn varieties were evaluated for suitability as silage and Longfellow was the best performer in 1918. Results from grass/clover trials showed that 9.0 kg/ha of red clover, 2.2 kg/ha of alsike and 9.0 kg/ha of timothy resulted in the best yield for a
mixed hay. Timothy was found to be superior to other grasses for hay. Red clover was found to produce superior yields than alsike clover (Blair, 1921).

At the time, seed was expensive and mostly imported from overseas so trials were conducted to determine the potential of seed production at Kentville and seeds were collected from everything grown. From 1918 to 1919 the station produced swede turnip seed which was no longer available from Europe due to the ongoing war (Blair, 1921). The varieties "Canadian Gem", "Corning Green Top" and "Ditmars Bronze Top" were most popular.

In 1921, seven varieties of mangels and three varieties of sugar beets were tested (Blair, 1922). Turnip varieties were wiped out by clubroot. More grass/legume mixtures were seeded and clover and timothy seed production plots were established (Blair, 1922). Grimm alfalfa did very well in 1922, particularly with no nurse crop. Sweet clover was tested but it did not survive the winter. European tufted bromegrass (Bromus sp.), seeded in 1921, yielded 2.1 t/ha of hay and had good seed yield. Red top, western rye, timothy, Kentucky bluegrass, orchardgrass and meadow fescue, in order of best yields, were evaluated for hay production (Blair, 1923).

Six varieties of soybeans were planted in 1923 to be evaluated for ensilage (Blair, 1924). Root crop varieties continued to be tested and turnips were evaluated for clubroot resistance. Sweet clover was tested and again found to be very susceptible to frost heaving. Nine timothy varieties were evaluated with an average yield of 5.0 t/ha and seed production was examined. Western ryegrass (Lolium sp.) trials were begun in 1923, with average yields of 4.6 t/ha. Early and late red clover were compared with late varieties yielding best (Blair, 1924).

Researchers in the Forage Crops Division spent the next few years testing corn and sunflowers for ensilage purposes, turnips for clubroot resistance; variety trials of mangels, sugar
beets and carrots; grass/legume mixtures for hay production; and alfalfa for hardy strains (Blair, 1926). Clubroot control in turnips was thought to be attainable through developing resistant varieties and by regular liming. Twenty-three different grass/legume hay mixtures were seeded to determine which were the most profitable. Preliminary results in 1924 indicated that a generous amount of red clover should be included in mixtures. Alfalfa trials continued to perform well (Blair, 1926). Field trials on rape and kale were begun in 1927 to evaluate their use as supplementary pasture plants. The average dry weight yield for rape was 1.6 t/ha and 1.4 t/ha for kale (Blair, 1928).

In the early 1930s, Grimm and Ontario Variegated were the standard alfalfa varieties recommended by the Kentville Station (Blair, 1938). Ladak was undergoing initial testing at the time and promised to outyield both of these varieties. Ladino white clover along with "Morso" and "Stryno" were found to yield considerably more herbage than the commercial variety White Dutch. The single-cut red clovers "Mammoth" and "Altaswede" showed good resistance to winterkilling. Among the varieties of sweet clovers tested, the white-blossomed varieties suffered from frost heaving while the yellow-blossomed varieties, particularly "Zouave", were less susceptible (Blair, 1938).

Soybeans were producing average hay yields of 3.4 t/ha (Blair, 1938). Seed yield averaged 175 L/ha. "Mandarin" was the most productive, followed by "Manitoba Brown" and "Wisconsin Black". Wilhelmsburger was the top yielding Swede turnip and Half Sugar White, the top yielding mangel variety. Of the corn varieties tested for ensilage, "Burr Leaming", "Iroquois" and Longfellow were the top yielders at this time (Blair, 1938).
From 1937 to 1946, a number of experiments using borax as a source of boron were made on a number of crop species (Kelsall, 1949). Tests on field crops, begun in 1936, were performed on four 3-year rotations, using several boron levels, with Swedes; oats, clover, mangels, potatoes and grain. All treatments were effective in reducing the incidence of brown heart in Swedes; mangel yields were increased but no benefit was gained from more than 22.4 kg boron/ha; there was no benefit to the other crops; and the borax did not appear to be toxic at up to 44.8 kg/ha (Kelsall, 1949):

Studies were initiated in 1935 and 1941 on fertilized pastures that had been seeded to timothy and clover in 1920. Data was recorded on average annual yields, botanical composition and, in some years, on moisture, ash and protein content of herbage. Detailed results of this study were published in the 1936-1947 Station Progress Report (Kelsall, 1949).

Up to this time, corn and roots were the principal winter feed for dairy cows at the Kentville Station. After some preliminary work on the ensiling of grass in 1947, it was decided in 1948 to cease the growing of roots and corn and depend entirely on grass silage (Leefe, 1954). Some of the problems looked at between 1947 and 1951 were the use of preservatives when ensiling grass/clover mixtures; losses, other than spoilage, that occurred during the ensiling, process; and the relative efficiency of silage-making versus hay-making (Leefe, 1954).

Between 1952 and 1956, grass silage research included a comparison of preservatives in a trench silo and estimations of dry matter losses in upright, trench, horizontal and stack silos (Leefe, 1957). Working with a mixture of orchardgrass, timothy and ladino clover, few differences were noted between silages made with the different preservatives and only the large upright, covered concrete trench and solid plank wall horizontal silos were considered to give satisfactory results (Leefe, 1957).
Experiments were conducted on grassland from 1952 to 1962 to evaluate the effectiveness of various insecticides in controlling wireworms (Agriotes spp.; Wright, 1965). All treatments resulted in increased yields of hay that in some cases exceeded 200% for several years after application (Wright, 1965).

In 1962, the Kentville Station reported on tests conducted at six localities in western Nova Scotia (Wright, 1964). Pasture herbage varied least through the season and legumes persisted best when nitrogenous fertilizer was applied in a split application, half in late April and half in early July. Hay and silage production showed greater yields under this regime as well. From other experiments, researchers recommended that phosphorous fertilizer for pasture and hay production be 112-134.4 kg of P205/ha and the optimum pH for red and Ladino clovers was 5.5 (Wright, 1964). Research on forages continued through the 1960s and 1970s with emphasis on fertility of pastures and haylands and the evaluation of forage species for adaptability to the western region of Nova Scotia.

2.1.4 Fredericton Research Station

Land for the Fredericton Experimental Station was purchased in 1912 and work began immediately to bring it into production (Nicholson, 1987b). Land that was not ready for breaking at the time was used for rough pasture and was the foundation for extensive research in the 1920's and 1930's on pasture renovation and management. Crop research begun in 1914 included variety tests on corn, turnips, sugar beets and forage carrots (Nicholson, 1987a).

The first alfalfa trial was planted in 1915 using the variety Ontario Variegated to examine liming treatments (Bailey, 1916). Grasses and clovers were seeded in 1916 to determine the
effect of cutting during the seeding year on roots and survival. 'Liscomb' alfalfa was planted to examine the effects of liming and inoculation. Red clover was harvested unsuccessfully for...seed and "Dwarf Essex" rape was grown for fodder (Bailey, 1917). Twelve varieties of corn were tested for silage in 1918 as were peas, oats and vetches. Fourteen mangel varieties yielded an average 44.8 t/ha while "1000 Headed" kale yielded 44.4 t/ha and rape averaged 35.6 t/ha (Bailey, 1921).

Turnips were grown extensively and by 1920, seed production was very successful (Bailey, 1921). Sunflowers were tested for use in silage in 1921 and hay yielded 5.6 t/ha (Bailey, 1922). After several years of grass/clover trials, alsike clover, red clover and timothy proved to make the best mixtures. Alfalfa plots revealed that the crop grew best without nurse crops and that broadcast seeding gave better yields than row seeding. Sweet clover and other clovers were grown to examine the potential for seed production (Bailey, 1923).

Variety trials continued through the 1920s at Fredericton on corn, sunflowers, mangels, carrots, turnips and sugar beets (Bailey, 1924). Clover grown from seed from Sweden, Italy and Quebec all winterkilled in 1923 while clover grown from Ontario seed survived. The effect of seeding rates on grass/clover mixtures was examined that year and variety trials on clovers, alfalfa and grasses continued (Bailey, 1926).

In New Brunswick, swedes were considered the most reliable source of succulent feed for livestock during the winter. Variety trials on this crop continued through the 1930s (Bailey, 1937a). The highest yielding varieties at that time were Ditmars, "Acadia" and "Hall's Westbury". Trials of clubroot resistant swedes at the Fredericton Station indicated that no variety could produce adequate yields when the infestation was severe. Wilhelmsburgher and "Bangholm
Herning" showed the greatest resistance, and although they were not as high yielding as Ditmars, they were recommended for use on land infested with clubroot. In 1931, a major effort was made to find a resistant variety or-control for brown heart. None of the varieties tested showed any resistance and the experiment was discontinued in 1933 when it was shown that brown heart could be prevented by applying borax to the soil (Bailey, 1937a). Mangels were grown by some farmers as a substitute for swedes because of their better keeping quality and resistance to disease. Varieties were tested at Fredericton and Half Sugar White produced the best yields, followed by "Yellow Intermediate" and Danish Sludstrup. Nearly all the forage corn grown in New Brunswick at this time was used for fall feeding with a few selections adapted to growing corn for silage. Trials at the Station showed the largest yields from the later maturing varieties. Burr Learning and Longfellow performed best. Rape and kale were grown because of less labour involved in harvesting them. Purple Marrow Stem kale was the highest yielding at the Station, followed by 1000 Headed kale and Dwarf Essex rape. Dwarf Essex rape was found to be suitable for fall pasture (Bailey, 1937a). The increased interest in annual hays in the early 1930s led to trials on single species and mixtures (Bailey, 1937a). Combinations of oats, peas and vetch gave the best yields. Field trials of soybeans for use as hay were conducted in 1933 and 1936. The late maturing "O.A.C. 211" gave better yield than the medium early variety, Mandarin. Millet varieties were tested for yield for use as a soiling crop (Bailey, 1937a). Studies on pasture improvement began in 1928, initially to look at fertilization systems (Bailey, 1937b). In 1929, the experiment was revised to compare rotational grazing and continuous grazing when the same amount of fertilizer was used in both cases. This experiment
was continued until 1935 and the seven years of data showed that rotational grazing provided slightly more herbage. Work on supplementary pasture involved testing cattle on oats and in 1936, New Zealand orchardgrass was seeded with oats to provide early pasture grass the next spring as well as supplementary pasture later in the summer (Bailey, 1937b).

Other experiments conducted in the 1930s included the effects of fertilizers and lime on permanent pastures and in 1929, work was done on the benefits of reseeding pastures. Trials at Fredericton showed that the seed mixture was not as important as proper fertilization and management. New Zealand orchardgrass was found to be an especially promising pasture species (Bailey, 1937b).

From 1937 to 1947, researchers continued to look at root and corn crops in addition to grass and legume species for hay and pasture (MacKenzie, 1948). The Station's Progress Report (MacKenzie, 1948) contains a description of the four varieties of swede turnips and four varieties of mangels that were still being tested at this time. Seed production of swede turnips was started in 1940 with good results. Lack of interest in mangels in New Brunswick resulted in only a few variety trials being conducted. Only corn hybrids were now being tested at Fredericton, with Canada 255 and Canada 275 being recommended for silage. Soybeans were grown at the Station beginning in 1928. The climate here did not favour seed production so by the mid-1940s, only variety trials were continued (MacKenzie, 1948).

Ten years' testing of various single species and mixtures for annual hay was completed in 1943 and the results were published in the Station Progress Report for 1937-1947 (MacKenzie, 1948). Oats proved to be the most reliable and adaptable annual hay tested and their feed value was increased when peas were grown with them. Testing was discontinued at this time since results were fairly conclusive (MacKenzie, 1948).
Experiments with timothy seed production found that sowing a mixture of red clover and timothy to grain yielded a first hay crop largely of red clover and a largely timothy crop in succeeding years (MacKenzie, 1948). The timothy was freer from weeds and produced a larger yield of seed than when timothy was seeded alone with grain. Alfalfa trials showed Rhizoma to be the best yielding variety and it was considered resistant to leaf spot disease, but lack of commercially available seed resulted in Grimm continuing to be recommended as the most suitable for New Brunswick farmers. An eight year study conducted from 1932 to 1940 on pasture seed mixtures led researchers to recommend using a simple hay mixture of 11.2 kg/ha timothy, 6.7 kg red clover and 4.5 kg alsike clover. The mixture would produce excellent hay or pasture for a few years and the species would then be replaced by volunteer clover and grasses that would provide good pasture. Good fertilization and pasture management practices were emphasized as keys to sustained pasture growth (MacKenzie, 1948).

Two experiments were conducted at the station between 1937 and 1947 to test the effectiveness of fall application of nitrogenous fertilizers (Chiasson et al., 1948). Results indicated very little difference in dry matter yield per acre when pastures were fertilized in spring or fall. The slight increase in growth from spring application was offset by the delay caused by cutting the sod during application (Chiasson et al., 1948).

Forage research at Fredericton over the next 5 years dealt chiefly with developing a more winterhardy strain of red clover for New Brunswick (Chiasson, 1954). Corn hybrids suitable for ensiling were also tested. Canada 240 had the highest average yield and was recommended as one of the most suitable hybrids for ensilage, green feed or dried forage. Further studies on seed mixtures for pasture again found simple mixtures of timothy and clovers to be the best for New Brunswick conditions. An experiment started in 1950 showed that pasture in crop rotation had
several advantages over permanent pasture (Everett, 1954). Other pasture experiments carried out at that time determined that a fertilizer mix of 3-16-12 NPK produced the highest yield and best mid-summer production at the Station (Everett, 1954).

Field trials on red clover were continued through the mid-1950s to compare single- and double-cut varieties for yield and hardiness for hay production (Chiasson, 1959). In 1953, an experiment was seeded to determine the value of bromegrass and orchardgrass for pasture and to determine the value of several grass species in association with ladino clover. Pasture fertilization and management trials in the mid-1950s dealt chiefly with sources of nitrogen and phosphorus for permanent pasture, fertilizer mixtures and permanent pasture vs. pasture in a crop rotation (Chiasson, 1959).

Eighty-one single species and mixtures of grasses and legumes were studied for 3 years for hay production and the results were. Published in the Station's 1958-1960 annual report (Hilton, 1962). Researchers continued to look at seed production in timothy which to date had not been successful. Experiments showed that inadequate N was the cause of the seed crop failures. Further studies on the effects of major elements on timothy productivity and longevity showed that N was most important for maintaining high yield. A study started in 1958 examined the effects of date of cutting and nitrogen applications on the first crop and aftermath of timothy. Fertility studies on alfalfa were conducted from 1955 to 1959 at project farms in association with the Fredericton Station. The effects of lime, fertilizer, manure and trace elements on establishment and persistence of the crop were examined. Researchers concluded that soil must be well drained and limed to a pH of 6.3 and that a borated fertilizer was essential for maintaining yields (Hilton, 1962).
In the early 1960s, researchers at Fredericton continued to look at timothy fertilization and performed experiments on reseeding legumes in grass stands after winterkill (Hilton, 1964). Tests on bromegrass varieties and strains showed a synthetic, which was later released as the cultivar "Redpatch", to be higher yielding and earlier maturing than the check cultivars "Saratoga" and "Lincoln" (Hilton, 1966). Tests on legumes and grasses were performed to study the release of growth inhibitors by plants to reduce the growth of other species growing in association with them. In descending order of inhibition, the species ranked as follows: alfalfa, birdsfoot trefoil, Ladino clover, red clover, reed canarygrass, bromegrass, timothy and orchardgrass (Hilton, 1964).

In 1966, there was a major shift in emphasis for the livestock program from genetics to nutrition research and the Station focused more resources on forage production, conservation and utilization (Nicholson, 1987b). Evaluation of forage handling equipment, development of new conservation techniques, development and improvement of forage analysis methods were all investigated. Livestock nutrition focused on the utilization of locally produced feedstuffs and maximizing production from forages. Current emphasis is on forage physiology involving growth factors which influence alfalfa and timothy and research on quality of stored forages, particularly silage, and animal performance (Willis and Kunelius, 1991). The Herve Michaud Experimental Farm is conducting adaptation trials of grasses and legumes.

2.1.5 St. John's West Research Station

The St. John's West Research Station was established in 1950 on the former Newfoundland Government Demonstration Farm at Mount Pearl (Chancey, 1966). Before this time, from 1942 to 1949, experiments were conducted at the Demonstration Farm and in conjunction with the
Nappan Experimental Farm, Nova Scotia. The focus of these experiments was variety trials and adaptation, and fertilizer tests. Forage research was conducted on hay and pasture mixtures, fertility practices and silage-making methods. In the 1950s, an entomology laboratory, the National Soil Survey and a plant pathology laboratory were established at the Station (Chancey, 1966).

Work on forage crops began at the Station in 1956 (Chancey, 1966). The main objective at this time was to evaluate species for use on Newfoundland's mineral and peat soils. Peatlands cover an estimated 2,000,000 ha in insular Newfoundland with their greatest concentration along coastal lowlands and on high plateaux (Pollett and Wells, 1979). The Newfoundland and Labrador Peat Association has published a book with an overview of Newfoundland peatlands and their potential utilization by several industries (Pollett et al., 1979).

Agricultural research on peatlands has been conducted at the Agriculture Canada, Research Branch Peat Sub-Station at Colinet, on the south coast of the Avalon Peninsula (Rayment, A.F. and Penney, 1979). This research was originally instigated by the results of the Newfoundland Royal Commission on Agriculture (Shaw, 1956) which showed that a lack of winter feed was the primary deterrent to expanding the livestock industry and suggested that peatlands might be developed primarily for the production of hay and pasture (Pollett and Rayment, 1973). Work on forage production on peat soils concentrated on evaluating yield potential and factors affecting it, such as species and varietal performance under optimized drainage and soil fertility conditions (Rayment, A.F. and Penney, 1979).

From 1956 to 1963, investigators found the following species to be productive on Newfoundland mineral soils: timothy, red clover, alsike clover, ladino clover, reed canarygrass,
orchardgrass, meadow fescue, bromegrass, alfalfa and birdsfoot trefoil (Rayment, F., 1961; Chancey, 1966). In trials of mixtures, timothy, meadow and tall fescue persisted best; white clover was the only legume to persist; and no orchardgrass varieties survived well. Management experiments looked at the benefits of manure and mineral fertilizers. On peat soils, timothy, reed canarygrass, red clover and white clover were promising species for hay and pasture (Rayment, A.F., 1959; Chancey, 1966). All of the species except white clover performed well in mixtures. Methods of draining peat soils were examined as were the effectiveness of a newly developed seeder and plough. Silage experiments compared the quality of first- and second-cut forages and tested "Roxton" oats for silage (Chancey; 1966).

Because of a need for long-lived legumes that were suitable for grazing and grew well on a wide variety of soils, alfalfa, birdsfoot trefoil and white clover varieties were evaluated in 4 year pasture trials (Chancey, 1968a). Alfalfa provided the highest yields with the variety Rhizoma performing and persisting best. The clovers were initially better than the trefoils, but stands did not persist well after the second year. Ladino clover yielded slightly better than did White Dutch. Birdsfoot trefoil varieties persisted well with Empire having higher yields than the earlier-established Viking (Chancey, 1968a).

Seeding of rough land over natural vegetation without cultivation was investigated in the mid 1960s (Chancey, 1968b). Birdsfoot trefoil produced excellent swards from one seeding but in a subsequent year, establishment failed after a severe drought followed germination. Red and alsike clover in mixture established well in some areas but poorly in others. "Champ" and "Bounty" timothy both performed well on mineral soils in tests in 1967. Efforts at growing com for silage were not very successful (Chancey, 1968b).

Ongoing peat pasture trials for grazing beef cattle and sheep examined grazing capacities,
trace element deficiencies (Chancey, 1966) and performance on various forage mixtures (Chancey, 1968b). Highest gains were obtained from cattle grazing tall fescue-timothy swards. However, in the third year, reed canarygrass produced the highest gain; predominance of tall fescue, generally associated with poor palatability, was believed to result in reduced performance in this sward (Chancey, 1971). Fundy oats grown for fodder in 1968 produced over 4.5 t of dry matter/ha (Chancey, 1969). Sorghum-sudangrass hybrids performed poorly. Seed from f, plants of swede X turnip (Brassica rapa L.) crosses were grown and roots from clubroot-free plants were retained for future parental material (Chancey, 1969). Evaluation of annual forages in 1969 showed kale to provide better yields than corn or oats under Newfoundland conditions (Chancey, 1970).

During the early 1970s, the Newfoundland Research Station investigated problems associated with forage harvesting and preservation on peat soil (Chancey, 1972). Experiments were conducted with the Provincial Department of Agriculture to develop a versatile system of harvesting and storing hay and silage under variable weather conditions (Chancey, 1972). Trials were conducted on harvesting equipment to overcome problems with the difficult bog terrain (Chancey, 1972, 1974). Feeding trials were conducted with pregnant ewes to assess performance on silage versus hay-silage (Chancey, 1974). Alfalfa variety yield, evaluated between 1968 and 1972, was noticeably variable; possibly due to stand thinning or variable persistence of the varieties (Chancey, 1973). Higher gain was obtained from animals grazing a mixture of red top and Kentucky bluegrass than reed canarygrass and tall fescue on peat soils (Chancey, 1975).

Forage research in the early 1980s at the Newfoundland Research Station concentrated on fertility management of forage crops - on peat soils with emphasis on the effect of molybdenum-induced copper deficiency on grazing lambs (Chancey, _ 1981). Studies were
conducted on the effects of residual and annual maintenance applications of molybdenum on timothy/reed canarygrass/red clover mixtures (Chancey, 1982, 1983, 1984). A four year study was conducted to evaluate the response of timothy to various applications of nitrogen and phosphorus on peat soils. Results were utilized to develop fertilizer recommendations for peat soils in Newfoundland (Chancey, 1984).

Cultivar evaluation trials for phacelia, perennial ryegrass and annual forages began in 1988 (Proudfoot, 1989). Sweet white lupines (Lupinus albus L.) were grown in mixture with oats and outyielded a field pea/oats mixture when harvested as green chop or silage (Proudfoot, 1990). Simulated grazing experiments when the lupine crop reached a height of 15-30 cm resulted in unexpectedly low amounts of lupine regrowth (Sudom, 1991). Sunflower cultivars were evaluated for forage use and found to be poorly adapted to eastern Newfoundland's climate when standard soil test fertilization rates were applied. Trials on the warmer, western coast showed that high applications of manure could significantly enhance production of sunflowers (Sudom, 1991).

Current emphasis of forage research is the identification of forage species adapted to the province and the development of suitable management practices for the province's short, cool growing season (Willis and Kunelius, 1991).

2.2 Provincial Departments of Agriculture

The Provincial Departments of Agriculture conduct applied research on species and variety evaluation, production management systems and utilization, with emphasis on problems unique
Areas of interest to the Nova Scotia Department of Agriculture and Marketing include: the effect of subsoiling on the performance of alfalfa and red clover; the effect of tile line spacing on soils and alfalfa persistence; potassium status of forage species and soils; annual rye grass and legume mixtures for pasture; and cultivar and mixtures evaluation under clipping and grazing management (Willis and Kunelius, 1991). The Prince Edward Island Department of Agriculture is currently looking at evaluating improved pasture management systems; crop management and cultivar evaluation; production of timothy for hay export to Japan; surveying of the impact of verticillium wilt in locally grown alfalfa; grass seed production; and the use of dandelion bees for pollinating legumes (Willis and Kunelius, 1991). At the New Brunswick Department of Agriculture, emphasis at this time is on evaluating pasture productivity and pasture improvement techniques for beef and deer farmers; studies on nitrogen fertility of reed canarygrass; and the impact of verticillium wilt on recommended and new alfalfa cultivars (Willis and Kunelius, 1991). The Newfoundland Department of Agriculture and Forestry conducts trials in conjunction with the St. John's Research Station to identify adapted forages and develop suitable management practices for the province's short, cool growing season.

2.3 **Nova Scotia Agricultural College**

The Nova Scotia Agricultural College was established in 1905 in Truro, Nova Scotia as a result of combining the School of Agriculture, established in Truro in 1885 and the School of Horticulture, established in Wolfville, Nova Scotia in 1893 (Cox, 1965). Current work includes the use of in vitro techniques for the development of persistent legume species for the region; management and evaluation of white clovers and grass/clover mixtures for pasture and silage; and
mono- and intercropping of annual legumes for forage and their residual effect on soil (Willis and Kunelius, 1991).

CHAPTER 3

FORAGE SPECIES
3.1 **Perennial Forage Species**

3.1.1 **Grass Species/Cultivars Adapted to the Region and Their Characteristics**

3.1.1.1 **Timothy**

(Phleum pratense L.) is by far the most important grass species grown for hay in the Atlantic provinces and is also used successfully for conserved feed and pasture (Rodd et al., 1992). It can produce excellent yields of up to 14 t/ha (Walton, 1988). It is adaptable to a wide range of conditions, easy to establish and maintain and is compatible with all legume species (A.A.C.C.P.C.F.C., 1991; Grant, 1964a). Timothy is a perennial bunchgrass characterized by a dense cylindric, spike-like inflorescence and erect culms. Individual shoots are biennial, but the plant maintains itself as a perennial through the development and growth of new shoots from bases of older culms (Powell and Hanson, 1973). Its root system is shallow and fibrous.

Advantages of timothy include rapid seedling growth, and small heavy seed that is easily sown with legumes and always available and inexpensive (Grant and Burges, 1978; Grant, 1964a and b). It is winterhardy, persistent and fairly free from pest problems (Grant and Burges, 1978). This species produces good forage for all classes of livestock and a good second crop can be produced if the first crop is harvested at the heading stage, before bloom appears (A.A.C.C.P.C.F.C., 1991).

Timothy has some disadvantages that have to be taken into consideration when growing this species. It rapidly loses palatability—once it reaches the bloom stage; it is not drought resistant due to its shallow rooting system; and it will not tolerate repeated close grazing (Grant and Burges, 1978; Grant, 1964a and b). Breeding programs have produced varieties which overcome some of these problems such as later maturing and higher yielding varieties (Grant,
1964b). Timothy is recommended as a component in many hay mixtures and is ideal to form the basis of ruminant livestock forage systems.

Investigators have conducted research on many aspects of timothy production and utilization including yield and quality evaluation (Grant, 1960, 1962; Nicholson and Langille, 1965; Childers and Grant, 1973; Kunelius and Suzuki, 1976; Kunelius and McRae, 1986b), effects of macronutrient application (Grant, 1961 a, 1963), maturity of varieties (Langille, 1961b), harvest management (Kunelius and McRae, 1986a), economics of its use in hay and silage systems (Burgess and Grant, 1974; Lovering and McIsaac, 1981; McIsaac and Lovering, 1982a and b), and use in pasture mixtures (Langille, 1977a, Rodd et al. 1992).

After 25 years of continuous hay production, timothy swards continued to produce up to 8 t/ha DM (Belanger et al., 1989). Table 3 reports the quantities of N, P and K required for maximum and most profitable forage yields during this study. Rodd et al. (1992) found timothy to be very productive as a pasture grass. Alfalfa/timothy swards produced more total DM than other grass/alfalfa mixtures (approximately 14% more than bluegrass, 17%, orchardgrass, and 33%, perennial ryegrass). Under hay management, timothy/alfalfa swards produced an average of 7.2 t/ha (2 cuts) and 8.0 t/ha (4 cuts; Rodd et al., 1992).

Of particular interest to researchers are effects of management on persistence (Kunelius and McRae, 1986a). Food reserves are required to overwinter plants in good condition and the

<table>
<thead>
<tr>
<th>Year</th>
<th>Maximum Yield (kg ha(^{-1}))</th>
<th>Maximum N</th>
<th>P</th>
<th>K</th>
<th>Most Profitable Yield (kg ha(^{-1}))</th>
<th>Most Profitable N</th>
<th>P</th>
<th>K</th>
<th>Maximum return ($ ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>7883</td>
<td>265</td>
<td>0</td>
<td>0</td>
<td>7688</td>
<td>205</td>
<td>0</td>
<td>0</td>
<td>491</td>
</tr>
</tbody>
</table>
level of these reserves in plants is influenced by the stage of development, time of harvest and nitrogen-potassium balance (MacLeod, L.B., 1965a; Grant and MacLean, 1966; Grant, 1971; Kunelius et al., 1976; Kunelius and McRae, 1986a; Belanger et al., 1989). The food reserves of timothy consist of long-chain fructosan, sugars and a small amount of short-chain fructosans (Suzuki, 1911a). Suzuki (1968b, 1971a, 1989b) and Suzuki and Pollock (1986a and b) have investigated the role of fructans in timothy.
3.1.1.2 Smooth Bromegrass

(Bromus inermis Leyss.) is the most widely utilized of the cultivated bromegrasses. It is an excellent companion crop for alfalfa in a hay or haylage system (A.A.C.C.P.C.F.C., 1991). The plant is a leafy perennial that forms a strong sod and usually dominates a sward several years after seeding. It has a deep root system that requires deep, well drained soils. It spreads underground by rhizomes and is readily propagated by seed. Bromegrass requires large amounts of nitrogen if grown alone or after the legume has thinned out of a mixture (A.A.C.C.P.C.F.C., 1991).

Bromegrass is a very winterhardy species and is fairly resistant to drought (Grant, 1964a). It maintains good palatability until late maturity and provides good yield and regrowth (Langille, 1977b). Currently recommended cultivars "Saratoga" and "Tempo" have produced total DM yields as high as 11.0 and 10.5 t/ha, respectively (2 cuts; Coulson and Kunelius, 1984). The species is sensitive to low soil fertility, however, and is occasionally subject to seeding failure (Grant, 1964a). Seeding can be difficult as the large, light seeds require separate sowing and covering the seed is essential (Newell, 1973; Grant, 1964a).

Langille and Warren (1962) found mean DM yields (over 6 clipping treatments) of an alfalfa/bromegrass mixture to be approximately 33% o higher than mixtures of alfalfa with timothy or orchardgrass. Kunelius (1979b) reported on the effects of intensive management practices on the yield, quality and ground cover of bromegrass. He found that dry matter (DM) and in vitro digestible DM (IVDDM) yields were greater when the crop was harvested at full heading and total nitrogen and percentage 1VDDM were greater when the crop was harvested at heads emerging stage. Ground cover was not influenced by applied nitrogen or harvest schedules. Other fertility studies on bromegrass looked at the effects of different sources of nitrogen
(Kunelius et al., 1987a), rates and timing of nitrogen and potassium fertilization (MacLeod, L.B., 1965a; MacLeod, L.B. and Carson, 1966; MacLeod, L.B. and MacLeod, 1974a; Narasimhalu et al., 1981) and rate of phosphate fertilization on establishment (MacLeod, J.A. and Kunelius, 1973).

3.1.1.3 Orchardgrass

(Dactylis glomerata L.) is a high yielding, cool-season grass that grows in clumps, producing an open sod. It starts growth early in the spring, develops rapidly, and flowers during late May or early June (Jung and Baker, 1973). Because of rapid seedling growth and sward regrowth, it should be seeded alone or with an aggressive legume (A.A.C.C.P.C.F.C., 1991). Orchardgrass is an excellent companion grass for white clover in both pasture and silage mixtures (Kunelius, 1988). Two cultivars, "Kay" and "Frode", are recommended in the Atlantic Provinces.

Orchardgrass has not been traditionally grown in Atlantic Canada because it does not survive well when snow cover is lacking and cold winter conditions prevail. Kunelius and Suzuki (1977b) found that orchardgrass could produce high DM yields with early seeding (up to 5.4 t/ha in the seeding year with 3 cuts) and that persistence could be improved with good fall management and proper nitrogen fertilization. Examination of post-seeding years (Kunelius and Suzuki, 1977a) saw better persistence with a four harvest system than with three harvests and DM yields of up to 7.0 t/ha (4 cuts). In a 5 year study on rates and timing of nitrogen fertilization, Kunelius et al. (1984b) found a single nitrogen application in spring increased annual yield by about 11% over equivalent summer applications. A recent study used small grazing pastures to detect forage quality differences among orchardgrass cultivars under grazing pressure (Papadopoulos et al., 1992b). Fredeen et al. (1992) analyzed the mineral composition of these
orchardgrass cultivars but final results are not yet available. Rodd et al. (1992) evaluated grass/alfalfa mixtures under hay and pasture management regimes and found orchardgrass to produce the most grass dry matter (4.1 t/ha) and the least alfalfa (0.9 t/ha) and weed (1.4 t/ha) dry matter. Orchardgrass has been grown with alfalfa in field and hydroponic experiments to investigate the role of potassium on establishment and maintenance of alfalfa in alfalfa-grass mixtures (MacLeod, L.B. and Bradfield, 1964; MacLeod, L.B. and Carson, 1965; MacLeod, L.B. and Suzuki, 1967).

3.1.1.4 Meadow Fescue

(Festuca pratensis L.) is a deep-rooted, long-lived perennial bunchgrass that has similar yield to timothy but faster mid-summer regrowth (A.A.C.C.P.C.F.C., 1991). "Mimer", the only currently recommended cultivar for the Atlantic region, produced yields ranging from 4.7 t/ha (Coulson, 1979, to. 1.1 2 t/ha (Coulson, 1990) in regional trials. It is a good grazing grass and is commonly grown in mixture with timothy and white clover for pasture (Grant, 1964a). In Newfoundland, it has been found to be slightly more winterhardy than perennial ryegrass (McKenzie and Connolly, 1991a). Meadow fescue has become more popular in recent years due to. its versatility, tolerance to variable drainage and its rapid regrowth potential (A.A.C.C.P.C.F.C., 1991).

Investigators at the Charlottetown Research Station evaluated fescue hybrids, such as "Prior", a meadow fescue and perennial ryegrass cross, in an attempt to produce winterhardy hybrids with good regrowth potential and nutritional quality for late summer and fall grazing (Kunelius, 1988; Kunelius and Coulson, 1989a). Halliday et al. (1992) found Prior to be associated with good intake and average daily gain (ADG) as hay, and to produce consistently stable, low pH and low NPN silage.
3.1.1.5 Perennial Ryegrass

(Lolium perenne L.) is a bunchgrass with no creeping growth habit and a shallow root system (Frakes, 1973). There has been significant interest in perennial ryegrass in the Atlantic provinces since the early 1970s and a great deal of research has been conducted at Research Stations, particularly at Charlottetown (Kunelius, 1978c). Smeltzer (1973) reported on 87 strains and varieties obtained from Europe and tested on soil at the Kentville Research Station in 1971. Perennial ryegrasses are currently being tested in Nova Scotia and Prince Edward Island for hardiness (Kunelius, 1988). The Nova Scotia Department of Agriculture is responsible for perennial ryegrass cultivar evaluation for the Maritime Provinces and has evaluated approximately 150 cultivars for adaptability since 1986 (Thomas, 1991c).

Perennial ryegrass is a high quality forage that makes an excellent pasture for grazing animals (A.A.C.C.P.C.F.C., 1991). It establishes rapidly and has a high nutrient value. Trials on the cultivar "Norlea" on dikeland soil produced yields of 3.3 t/ha using a 4 cut system and 7.8 t/ha with a 2 cut system (Langille, 1978). Highest levels of protein (771 kg/ha) and digestible dry matter (5.2 t/ha) were also obtained from the 2 cut system.

Cultivar evaluation trials have identified four cultivars that are equal to the standard Norlea (Thomas, 1991c). Two of these cultivars, "Bastion" and "Gunne", have been added to the recommended list of cultivars for the Atlantic region, although neither are sufficiently winterhardy for general recommendation. Yields of 8.7 and 9.5 t/ha have been reported for the two cultivars, respectively (Thomas, 1986b). Perennial ryegrass is susceptible to winter injury when exposed to extended low temperatures, particularly in late winter (Thomas, 1986b; McKenzie and Connolly, 1991a), and researchers recommend this species should not be the main grass in a mixture when grown under Atlantic conditions (Thomas, 1991c; Rodd et al., 1992). Current work
at the Charlottetown Research Station is evaluating perennial ryegrass and fescue crosses for herbage DM yield and persistence (Kunelius and Coulson, 1989a).

### 3.1.1.6 Reed Canarygrass

*(Phalaris arundinacea L.)* is a tall, coarse, sod-forming, cool-season perennial. It can be successfully grown for hay, silage and pasture (Calder, 1976). It will tolerate wet soils and low pH and produces high yields on well, drained, fertile soils (up to 15.7 t/ha for the check variety Vantage; Coulson, 1988). It is very winter hardy and is easily seeded with legumes (Grant, 1964a).

Disadvantages of reed canarygrass include slow germination and seedling growth, and unpalatability and poor animal performance due to the presence of alkaloids (Grant, 1964a). Alkaloids are nitrogen-containing compounds found in plants that can be toxic to livestock. Johnson (1976) conducted an extensive study on the nutritive value of reed canarygrass grown on peat and mineral soils of Newfoundland and the role of alkaloids in animal performance. Alkaloid concentrations as a percent of DM ranged from 0.001 to 0.007, for sun dried samples, and 0.005 to 0.02, for fresh frozen samples. Total alkaloid concentration was higher on mineral soil than on peat soil and concentration decreased with advancing forage maturity on both soils. Alkaloid concentrations, however, were relatively low in this study; Marten (1975, in Johnson, 1976) considered alkaloids to be important in palatability of reed canarygrass only when levels exceeded 0.2%.

Kunelius et al. (1991) and McKenzie and Connolly (1991b) reported on trials conducted in Charlottetown, P.E.I. and St. John's, Nfld on the low-alkaloid varieties, "Palaton" and "Venture", which compared favourably with the check variety "Vantage" (Table 4). The agronomic and nutritional qualities of these and other varieties are currently being studied at the
Nappan Experimental Farm, Charlottetown Research Station and by the Nova Scotia Department of Agriculture and Marketing which could result in increased use of reed canarygrass in the region.

### 3.1.1.7 Tall Fescue

(*Festuca arundinacea* L.) is a deep-rooted, long-lived perennial that is very similar morphologically to meadow fescue. It is essentially a bunchgrass but it will produce an even sod if it is kept mowed or grazed. It is adapted to a wide range of climatic conditions and soil types, it tolerates poor drainage, it is fairly drought resistant and it is resistant to trampling. "Kenhy" and "Johnstone" are tall fescue-ryegrass hybrids that are currently on the recommended list for the Atlantic region. Trials conducted in 4 locations across the region resulted in yields ranging from 6.2 to 10.8 t/ha for Kenhy and 5.2 to 10.3 t/ha for Johnstone.

<table>
<thead>
<tr>
<th>Table 4. Dry matter yields of reed canarygrass cultivars&lt;sup&gt;z&lt;/sup&gt;</th>
<th>Charlottetown</th>
<th>St. John's</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivar</td>
<td>1985&lt;sup&gt;x&lt;/sup&gt;</td>
<td>1986&lt;sup&gt;x&lt;/sup&gt;</td>
</tr>
<tr>
<td>Vantage</td>
<td>9.1</td>
<td>8.6</td>
</tr>
<tr>
<td>Palatonz</td>
<td>8.7</td>
<td>7.4</td>
</tr>
<tr>
<td>Venturez</td>
<td>9.2</td>
<td>7.3</td>
</tr>
<tr>
<td>Rival</td>
<td>8.5</td>
<td>6.6</td>
</tr>
<tr>
<td>NGR 791</td>
<td>8.8</td>
<td>7.4</td>
</tr>
<tr>
<td>NGR 792</td>
<td>8.2</td>
<td>6.8</td>
</tr>
</tbody>
</table>

<sup>x</sup>Adapted from Kunelius et al. (1991)  
<sup>y</sup>Adapted from McKenzie and Connolly (1991b)  
<sup>z</sup>Low-alkaloid cultivars
(Coulson, 1985). In vitro digestibility from 2 locations ranged from 60.4 to 70.0% and 57.8 to 72.6% for Kenhy and Johnstone, respectively.

Tall fescue is adapted to both pasture and stored feed. Pure stands have been known to result in nutritional problems for cattle due to low intake although new cultivars and fescue-cross hybrids may improve livestock acceptance and performance (Buckner and Cowan, 1973). Kunelius (1986) found tall fescue X ryegrass hybrids performed well in tests on Prince Edward Island. They were suitable for frequent cutting or grazing and persistence was good. Hybridization attempts to transfer the fall growth and winterhardiness of the fescues and the forage quality of the ryegrasses into one species (Clare, 1985b). Laflamme and Papadopoulos (1987) grew Kenhy tall fescue with white clover and birdsfoot trefoil and found Kenhy to yield more grazing days per hectare (585.2 days/ha) than a red fescue/white clover mixture (538.0 days/ha).

3.1.1.8 Redtop
(Agrostis spp.) is a perennial grass with both upright and creeping stems that produces a loose sod. It grows on very acid soils and tolerates poor drainage but it does not generally produce good yields in this region. A trial conducted by Langille (1977b), however, found redtop to produce the most total dry matter (8.6 t/ha) and digestible dry matter (5.3 t/ha) of 14 grass species tested. Redtop, however, is seldom sown alone. It is generally recommended to sow the species in mixture with timothy as the time of maturity is similar. Palatability declines rapidly after heading (Grant, 1964a). Redtop is usually used in pasture mixtures but it can be used for stored feed when grown on poor soils.

3.1.1.9 Kentucky Bluegrass

(Poa pratensis L.) is a long-lived perennial grass that is rhizomatous and produces dense sod and lush, palatable growth (Fergus and Buckner, 1973). It is the dominant grass species in native swards and attempts to identify superior varieties for pasture use found that none of the commercial varieties could outperform the naturalized bluegrass (Kunelius, 1988). The cultivars "Birka" and "Barkenta" were evaluated in grazing trials and produced 748 and 546 kg of animal gain per hectare, respectively (Calder, 1985). Birka provided 946 animal grazing days/ha and 7.3 t/ha dry matter production, while Barkenta provided 673 grazing days/ha and 4.4 t/ha.

Advantages of Kentucky bluegrass are its ability to survive close, continuous grazing and its dense sod resists "punching" by grazing animals. Its disadvantages include sensitivity to drought and heat which results in poor mid-summer pasture and slow seedling growth (Grant, 1964a).

Mainly a pasture grass, bluegrass grows in the spring and is stockpiled for pasturing in
the summer. Rodd et al. (1992) evaluated several alfalfa/grass mixtures under hay and pasture conditions. The alfalfa/Kentucky bluegrass mixture produced the greatest three year average DM of any grass species under a four cut hay system (8.2 t/ha), which was attributed to an extremely high yield during one season. Pasture productivity was intermediate to other mixtures although bluegrass consistently produced the lowest grass DM (35%) and the highest alfalfa DM (32%) and weed DM (31%). The dense root system and creeping growth habit of Kentucky bluegrass make it suitable as a "bottom grass" for horse pastures and it is often used on banks to protect against erosion. Canada bluegrass (P. compressa L.), a similar species, maintains quality better than Kentucky bluegrass for summer feeding and it is more tolerant to acid, droughty soils (Fergus and Buckner, 1973).

3.1.1.10 Creeping Red Fescue

(Festuca rubra L.) is a perennial, fine-leaved species that has an extensive, fibrous root system (Elliott and Baenziger, 1977). It grows well on a wide range of soil types but performs best on moist soils. The dense turf it produces can withstand heavy trampling and this makes the species a suitable addition to pasture mixes as a "bottom grass" (Elliott and Baenziger, 1977). Creeping red fescue is not a good hay crop because it is too short and hard to cut (Elliott and Baenziger, 1977). It is often used on banks and steep slopes to prevent erosion. Langille (1977b) found "Durlawn" red fescue could produce 6.3 t/ha DM, 706 kg/ha protein and 4.0 t/ha digestible DM. Little research has been conducted on this species in the Atlantic region.

3.1.1.11 Broadleaf

(Spartina pectinata L.) or tall cordgrass is a variety of cordgrass that grows on reclaimed salt marshes (Nicholson and Langille, 1965). It is a tall-growing, rhizomatous species that thrives on poorly drained areas and is very tolerant of salt conditions
(Langille et al., 1966). This species has been traditionally grown on dikelands surrounding the Bay of Fundy in Nova Scotia and New Brunswick. Yields as high as 8.0 t/ha (seed stage) were reported by (Langille and Warren, 1964; Nicholson and Langille, 1965). Because of the large acreage of dikeland in the Atlantic region and the long history of use of this species as animal forage, investigations were carried out at the Nappan Experimental Farm on the effect of management practices on its productivity (Langille, 1963; Langille and Warren, 1964a; Langille et al., 1966). An investigation of its agronomic and nutritive characteristics was carried out by Nicholson and Langille (1965).

3.1.1.12 Tall wheatgrass

(Agropyron elongatum (Host) Beauv.), another salt marsh grass investigated at Nappan in the 1950s, was found to be very useful for seeding new dikes to prevent erosion and damage by wave action (Warren, 1955). Yields of 6.9 t/ha were reported by Langille (1977b). Other wheatgrasses, slender (A. trachycaulum (Link) Malte), intermediate (A. intermedium (Host) Beauv.), and crested (A. smithii Rydb.), produced 7.1, 7.0, and 6.8 t/ha, respectively. Quaker comfrey was evaluated over a 3 year period but was discarded and was not considered to be a very promising forage crop for the area (Langille, 1962b).

3.1.1.13 Sorghum

(Sorghum bicolor L. Moench) has high protein and TDN content and can produce high yields of good quality forage. It is not suitable for pasturing until it reaches 60-65 cm in height as young plants and early regrowth contain high levels of prussic acid (Thomas, 1989). Studies on sorghum, sudan grass and sorghum-sudan hybrids were conducted
in 1965 at the Nappan Experimental Farm and yields ranged from 3.1 to 5.1 t/ha (Langille, 1965b) and 4.2 to 7.1 t/ha (Langille, 1965a). Trials conducted by Grant (1969) at the Fredericton Station produced yields ranging from 2.2 to 4.2 t/ha (early vs. late harvest) when seeded in June and harvested once; and yields ranging from 2.4 to 4.7 t/ha when seeded in July. Yields obtained from recent field trials in Nova Scotia ranged from 6.4 to 9.9 t/ha DM (Thomas, 1989).

3.1.2 Legume Species/Cultivars Suited to the Region and Their Characteristics

3.1.2.1 Alfalfa

(Medicago sativa L.) is the most important forage species grown in Canada, comprising about two-thirds of the forage legume purchased each year by farmers, and 4 to 6 million ha are presently under cultivation (Michaud et al, 1988). "Saranac" is the Flemish check cultivar for evaluation in the Atlantic region and "Iroquois" is the Standard check cultivar. These cultivars can produce DM yields as high as 12.5 t/ha (Papadopoulos, 1990) and 12.7 t/ha (Papadopoulos, 1989), respectively. Alfalfa and alfalfa-based mixtures are becoming more prominent in the Atlantic Canada region because they can produce higher yields and quality of herbage than other species.

Alfalfa is a deep-rooted perennial that requires well-drained and well-limed soils. It has rapid seedling growth and excellent drought resistance (Grant, 1964a). The species is best suited for use as hay or silage. Alfalfa can be used in specialized pasture mixtures for rotational grazing if it is well-managed (Kunelius, 1988). Rodd et al. (1992) evaluated the performance of six alfalfa/grass mixtures under hay and pasture conditions. The hay management system produced approximately 50% greater DM than pasture management; the alfalfa component of the pasture
sward decreased from 20% to approximately 2% by the third year. Bloat-safe varieties are being developed but it may be many years before this is accomplished (Kunelius, 1988).

Alfalfa has not been traditionally grown in Atlantic Canada. Extensive research conducted by Atlantic Research Stations, the increase in the use of lime since the 1950s, and improvements in drainage have contributed to increased interest in alfalfa in this region. Suzuki et al. (1989a) prepared a publication for Agriculture Canada on alfalfa production and management in Atlantic Canada. It provides information on climatic and soil requirements, selection of cultivars, stand establishment and maintenance, diseases, harmful insects and nematodes, winter survival and value as livestock feed.

3.1.2.2 Red Clover

(Trifolium pratense L.) is a biennial or short-lived perennial legume that is made up of numerous leafy stems rising from a crown. It is a major forage legume in eastern Canada and is used most commonly for stored feed. It will produce good hay yields in late July and again in late fall and makes excellent plough-down or green manure (A.A.C.C.P.C.F.C., 1991).

Timothy is the best grass to use in mixtures with red clover. Red clover competes severely with alfalfa, resulting in a poor stand of alfalfa after the clover has died out. Red clover is not generally recommended for pasture as it has a short life and is not tolerant to grazing (A.A.C.C.P.C.F.C., 1991). If it is used for pasture, it should be rotationally grazed and it will likely last for only 1 year (Kunelius, 1988).

There are two types of red clover, single-cut and double-cut. Choo et al. (1984), compared the performance of the two types at 5 locations in Atlantic Canada (12 cultivars). They found that double-cut clovers outyielded single-cut clovers (6.6 to 7.8 t/ha vs. 5.5 to 6.0 t/ha) at
all locations except on the peat soil of Newfoundland, where single-cut cultivars outyielded
double-cut cultivars. The single-cut clovers, however, were found to survive the first winter
much better than double-cut cultivars. They suggested that since single-cut cultivars can yield
equally well as double-cut cultivars when harvested twice yearly, more work should be done to assess
the potential of single-cut cultivars for use in Atlantic Canada.

"Florex", a double-cut cultivar, is used as a check in screening trials in the region and can
produce yields as high as 9.7 t/ha (Christie and Sterling, 1991). "Marino", a diploid, double-cut
red clover developed in East Germany, is well adapted to Eastern Canada and was licensed in
this country in 1986 (Choo et al., 1987). Marino has recently replaced "Prosper I" as a check
cultivar for the Atlantic region. Choo et al. (1987) examined the performance of Marino and
found it outyielded Prosper 1 by 9.7% (average of 36 location-years) and Florex by 8.6%
(average of 21 location-years). Red clover screening trials are being conducted at the
Charlottetown and Fredericton Research Stations, the Napan Experimental Farm and at the Nova
Scotia Agricultural College and include several entries which were developed at the
Charlottetown Research Station.

Winterkilling is a major production problem for red clover in Atlantic Canada. Researchers are looking at mechanisms of and factors associated with winter survival (Choo,
1983; Choo and Suzuki, 1983a and b; Bubar, 1986; MacLean and Nowak, 1989; Christie and
Choo, 1991 a; Nowak, 1991; Nowak et al., 1992) as well as breeding strains with increased cold
tolerance (Nowak and McLean, 1992). Other factors associated with lack of persistence in red
clover include root-feeding insects (Thompson, 1966, 1989; Thompson and Willis, 1967), root
and crown rots (Willis, 1965b, 1966b; Porth, 1979; Nowak, 1992), internal breakdown (Willis,
1966a) and viruses (Willis, 1965a). Willis (1965a) reviewed the diseases affecting red clover in
Prince Edward Island.
Another major research effort with red clover in the Atlantic region has involved the effects of soil nematodes on productivity and persistence. The root lesion nematode (Pratylenchus penetrans L.) and its infestation of red clover has been studied extensively (Willis and Thompson, 1967, 1969; Thompson and Willis, 1969, 1970a, 1971 a and b, 1975; Willis et al., 1971, 1982; Willis, 1976x; Kimpinski et al., 1984, 1988x, 1992; Kimpinski and Kunelius, 1987x, 1988; Kunelius et al., 1988; Kimpinski, 1992).

3.1.2.3 White Clover

(Trifolium repens L.) is the most important pasture legume in Atlantic Canada and it is primarily used in mixture with grasses. It has a high potential as a forage crop because of its palatability, high protein content, excellent regrowth and nitrogen fixing capabilities (Fraser, 1.986c). White clover is also an excellent source of minerals, being especially rich in Na, P, Cl and Mo (Leffel and Gibson, 1973). Lirette et al. (1993) found white clover to make good, high quality silage that was superior to alfalfa and comparable to red clover silages. It was superior in regards to chemical composition, but it was difficult to grow and ensile under Nova Scotia conditions. Fraser (1986c) prepared a set of general management guidelines for white clover in' the Atlantic provinces.

White clover is classified into 3 distinct types based on leaf size. "Wild" or naturalized white clovers have the smallest leaves and are generally found in many older pastures. These plants are very persistent, having evolved under continuous grazing conditions, but they are not as productive as the larger-leaved cultivars. The intermediate type of white clover has greater forage production and is typified by the recommended cultivars "Sonja" and "Milkanova". The large leaf or Ladino type clovers are more productive than the other two types but they are
difficult to maintain because of their poor winter hardiness (A.A.C.C.P.C.F.C., 1991). "Sacramento" is the recommended Ladino cultivar for the Atlantic region. Regional trials evaluating these cultivars with orchardgrass produced yields up to 9.9, 10.3 and 9.9 t/ha for Sonja, Milkanova and Sacramento, respectively (Fraser, 1986b, 1989b).

Naturalized white clover is widely distributed in the Atlantic Provinces (Fraser, 1989x). It dominates old native pastures on a variety of soil types where it coexists with bentgrasses (Agrostis spp.) and bluegrasses (Pox spp.). Fraser (1989x) has identified several ecotypes in the region and documented considerable variation in their growth habit. Christie (1991) subsequently conducted similar work on Prince Edward Island. Fraser (1988, 1988x, 1991) also examined differences in naturalized populations and cultivars and suggested that natural ecotypes would be useful as germplasm for plant breeding. There is a need to develop improved winter hardy cultivars for the region.

White clover varieties and ecotypes have been evaluated in monoculture (Fraser, 1988x) and in mixtures with grasses, particularly for pasture use (Fraser, 1987b; Papadopoulos et al., 1992b). Fraser (1987b) found Sonja white clover/Kenhy tall fescue produced the highest DM yields (9.2 to 9.5 t/ha) followed by Ladino/orchardgrass (8.8 to 9.1 t/ha). Papadopoulos et al. (1992b) found that orchardgrass/white clover swards resulted in excellent livestock gains (up to 0.23 kg/day). Researchers have also examined floral development (Fraser, 1991; Retallack et al., 1990), nitrogen fixation (Vessey and Patriquin, 1984), cyanogenesis (Fraser, 1986x, 1987x; Fraser and Nowak, 1988) and the role of polyamines in cold hardiness of white clover (MacLeod and Nowak, 1990).

3.1.2.4 Birdsfoot trefoil
(Lotus corniculatus L.) is a perennial legume that can be used for pasture, hay and silage. It produces a very digestible forage with high levels of protein, it is adaptable to a wide range of soil types and conditions and it can be very long-lived if properly managed. It tolerates wet soil and has good drought resistance (Grant, 1964x). Two cultivars, "Leo" and "Empire", are currently recommended for the Atlantic region.

Trefoil makes excellent hay or silage that equals that made from alfalfa and other legumes. Birdsfoot trefoil pasture does not cause bloat in cattle or sheep, it is low in estrogens that cause breeding problems and it retains good feed quality when plants go to seed (Langille and Bubar, 1965). Intensive grazing restricts persistence but carefully controlled rotational grazing will result in adequate regrowth (Black, 1967; Langille and Bubar, 1965). Langille and Bubar (1965) prepared a publication outlining establishment and management guidelines for the crop.

Birdsfoot trefoil is of widely used in the Atlantic Provinces at present but it has good potential if it is carefully managed. The major problem with birdsfoot trefoil production is stand establishment. Factors contributing to this problem are poor seedling vigour and poor competition with weeds and grasses. Papadopoulos et al. (1992c) conducted greenhouse and field studies to test improved seedling vigour selection techniques by comparing selected and non-selected synthetics with their parent genotypes. The synthetics had been selected from pure or mixed sward (interseeded with bromegrass) growing conditions. They found these techniques to be effective in assessing and improving establishment year seedling vigour in one cycle of recurrent selection and that selection was more efficient under monoculture conditions than mixture. Sutherland (1993) completed a MSc thesis on this research and reported total DM yield of selected synthetics exceeded base population and random synthetics by 23% and 7%, respectively. Synthetics derived from monoculture had 21% higher total DM yield and 10% better root ratings
than synthetics derived from mixtures. Nowak et al. (1992b) developed in vitro methodology for the selection of birdsfoot trefoil with upgraded seedling competitiveness.

A small amount of nitrogen fertilizer is often recommended when seeding pure forage legumes to improve their early growth. Such applications on birdsfoot trefoil, however, greatly increase the growth of weeds which can severely suppress young trefoil (Kunelius, 1974b). Kunelius (1974b) examined the effect of rate of nitrogen fertilization on the growth and nodulation of trefoil under three weed control methods. From this study, he concluded that applied nitrogen may improve seedling growth only where the soil nitrogen level is low and if weed infestation is very minimal.

Studies were conducted on birdsfoot trefoil at Napan to determine the species' potential and suitable management practices for the region (Langille et al., 1968; Langille and Calder, 1971). These studies examined the effects of harvest practices on yield, carbohydrate reserves, etiolated regrowth, potassium uptake, foliage and root development, digestibility, cold hardiness and nodulation. Both studies found the variety Empire to be a slightly superior pasture legume to Viking in persistence. Frequent cutting (3 or 4 cut systems) was found to reduce total yield and contribution to the sward. Total available carbohydrates (TAC) in the roots were found to remain at low levels under each management (means of 41.9, 29.1 and 16.4% of DM in 1964, 1965 and 1966, respectively) until restored during the fall months (Langille et al., 1968). Plants harvested at different growth stages exhibited the same responses to cold hardiness tests. Etiolated regrowth, root weight and nodulation were greatest when harvested at maximum growth stage. Results from greenhouse experiments were in agreement with results from the field experiments (Langille et al., 1968; Langille and Calder, 1971).
3.1.2.5 Alsike Clover

(Trifolium hybridum L.) is a perennial clover that is often treated agriculturally as a biennial. It is adapted to a wide range of soil types and it will grow on wet, acid soils. It is a medium height clover but has smaller leaves and flowers than Ladino clover. It is not a very long-lived species and is not generally recommended for perennial mixtures. It is particularly useful in short rotations for improving soil structure and fertility and may have potential if combined with annual ryegrass (Elliott and Pankiw, 1972; A.A.C.C.P.C.F.C., 1991). It makes excellent hay and silage and good yields are obtainable (up to 6.8 t/ha; Coulson, 1978) under optimum conditions but are not consistent from year to year.

Both diploid (2n=16) and tetraploid (4n=32) types of alsike clover are grown in Canada although the common type is diploid. Tetraploids are formed when plant breeders double the number of chromosomes by treating the plants with chemicals or x-rays (Elliott and Pankiw, 1972). They are taller, have larger leaves and blossoms and flower later than the diploids. They can have higher yields in some areas.

3.1.2.6 Sweet clover

(Melilotus albs L.) is a tall, coarse legume that thrives under a wide range of soil and climatic conditions. It is an excellent soil-improving crop and is used for green manure, winter cover and to improve the physical condition of the soil. Its deep taproot system which reaches 2 feet or more increases aeration in the subsoil, provides nutrients for succeeding crops and adds organic matter to the subsoil (Gorz and Smith, 1973; MacMillan and Buchanan,
1987). It also has good topgrowth which decays rapidly when plowed down at the right time (MacMillan, 1981). Its major restriction is that it will not grow well on acid soils.

Sweet clover contains coumarins (aromatic compounds which give the plant its characteristic odor) which may cause "sweet clover bleeding disease" and so it is recommended to ensure conserved sweet clover is not mouldy when used for livestock feed (A.A.C.C.P.C.F.C., 1991). When the plant is chewed by animals, coumarin is liberated and produces an undesirable taste which reduces intake. During heating and spoilage in sweet clover hay or silage, coumarin is converted to a toxic substance which reduces blood clotting. Animals who ingest this toxin may bleed to death from small wounds or internal haemorrhages (Gorz and Smith, 1973). Low coumarin cultivars have been tested but do not survive well in the Atlantic Provinces.

MacMillan and Buchanan (1987) conducted a study to assess the use of sweet clover and other deep-rooted crops as soil conditioners. As well as their soil improving capabilities, they looked at ease of establishment, adaptability to various soil conditions, value as livestock feed and as bee pasture. They found sweet clover to be adaptable to most soil conditions although it performed best with pH of 6.0 or higher. They rated it close to alfalfa as livestock feed and very promising with more palatable, low coumarin varieties (MacMillan and Buchanan, 1987).

3.1.2.7 Zigzag clover

(Trifolium medium L.) is a polyploid, perennial species that resembles red clover. It is generally more persistent and winter hardy than red clover but has not been commonly grown in the Maritimes due to poor seed production (Choo, 1981). A study begun at the Charlottetown Research Station in 1979 (Choo, 1981) found that Zigzag clover flowered later than Ottawa red clover, survived better, but did not compete well with the double-cut variety of red clover and did not yield as well (Table 5).
Robinson and Bubar (1981) discovered high levels of the isoflavone formononetin in a sample of zigzag clover at the Nova Scotia Agricultural College; 1.36% vs. 0.003-0.005% in

<table>
<thead>
<tr>
<th>Clover</th>
<th>Flowering (%)</th>
<th>Winter survival (%)</th>
<th>Dry matter yield (t/ha)</th>
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<tr>
<td></td>
<td>July 11/80</td>
<td>May 15/80</td>
<td>June 5/81</td>
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<tr>
<td>St. Hyacinthe strain</td>
<td>20</td>
<td>93</td>
<td>65</td>
</tr>
<tr>
<td>Beaverlodge strain</td>
<td>13</td>
<td>95</td>
<td>58</td>
</tr>
<tr>
<td>St. Hyacinthe strain + Ottawa red clover (1:1)</td>
<td>100</td>
<td>90</td>
<td>36</td>
</tr>
<tr>
<td>Beaverlodge strain + Ottawa red clover (1:1)</td>
<td>100</td>
<td>88</td>
<td>29</td>
</tr>
<tr>
<td>Ottawa red clover</td>
<td>100</td>
<td>93</td>
<td>38</td>
</tr>
</tbody>
</table>

Reproduced from Choo (1981).
other legumes. Isoflavones are estrogenic compounds that can affect reproduction in livestock. They suggested that any breeding work on the species consider examining this characteristic and perhaps aim at reducing the problem during the breeding work.

Christie and Choo (1991b) released a very winter hardy zigzag clover germplasm, CRS-Z-1, in 1991. It was obtained by crossing 2 local strains found on Prince Edward Island. Choo (1979) documented the origins of one of the strains, Simpson's zigzag clover which was discovered on a local farm in 1892. The second strain was discovered by Research Station scientist J.D.E. Sterling in 1979. Tests were conducted to compare CRS-Z-1 with several strains of red clover and with alfalfa and birdsfoot trefoil; CRS-Z-1 proved to be the most winter hardy and persistent (Christie and Choo, 1991b).

3.1.2.8 Sainfoin

(Onobrychis viciaefolia Scop.) is a perennial legume that is well adapted to most areas of western Canada where alfalfa is grown (Hanna et al., 1977). It does not cause bloat in ruminants and it is relatively free from serious disease and insect problems (Hanna et al., 1977). During assessment of sainfoin in the Atlantic region, extensive mortality was observed in a new seeding (Willis, 1976b). Willis (1976b) conducted a study to determine the susceptibility of several cultivars to the northern root knot nematode (Meloidogyne hapla Chitwood). He found that all cultivars were highly susceptible to M. hapla and even more susceptible than red clover. Damage from M. hapla was not a problem in western Canada.

3.1.2.9 Big trefoil
(Lotus pedunculatus L.) is a forage legume that grows well on very acid and low fertility soils, although it does not produce high yields or high quality herbage (Suzuki, 1983). It performed well on unlimed soil but took 15 months to establish with no yield during this period.

3.1.3 Mixtures

Legume-grass mixtures are sown on the majority of forage hectarage in eastern Canada. Mixtures are preferred to pure stands because they combine the advantages of both types of forages. Grasses have fibrous root systems which are useful in erosion control, they are more competitive with weeds, they spread easily and are able to maintain full stands and they are seldom winterkilled. Legumes in mixtures with grass make better quality feed than pure grass stands. Legumes are beneficial as they contain more crude protein than grasses and they have nitrogen-fixing capabilities which improve yield and soil structure and provide nitrogen for subsequent crops (A.A.C.C.P.C.F.C., 1991). Kayler (1988) found that alfalfa, red and alsike clover performed better and persisted longer in mixture with a hardy grass such as timothy than when seeded alone.

Simple mixtures are most often recommended as they are more productive than complex mixtures. Species should be chosen to suit the conditions under which the mixture will be grown. Complex mixtures can provide for continued production throughout the season, more nutritionally balanced feed and increased voluntary intake but they also have problems with competition and decreased overall yield (A.A.C.C.P.C.F.C., 1991). An important feature of species selection for mixtures is compatibility. Care must be taken to select species that are suited to intended use;
will not compete too strongly with each other and depress yield; and will reach maturity at the
desired time. Legumes should reach first flower when the grass -starts to head to ensure

Proper liming and fertilization are essential to attain good yields and to maintain a
favourable species balance in grass/legume mixtures (MacLeod, L.B., 1965c; MacLeod, L.B. et
al., 1965b; MacLeod, L.B. and MacLeod, 1974b; Gupta and Kunelius, 1980). Competition for
space and nutrients, particularly nitrogen and potassium, has been known to limit the total yield
of mixtures and has been investigated by several researchers (MacLeod, L.B. and Bradfield, 1963;
MacLeod, L.B. et al., 1964; MacLeod, L.R, 1965c). Competition may also occur among plants
for light, water, oxygen and carbon dioxide. Harvest stage, cutting frequency and cutting height
also play a major role in yield and quality of forage mixtures. Frequent cutting often results in
reduced total yield. Langille and Warren (1962) found that frequent clipping reduced root
production and suggested this was the cause of yield reduction. An earlier study saw overall
yield reduced and definite differences in the persistence of each species (Langille and Warren,
1961).

Alfalfa/grass mixtures are most commonly recommended for hay or haylage on well
drained soils and red clover/grass mixtures for imperfectly drained soils in the Atlantic Provinces
(A.A.C.C.P.C.F.C., 1991). Alfalfa/timothy and alfalfa/bromegrass mixtures make excellent hay,
fresh cut forage and high value silage (Kunelius et al., 1975; Kayler, 1989). Langille and Warren
(1962) reported an alfalfa/bromegrass mixture produced the greatest total yield, while the grass
fraction of an orchardgrass/alfalfa mixture was 25% higher than the timothy and almost 150%
higher than the bromegrass mixture. Kunelius and Narasimhalu (1983) found that annual
ryegrass/legume mixtures had 15 to 52% greater DM yields than legumes grown in monoculture. White clover is the legume of choice for pasture mixtures while the grass component is dependent on grazing system as well as soil condition. Fraser (1987b) examined the productivity of white clover/grass mixtures and found that white clover was compatible with the recommended pasture grasses and that mixtures could provide excellent quality pasture for grazing livestock (Fraser, 1987b).

3.2 Annual Forage Species and Their Characteristics

Permanent, long-term pastures in temperate regions typically produce high levels of forage in late spring and early summer, with frequent shortages of herbage resulting after mid-summer. Alternative sources of forage are required at this time to maintain the performance of grazing livestock (Kunelius and Sanderson, 1989). Annual crops can be used to supplement perennial forages during this later part of the growing season. Annuals are also useful to replace perennial forages which are winterkilled and may also be used for soil conditioning in cash crop rotations and as cover crops for cereals.

3.2.1 Persian Clover

(Trifolium resupinatum L.) is a relatively new clover for the Atlantic region and has shown promise as an annual legume. It acts as an annual under Maritime conditions and is most commonly included in mixtures of annual ryegrass for pasture or silage (A.A.C.C.P.C.F.C., 1991). It has good seedling vigour, produces good yields (3.7 to 8.8 t/ha; Coulson, 1986, 1987) and grows well under cool temperatures (Kunelius and Narasimhalu, 1983; Kunelius and Coulson, 1989b). "Felix" has been the highest yielding cultivar in variety trials in the region since 1981 (up to 8.8 t/ha; Coulson, 1986).
Kunelius and Narasimhalu (1983) grew Persian clover and other legumes in monoculture and in mixture with Italian and Westerwolds ryegrasses to examine the yield and quality of ryegrass-legume mixtures when grown as summer annuals. Persian clover yielded better than red clover, alfalfa and birdsfoot trefoil, in both monoculture and mixture (Table 6). Annual ryegrasses require large amounts of nitrogen for good yields. This study suggested that the addition of Persian clover to Italian ryegrass could provide considerable cost savings to farmers (Kunelius and Narasimhalu, 1983).

3.2.2 Subterranean Clover

(Trifolium subterraneum L.) is a low growing annual clover that can produce yields ranging from 3.4 t/ha (Coulson, 1988) to 7.0 t/ha (Coulson, 1986) in the Atlantic region. Several varieties were evaluated with red and Persian clovers and showed promise as an underseeded legume with barley (Kunelius and Coulson, 1983).

3.2.3 Annual Medics

(Medicago spp.) The use of annual legumes in Atlantic Canada is very limited. They are more commonly grown in tropic climates which have a distinct and reliable wet season followed by a reliable dry season (Martin et al., 1992b). Annual medics (Medicago- spp.) are native to Western Asia and the Mediterranean countries where they grow as winter annuals (Reed et al., 1989). Recently, sixteen annual legume species, including medics, clovers (Trifolium spp.) and vetches (Yicia spp.), were brought from Turkey to Truro, Nova Scotia to evaluate their potential as annual legumes for Atlantic Canada (Martin, R.C. et al., 1992b; Altinok, Unpubl.).

<p>| Table 6. Total dry matter yields (t/ha) of legumes and annual ryegrasses grown in monoculture and mixtures² |</p>
<table>
<thead>
<tr>
<th>Species</th>
<th>Monoculture</th>
<th>Legume Italian Ryegrass +</th>
<th>Legume Westerwolds ryegrass +</th>
</tr>
</thead>
<tbody>
<tr>
<td>Persian clover</td>
<td>7.1</td>
<td>8.2</td>
<td>8.2</td>
</tr>
<tr>
<td>Red clover</td>
<td>5.9</td>
<td>7.0</td>
<td>7.8</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>5.2</td>
<td>6.1</td>
<td>6.5</td>
</tr>
<tr>
<td>Birdsfoot trefoil</td>
<td>4.0</td>
<td>4.9</td>
<td>6.1</td>
</tr>
<tr>
<td>Italian ryegrassy</td>
<td>9.8</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Westerwolds ryegrassy</td>
<td>11.8</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Westerwolds ryegrass, no N</td>
<td>6.0</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

*Reproduced from Kunelius and Narasimhalu (1983a)

*NH₄NO₃ applied at plant emergence, and after cuts 1 and 2 at 75 kg/ha/ application
The annual medics and clovers showed excellent vegetative growth under Truro conditions, better in fact than their performance in Turkey, while vetches had good yields but poor regrowth (Altinok, Unpubl.). Seed production was low for all species. These Mediterranean species, along with several perennial legumes, were evaluated for agronomic potential as intercrops with barley (Martin et al., 1992b). Intercropping of legumes with cereals can reduce competition for soil nitrogen (Searle et al., 1981) and provide for nitrogen transfer from legumes to non-legumes (Martin et al., 1991). This research is also the basis of a Master's thesis in progress at the Nova Scotia Agricultural College (Sampson, Unpubl.).

3.2.4 Italian and Westerwolds Ryegrasses

(Lolium multiflorum Lam.), collectively known as annual ryegrasses, are important summer annual forage species in the Atlantic Provinces. Their growth pattern makes them suitable for mid- to late-season production which provides much needed forage for livestock (Kunelius, 1978b). Italian ryegrass remains vegetative during the seeding year and its leafy herbage is best suited for pasture use (Narasimhalu et al., 1992b). Westerwolds ryegrass produces seed-bearing tillers in the seeding year, which results in tall, upright stands suitable for conserved forage, green chop, pasture and cover crop (Kunelius, 1980).

Italian ryegrass is a biennial from northern Italy and Westerwolds ryegrass is an annual that was developed from Italian ryegrass in Holland by selection of plants that produced seed in the year of sowing (Kunelius, 1991 a). They are well adapted to the soil and climatic conditions in Atlantic Canada where they both perform as annuals. Eight cultivars are currently recommended (Table 7). A publication prepared by Kunelius (1991a) for Agriculture Canada contains information on cultivars; establishment and management; use as pasture, hay, haylage,
Table 7.  Recommended cultivars of annual ryegrasses for the Atlantic Provinces in 1990

<table>
<thead>
<tr>
<th>Cultivar (Ploidy)</th>
<th>Use</th>
<th>Dry matter</th>
<th></th>
<th></th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Yield (%)</td>
<td>Digestability (%)</td>
<td>Crude Protein (%)</td>
<td></td>
</tr>
<tr>
<td>Barmultra (tetraploid)</td>
<td>Pasture plow under</td>
<td>97</td>
<td>75</td>
<td>16</td>
<td>Leafy, satisfactory grazing tolerance</td>
</tr>
<tr>
<td>Bartolini (diploid)</td>
<td>Pasture plow under</td>
<td>99</td>
<td>76</td>
<td>16</td>
<td>Persistent under grazing</td>
</tr>
<tr>
<td>Lemtal (diploid)</td>
<td>Pasture plow under</td>
<td>100&lt;sup&gt;y&lt;/sup&gt;</td>
<td>76</td>
<td>16</td>
<td>Persistent under grazing, overwinters under favorable conditions</td>
</tr>
<tr>
<td>Maris Ledger (tetraploid)</td>
<td>Pasture plow under</td>
<td>104</td>
<td>79</td>
<td>16</td>
<td>Unsuitable for close grazing</td>
</tr>
<tr>
<td>Aubade (tetraploid)</td>
<td>Silage Pasture</td>
<td>119</td>
<td>64</td>
<td>15</td>
<td>Stemmy, suitable for cutting then for grazing</td>
</tr>
<tr>
<td>Barspectra (tetraploid)</td>
<td>Silage Pasture</td>
<td>111</td>
<td>68</td>
<td>15</td>
<td>Stemmy, used for cutting and grazing</td>
</tr>
<tr>
<td>Marshall (diploid)</td>
<td>Silage Hay Pasture</td>
<td>120</td>
<td>61</td>
<td>14</td>
<td>Very stemmy, slow regrowth in fall</td>
</tr>
<tr>
<td>Promenade (tetraploid)</td>
<td>Silage Pasture Plow under</td>
<td>104</td>
<td>71</td>
<td>16</td>
<td>Intermediate between leafy Italian and stemmy Westerwolds ryegrass</td>
</tr>
</tbody>
</table>

<sup>z</sup>Reproduced from Kunelius (1991).
<sup>y</sup>Dry matter yield under cutting, 8.7 t/ha = 100%.
cover and soil improvement crops; and seed production.

Dr. H.T. Kunelius of the Charlottetown Research Station, in conjunction with other Atlantic research scientists, has conducted a great deal of work on annual ryegrasses. The results of variety evaluation and management experiments are published in the Charlottetown Research Station Reports from 1972 to 1989. Wilson (1987) evaluated annual ryegrass/cereal/legume mixtures for use as haylages and found that adding Leger barley to Promenade ryegrass nearly tripled first cut yield of Promenade alone. The effects of nitrogen fertilization and harvest schedules on yield and quality of ryegrasses were examined by Kunelius (1980) and Kunelius and Calder (1978) because of the limited information at the time on annual ryegrasses grown in Atlantic Canada. The use of legumes in mixture with annual ryegrasses was investigated by Kunelius and Narasimhalu (1983). They found the mixtures increased dry matter yields from 15 to 52% over legumes grown in monocultures (Table 6). Nitrogen provided by the legumes may be useful in lowering the cost of ryegrass production.

Several Canadex bulletins have been published with information on management, seed production and use as soil conditioners (Kunelius, 1976, 1978a, b, and d; Kunelius and Coulson, 1984; Kunelius et al., 1984a). Kunelius et al. (1985) compared four establishment methods on the yield, herbage quality and soil compaction of Italian ryegrass. Burgess and Kunelius (1982) compared native and Italian ryegrass pasture for field and dairy cow productivity and preliminary results showed that Italian ryegrass responded best to intensive management systems with high levels of fertilization. The ryegrass stood up to intensive grazing and was readily consumed, but cows showed low milk fat levels and needed to be supplemented with hay. McLean (1983) evaluated the potential of annual ryegrasses for use as forage in New Brunswick and found
“Lemyal” and “Aubade” had higher yields (3.7 and 4.1 t/ha) and protein content (668.8 and 747.0 kg/ha DM) than Iroquois alfalfa, “Leo” birdsfoot trefoil, “Ottawa” red clover and triple mix (from 0.9-1.0 t/ha DM yield and 158.8-195.0 kg/ha DM) in the seeding year.

Several studies have examined the usefulness of annual ryegrasses as silage. In a study to determine dry matter yield and composition and utilization of silage by sheep, Narasimhalu et al. (1992b) found that Italian ryegrasses were superior in comparison with the Westerwolds on basis of composition, ingestibility and digestibility but that Westerwolds ryegrasses matured faster and yielded more than Italian ryegrasses (6.4 vs. 5.1 t/ha). Other studies by Narasimhalu et al. (1985) on annual ryegrass and timothy silages had similar results. McIsaac and Lovering (1982a) found that timothy hay was more profitable than corn silage or ryegrass silage as conserved forages for dairy cows.

The use of annual ryegrasses as spring-seeded cover crops for cereals (Edwards, 1986, 1988, 1992; Kunelius et al., 1992) and fall-seeded with grain (Edwards and Sadler, 1992) for rotation with potatoes has been investigated by researchers at the Charlottetown Research Station. Cover crops help to prevent soil erosion and winterkill. Rotation crops are planted to prevent build-up of soil-borne pathogens, maintain soil structure and provide ground cover (Kunelius et al., 1992). An advantage of using annual ryegrasses in rotation with potatoes is that they appear to be less susceptible to root lesion nematodes (Pratylenchus penetrans) than are red clover and timothy (Kimpinski and Kunelius, 1982).

3.2.5 Corn

(Zea mays L.) is an important, high yielding and high energy supplement for livestock feed in the Maritime Provinces (A.A.C.C.P.C.F.C., 1991). Corn is one of the most
widely grown annual forage crops in Canada and can be used for green chop, silage and high-moisture grain silage (Langille and Warren, 1966). Corn silage is an excellent feed for cattle and combines well with high protein forages in the diet. Silage corn produces more total digestible nutrients per unit area than other locally-grown forage crops, it is highly palatable and is very high in energy (A.A.C.C.P.C.F.C., 1991).

A major restraint to corn production in Atlantic Canada today is the difficulty associated with obtaining a mature crop at harvest. For this reason, investigators are evaluating hybrids for suitability for the region. The Atlantic Com Hybrid Evaluation Committee has prepared a publication that stresses the importance of hybrid selection and presents the results of silage and grain corn trials conducted from 1986 to 1991 and presently recommended varieties (A.C.H.E.C., 1992).

Some early work on silage corn was conducted by R.P. White (1976, 1977) on Prince Edward Island. He examined the effects of plant population and planting dates on yield and maturity and found that 50,000-80,000 plants/ha produced the best yields but that populations of 50,000-60,000 plants/ha could result in stronger plants with more advanced maturity (White, 1976). Mid-May planting was found to be best suited to Prince Edward Island and Nova Scotia conditions; sufficient maturity was obtained although germination at this time was slow (White, 1976; Papadopoulos, 1991, Unpubl. Data). If germination could be improved at these early plantings, it was felt that yields of silage corn could be greatly increased (White, 1977).

3.2.6 Cereal Crops

Cereal crops are often grown in the Atlantic Provinces for supplemental grazing, green chop or
silage. Oats, fall and winter rye, wheat and barley have been the most common species used. Spring cereals can be grown for summer or fall grazing and winter cereals can be grown for fall or spring grazing (Rayment, A.F., 1961). Cereal crops are suitable for ensiling due to their high water-soluble carbohydrate levels, low buffering capacity and easily controlled moisture content (A.A.C.C.P.C.F.C., 1991). Cereals can also be grown alone (Kayler, 1990) or undersown to forages as a cover crop. The cereal can be harvested as silage while the forage is left for grazing and the cereal lodging helps prevent forage stand damage (A.A.C.C.P.C.F.C., 1991). Barley added to annual ryegrass nearly tripled the yield of ryegrass grown alone for haylage (Wilson, 1987).

A number of investigative studies on cereal forages were conducted during the 1960s and early 1970s at Atlantic Research Stations. These dealt with yield and quality evaluation (Langille, 1961c; Grant, 1969; Langille and Calder, 1975), performance as silage (Langille, 1969a and b) and pasture (Langille, 1961a, 1962a), effect of seeding date (Smeltzer, 1970), nitrogen fertilization (Nass et al., 1975), cutting dates and frequency (Warren, 1960a, 1961; Riordon, 1961; Langille, 1962c; Riordan, 1962; Warren et al., 1963, 1964b; Warren and Langille, 1965), influence as companion crops for forages (Warren et al., 1964a; Warren, 1965a and b) and feed value (Burgess et al., 1972).

### 3.2.7 Green Fodder Crops

Green fodder crops include the forage brassicas such as kale (Brassica oleracea L.), rape (B. napus L.) and stubble turnips (B. rapa L.) and fodder beets (Beta vulgaris L.). These crops are frost-tolerant, have excellent yield, maintain feed quality and provide late season grazing (Langille
et al., 1985; A.A.C.C.P.C.F.C., 1991; Kunelius, 1991b). Due to increased interest in the mid-1980s for fodder crops for late season grazing, extensive testing was carried out at Atlantic Research Stations. Kunelius (1991b) prepared a bulletin outlining recommended cultivars and information on management.

Forage rape is a rapid-growing crop that can withstand early frost (Langille and Warren, 1966). It may be used for green chop or pasture from mid-August and well into November. Yields from 5.5 to 7.9 t/ha (Kunelius and Coulson, 1983a; Kunelius and Sanderson, 1989) and crude protein levels of 9.4% (Kunelius 1984a) have been reported. Kale is similar to rape in appearance and use. It can also be used for green chop or pasture and yields of 4.9 to 10.5 t/ha have been reported (Kunelius and Coulson, 1983a; Kunelius, 1984a; Kunelius et al., 1989). It does not, however, recover as well as rape (Langille and Warren, 1966). Kale requires a long growing season (90-100 days) but its resistance to frost enables it to be grazed until December (Kunelius, 1988). Stubble turnips are fast-growing crops that have large leaves and a root bulb, of which three quarters lies above ground and is readily grazed by livestock (A.A.C.C.P.C.F.C., 1991; Kunelius, 1991b). Hybrids are leafier with little or no root bulb and can be used for green manure and ground cover (Kunelius, 1991b). Kunelius (1991) reported on average yields, protein and digestibility values for kale, rape and stubble turnips (Table 8). Fodder beets can be grazed until mid-November for best results (Winter and Kunelius, 1987) and the bulb can be harvested and stored. It is a high yielding crop with a high energy content (A.A.C.C.P.C.F.C., 1991).

A study by Kunelius et al. (1987b) found that early planting was more advantageous to kale than to rape, radish (Raphanus sativus L.), or turnips. Seeding in mid-August reduced primary growth yields by 90, 25, 38 and 25%, for kale, rape, radish and turnip, respectively.
Table 8. Average yields and quality of kale, rape and stubble turnip

<table>
<thead>
<tr>
<th>Crop</th>
<th>Dry matter (t/ha)</th>
<th>Protein (%)</th>
<th>Digestibility (%)</th>
<th>s-methylcysteine sulphoxide (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kale</td>
<td>9.8</td>
<td>14</td>
<td>14</td>
<td>85</td>
</tr>
<tr>
<td>Rape</td>
<td>8.1</td>
<td>12</td>
<td>16</td>
<td>82</td>
</tr>
<tr>
<td>Stubble</td>
<td>7.5''</td>
<td>10</td>
<td>16</td>
<td>85</td>
</tr>
</tbody>
</table>

Langille (1960) found that row seeding was much more productive for both rape and kale than broadcast seeding. Kale harvested between September and December provided highly digestible feed, until early December with dry matter declining in early November, and adequate mineral composition to satisfy the dietary requirements of ruminants with the exception of Cu, Mn and Zn (Kunelius et al., 1989b). Under a similar regime, rape had dry matter yields that increased to late October and then remained unchanged until early December and concentrations of P, S, Cu, Mn and Zn were not adequate for the requirements of beef or sheep (Kunelius and Sanderson, 1989). Effective weed control, a major limitation to fodder crop establishment, was addressed by McCully and McLean (1988). They found that Trifluralin could be safely applied on kale, rape and turnips, but not beets.

3.2.8 Other Annual Forage Species

Several other annual species that have been used for forage in the past are Swedes, mangels, vetches, peas, millet and sunflowers. Swedes and mangels were very common crops for use as winter feed for livestock before the advent of grass silage in the 1950s. Root crops are particularly well suited to Atlantic Canada soil and climatic conditions and almost every farm grew them to some extent. A great deal of research was conducted on swedes at Atlantic Research Stations, with emphasis on variety testing and breeding for yield improvement and disease resistance (Warren, 1957). The variety Chignecto, developed at the Nappan Experimental Farm in 1942, had excellent yields and superior resistance to clubroot (Warren and Langille, 1961). The inheritance of flesh colour and clubroot reaction was investigated by Sterling (1951). Warren (1960b) reviewed swede research at the Nappan Experimental Farm in 1960 at which
time Swede utilization on Canadian farms had dramatically decreased but was still relatively valuable in the Atlantic Provinces.

Peas were very popular for forage at one time and were grown alone or in mixtures with oats and vetches and were suitable for silage or green chop (Langille and Warren, 1966; Langille, 1980). Trials at Nappan found yields as high as 8.9 t/ha, crude protein levels from 15.8 to 23.1% and digestibility from 59.6 to 69.7% (Langille, 1980). Most peas grown today are processed for human consumption. Trials on Prince Edward Island found fodder radish to yield 5.4 to 6.6 t/ha (Kunelius and Coulson, 1983a). Vetches were most commonly grown in mixtures with other annual forages because of their nitrogen fixing capabilities. These mixtures were normally harvested for green chop or silage (Langille and Warren, 1966). Vetch grown with corn, oats, peas and kale yielded up to 5.0 t/ha; vetch, oats and peas, 4.7 t/ha; and vetch and oats, 4.1 t/ha (Langille and Warren, 1966). Grant (1969) evaluated Hungarian and Japanese millets and found yields as high as 6.2 and 6.2 t/ha, respectively, when seeded in June, and 6.2 and 4.9 t/ha when seeded in July. Sunflowers are a very productive crop (3.0 to 7.3 t/ha) but they have poor palatability and high labour costs (Langille and Warren, 1966). They were evaluated at Atlantic Research Stations for use as silage, in monoculture and in mixture with corn.

3.3 Cultivar Evaluation

The Forage Variety Evaluation Sub-Committee of the Advisory Committee on Forage Crops is responsible for recommendations on forage crops that are published in the Atlantic Provinces Field Crop Guide' and Guide to Variety and Pesticide Selection (A.A.C.C.P.C.F.C., 1991, 1992) which are distributed by the four Atlantic Provincial Agriculture Departments. Evaluation trials are conducted by the Atlantic Agriculture Canada Research Stations, the Provincial Agriculture
Departments and the Nova Scotia Agricultural College. This trial information, in addition to being reported in the respective agencies' research reports, is also assembled by the Forage Sub-Committee and presented as the Forage Evaluators Reports. This report has been published continuously since 1971, originally as the Atlantic Field Crops Committee, Forage Sub-Committee, Report of Field Trials. Each forage crop is assigned to an individual who is responsible for coordinating the trials. The report is currently compiled by N.N. Coulson at the Charlottetown Research Station. Recommended forage crop varieties for the region are updated and published in this report each year. A list of the species evaluated, their respective coordinators and the years in which data was available is presented in Table 9.

A project was recently commissioned by the Atlantic Advisory Committee on Forage Crops and initiated under the leadership of the Regional Statistician at the Kentville Research Station of Agriculture Canada to develop statistical methods for evaluating the stability of perennial crops (alfalfa initially), to develop a computer record system, and to propose procedures for making recommendations (McRae, 1991). This Atlantic Forage Cultivar Evaluation System (AFCES) has been proposed as a means of determining the performance of perennial forage cultivars over years. While the yearly evaluation trials provide valuable information on yield, the ability of forage cultivars to persist over years is also an important factor to consider when selecting crop species. The project is administered by the N.S. Crop Development Institute with funding from the four Atlantic Provinces.

Table 9. Forage species included in Forage Evaluators Reports, years of recorded Field trial data and current coordinator

| Forage species included in Forage Evaluators Reports, years of recorded Field trial data and current coordinator | |
|---|---|---|---|---|---|
| |

<table>
<thead>
<tr>
<th>Crop</th>
<th>Years of Data Available</th>
<th>Current or Most Recent Coordinator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>1970-Present</td>
<td>B.R. Christie</td>
</tr>
<tr>
<td>Red Clover</td>
<td>1970-Present</td>
<td>B.R. Christie</td>
</tr>
<tr>
<td>Alsike clover</td>
<td>1970-1984</td>
<td>T.M. Choo</td>
</tr>
<tr>
<td>Timothy</td>
<td>1970-Present</td>
<td>R.B. Walton</td>
</tr>
<tr>
<td>Annual ryegrass</td>
<td>1973-1987, 1990-Present</td>
<td>N.N. Coulson</td>
</tr>
<tr>
<td>Kentucky bluegrass</td>
<td>1978-1979, 1982-1983</td>
<td>N.N. Coulson</td>
</tr>
<tr>
<td>Ryegrass X Fescue hybrids</td>
<td>1986-1988</td>
<td>N.N. Coulson</td>
</tr>
<tr>
<td>Meadow foxtail</td>
<td>1982-1983</td>
<td>N.N. Coulson</td>
</tr>
<tr>
<td>Sweet clover</td>
<td>1982</td>
<td>M. Suzuki</td>
</tr>
<tr>
<td>Vetch</td>
<td>1984-1988</td>
<td>N.N. Coulson</td>
</tr>
</tbody>
</table>

Table 9. Forage species included in Forage Evaluators Reports, years of recorded field trial data and current coordinator.
### Annual forages and Leger barley

<table>
<thead>
<tr>
<th>Crop</th>
<th>Years</th>
<th>Coordinator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual forages and Leger barley</td>
<td>1986-1988</td>
<td>N.N. Coulson</td>
</tr>
<tr>
<td>Stubble turnip</td>
<td>1983, 1985-1987</td>
<td>N.N. Coulson</td>
</tr>
<tr>
<td>Fodder radish</td>
<td>1983, 1985-1986</td>
<td>N.N. Coulson</td>
</tr>
<tr>
<td>Fodder beets</td>
<td>1985-1987</td>
<td>N.N. Coulson</td>
</tr>
<tr>
<td>White mustard</td>
<td>1985-1987</td>
<td>N.N. Coulson</td>
</tr>
<tr>
<td>Mangels</td>
<td>1985, 1987</td>
<td>N.N. Coulson</td>
</tr>
<tr>
<td>Forage peas</td>
<td>1984-1985</td>
<td>N.N. Coulson</td>
</tr>
<tr>
<td>Phacelia</td>
<td>1985-1989</td>
<td>N.N. Coulson</td>
</tr>
</tbody>
</table>

Adapted from Forage Evaluators Reports (1970 – 1991)
4.1 Forage Establishment

4.1.1 Methods

Establishing a forage is traditionally achieved by ploughing, disking, harrowing and directly seeding the forage crop. In Atlantic Canada it is common practice to underseed a forage crop with a companion crop, usually a cereal. This method of seeding provides better erosion control, increased haylage or grain straw production in the seeding year and reduced weed growth (A.A.C.C.P.C.F.C., 1991). Forages differ in their compatibility with companion crops. Langille (1966a) compared forage mixtures with and without oats as a companion crop and found red clover to be more productive when established with a companion crop but the percentage grass was generally higher when no companion crop was seeded.

Not all forages adapt well to underseeded situations as the cereals compete for sunlight, nutrients and water and may severely inhibit the establishment and growth of some forage species. Red clover and timothy establish better in underseeded situations than do alfalfa and most grasses (A.A.C.C.P.C.F.C., 1991). Companion crops should be chosen carefully. They should provide sufficient weed control but not discourage forage establishment and they should provide an adequate economic return.

With the development of effective herbicides and increased demand for intensive forage production, companion crops are not as necessary as they once were. The establishment of forage stands without a companion crop (direct seeding) has been found to be a viable alternative for some crops in Atlantic Canada. Kunelius and Suzuki (1973, 1976) found that early seeding,
adequate nitrogen fertilization and weed control produced good dry matter yields of direct-seeded timothy, bromegrass and orchardgrass in the seeding year.

The tillage required for traditional seedbed preparation is time consuming, costly and contributes to soil and water loss. In addition, many fields are not suitable for conventional tillage because of topography, rocks, etc (Walker and Everett, 1979). Newly developed equipment that is capable of properly placing and covering forage seed into existing sod and stubble (Campbell, A.J. and Kunelius, 1983; TerBeek, 1991), and the wide availability of herbicides have allowed for the development of minimum tillage techniques.

Frostseeding involves broadcasting seed in late winter or early spring when the soil surface is honeycombed with ice crystals. The cumulative actions of freezing, thawing and rainfall work the seed to the right depth (Decker et al., 1973). Grant (1961b) compared the effectiveness of frostseeding with drilling techniques for reseeding legumes into an established grass stand. He found both techniques to be equally effective. He concluded that frequent clipping (simulated grazing) was essential to insure maximum seedling establishment. Bosveld (1989) examined the potential of frostseeding white clover as a method of pasture renovation but found no advantage to this seeding method.

Sod seeding is a minimum tillage technique that incorporates seed into an existing sod without conventional cultivation. It is especially useful for the renovation of pastures, periodic reseeding of long-term swards and for the fast establishment of annual forages (Carter and Kunelius, 1989). Early work on pasture improvement by Calder and Warren (1967) concluded that renovation could be accomplished without the use of extensive soil cultivation. Pastures generally require periodic reseeding of legumes to maintain the legume component. A series of studies at the Charlottetown Research Station assessed the performance of sod-seeded alfalfa and
birdsfoot trefoil (Kunelius et al., 1982) and timothy, alfalfa, red clover and white clover (Kunelius and Campbell, 1984). They concluded that vigorous species such as red clover, white clover and timothy established the best; alfalfa and trefoil established well on average but their establishment was variable among the sites in the study. Direct drilling methods (sod seeding) have also been successful in reseeding annual forages (Kunelius et al., 1985). Italian ryegrass is not very winterhardy in Atlantic Canada and it must be reseeded frequently to maintain productive swards. When compared with conventional sowing techniques, direct drilling produced similar yields and no adverse effect on soil structure (Kunelius et al., 1985). Papadopoulos (Unpubl. Data) found sod-seeding several grass species into bluegrass swards enhanced mid-summer production; orchardgrass produced slightly more DM than other species under rotational grazing (Table 10).

One limitation to the use of direct drilling techniques is the susceptibility of some soils to compaction when tillage is omitted (Carter, 1987); many of the soils in Atlantic Canada are susceptible to soil compaction (Carter et al., 1990). Direct drilling for renovation of pastures, however, has not generally been found to adversely affect soil structure. The presence of a surface mulch at the soil surface may alleviate soil compaction by modifying the effect of applied stress (Carter et al., 1990). A series of studies on the effects of direct-drilling on soil structure for Italian ryegrass (MacAulay, 1979; Kunelius et al., 1985), and alfalfa, red clover and timothy (Kunelius et al., 1988) found that soil condition was not adversely affected.

<table>
<thead>
<tr>
<th>Species</th>
<th>Cultivar</th>
<th>DM Yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timothy</td>
<td>Basho</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Table 10. Mid-summer production (July 15, 1988) of rotationally-grazed grass species sod-seeded into bluegrass swards in 1986.
Many forage legumes under conventional cultivation in Atlantic Canada are susceptible to infestation of nematodes (Thompson and Willis, 1975; Willis and Thompson, 1979). Observations at several locations in Prince Edward Island have suggested that damage by

<table>
<thead>
<tr>
<th></th>
<th>Farol</th>
<th>1.8</th>
</tr>
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<tbody>
<tr>
<td>Timothy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Timothy</td>
<td>Goliath</td>
<td>2.3</td>
</tr>
<tr>
<td>Tall fescue hybrid</td>
<td>Kenhy</td>
<td>2.2</td>
</tr>
<tr>
<td>Orchardgrass</td>
<td>-</td>
<td>2.4</td>
</tr>
<tr>
<td>Red fescue</td>
<td>-</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Adapted from Papadopoulos (Unpubl. Data)
nematodes and fungal pathogens are responsible for thin stands, slow seeding development and reduced yields of direct-drilled forages as well (Kunelius et al., 1987c). Kunelius et al. (1987c) conducted a study to assess the effects of several pesticides on the performance of direct-drilled alfalfa. They found that the pesticide fenamiphos applied broadcast in existing swards generally improved establishment but that this practice was not very cost effective at present in Atlantic Canada. They suggested selection of fields with low infestations, development of tolerant cultivars and detailed studies of nematode dynamics in direct-drilled legumes should help to reduce the adverse effects of nematodes on seedling establishment.

4.1.2 Seeding Date

Crops should be planted at the time of year when the different stages of their development will be most perfectly correlated with the expected weather variations. Spring is generally considered the best time to seed forage crops in Atlantic Canada. Seeding in early spring allows forage
seedlings to establish before weeds, which require warmer temperatures to germinate than grasses and legumes, begin to compete for nutrients, space, light and water (Langille & Warren, 1964b). Summer is not reliable for seeding due to wide fluctuations in the amount of seasonal rainfall, and autumn seeding does not allow forages, especially legumes, to establish sufficiently to survive the winter. Thomas (1991) established trials in September, 1991 to evaluate the effectiveness of fall seeding of several forage grasses and legumes.

Langille and Warren (1964b) conducted a study in which two forage mixtures were seeded at 2 week intervals from the end of May until early September. Satisfactory results were obtained from seeding dates up to about mid-July (mean of 6.9 t/ha seeded at end of May and 6.1 t/ha, mid-July), after which yield was substantially reduced (4.4 t/ha early September). The establishment of legumes in both mixtures was adversely affected by delayed seeding. Timothy established itself and persisted much better than any other species. Percentage of bare ground and weed growth were greatest in the later seeded plots during the first harvest year but were relatively even in succeeding years (Langille and Warren, 1964b).

Recent research on sod-seeded forages showed that red clover and white clover performed better than alfalfa when seeded in the spring (Kunelius & Campbell, 1984). A subsequent study examined the effect of seeding date on the growth of sod-seeded alfalfa and red clover. Kunelius and Calder (1986) found that sod-seeding alfalfa between late-April and Mid-June resulted in the best establishment and yields. Red clover again performed better than alfalfa and it was suggested that red clover may be superior for sod-seeding in this region.

Kunelius et al. (1987b) assessed the effect of seeding date on yields and quality of green forage crops. These crops are invaluable for late season grazing. They concluded that kale should be planted by mid-June for highest yields and that rape, radish and turnip hybrid could
be seeded until mid-July with good results. Planting forage corn later than June 6th was shown to significantly reduce yields of both whole plant and grain (White, 1977). Annual ryegrass is often grown as a cover crop or for soil improvement. Italian ryegrass and red clover provided good cover for winter rye when seeded in late April, although red clover outyielded the ryegrass by 48% (Edwards, 1989). Fall seeding of Italian ryegrass as a cover crop is possible but is inferior to fall-seeded cereal crops (Edwards and Sadler, 1992). Good cover could be achieved by Italian ryegrass if growth was initiated in early fall. Shoot growth decreased significantly with later seeding dates (67.5% between September 16 and September 24 and 96.5% between September 16 and October 2) (Edwards and Sadler, 1992).

4.1.3 Fertility Management

Soil fertility, the ability of the soil to supply nutrients to plants, is a major factor in forage production (Woodhouse & Griffith, 1973). Legumes require soils that are well supplied naturally or artificially with P, K, Ca, and Mg while grasses require large amounts of N. There are 12 different chemical elements supplied by the soil that are necessary to plant growth. The most important elements, or macronutrients, are nitrogen, phosphorus, potassium, calcium, magnesium and sulfur. Other important elements, or micronutrients, are boron, molybdenum, manganese, copper, iron, chlorine and zinc. Applying fertilizers to maintain and improve soil fertility is necessary when soils become depleted of nutrients by crop removal, leaching and erosion and as demand for higher yields increases.

Research on forage crop fertilization in Atlantic Canada has focused on finding cost effective ways to provide the nutrients for optimum yield and persistence. Of particular interest have been timing, rates, and sources of the fertilizer and lime elements; the effects of
micronutrients on plant growth, herbage yield and livestock production; and the effects of long-term fertilization on forage productivity. Several major reports have been presented on crop responses to various nutrients. Rayment (Unpubl.) prepared a report discussing current theory on the relationship between plant nutrients and crop growth. Gupta (1979) compiled a review of a large number of field and vegetable crops that respond to boron.

Pastures in Atlantic Canada are characterized by lush growth of herbage in late spring and early summer, producing upwards of 70% of the annual growth before mid-July (Black, 1972). Several nitrogen applications may be necessary to maintain forage production throughout the growing season. Calder and Nicholson (1970) showed that N fertilization resulted in increased DM yields when applied to legume swards (3% increase), grass/legume swards (16%) and grass swards (59%). Studies have been conducted to examine the relative benefits of applying N in the spring, summer and as split applications for pure stands of timothy, bromegrass, reed canarygrass (Kunelius et al., 1976; Narasimhalu et al., 1981) and orchardgrass (Kunelius et al., 1984b), grass-legume mixtures (Leefe, 1958) and natural pasture swards (Black, 1978). Thomas (1986a) examined the possibility of using the T-sum system, based on mean daily air temperatures and currently used in Europe, to determine the best time to apply N fertilizer in the spring in the Atlantic region. He found that provided sufficient N fertilizer was present when spring growth began, there was no exact time for application that would result in maximum yields.

The rate of N application is also important, especially to the management of perennial grasses. Dry matter yields were found to increase with N fertilization up to 148 kg/ha/yr during the seeding year (Kunelius & Suzuki, 1977b) and up to 297 kg/ha/yr (2 harvest system) in post seeding years for orchardgrass (Kunelius & Suzuki, 1977a); up to 198/kg/ha/yr in the seeding
year and up to 264 kg/ha/yr (2 harvests) and 495 kg/ha/yr (3 and 4 harvests), in the post-seeding years for timothy (Kunelius et al., 1976); and up to 360 kg/ha/yr (3 harvests) for bromegrass (Kunelius, 1979b). Kunelius et al. (1976) found that timothy grown under a 2 harvest system produced higher DM yields but had lower N and IVDDM concentrations than under 3 and 4 harvest systems. Stand persistence was adequate under the 2 and 4 harvest systems, but greater stand deterioration under the 3 harvest system was attributed to harvesting at early heading stage. Harvest management also plays a very important role in stand productivity.

Nitrogen application is generally not considered necessary when legumes make up more than 25% of total yield (Smeltzer, 1967). Nitrogen applications have been found to suppress ladino clover growth in mixture with orchardgrass (Leefe, 1958) and white clover growth in mixture with timothy and reed canarygrass (Narasimhalu et al., 1981). Grant and Brown (1961) found red clover and alfalfa seeded in mixture with timothy and bromegrass produced similar yields to pure grass stands initially but in subsequent cuttings, total yield and legume fraction were depressed by N treatment. Apparent N fixation by the legumes was consistently reduced with applied nitrogen. Kunelius (1975) found that N fertilizer rates above 50 kg/ha resulted in reduced nodulation and growth of pure stands of alfalfa and that alfalfa does not require applied N to stimulate growth of seedlings. Nitrogen fertilization can increase yields substantially when legumes are decreased by winterkilling and replaced by volunteer species (Calder & Nicholson, 1970).

Ammonium nitrate has been the principal source of N fertilizer used in Atlantic Canada but there is increased interest in urea because of its lower handling and production costs. In a study which compared the effectiveness of the 2 sources on yield and quality of timothy and bromegrass, urea and ammonium nitrate were found to be equivalent N sources for fertilizing
grass in the spring, but urea was less effective when applied during the summer (Kunelius et al., 1987). Urea is converted to ammonia on the soil surface and transferred into the soil where it forms the ammonium ions which are utilized by the crop. The warmer temperatures of summer contribute to the rapid loss of urea to the atmosphere and decrease the amount that is made available to the plants (MacLeod, J.A., 1980). Leefe (1958) found ammonium nitrate to be more effective on yields of an orchardgrass-ladino clover mixture but calcium cyanamide, another source of N fertilizer, was less detrimental to clover production.

Phosphorus (P) is required by young seedlings as it is a key nutrient in growth and cell division. The most limiting factor to P utilization by plants is the ease with which most soils tie up large amounts of this element in forms not readily available to plants (Woodhouse and Griffith, 1973). Hilton and Cameron (1939) concluded that lack of P was the chief limiting factor in the economical production of hay during a 7 year study. Clare (1982) evaluated the effect of excess P applied to alfalfa land prior to seeding. He found no significant differences in yield in the seeding year but P levels in plant tissues increased with the amount of fertilizer applied.

MacLeod and Kunelius (1973) showed that banded phosphate was more effective than broadcast phosphate to establish alfalfa and brome grass. Ammoniated superphosphate, diammonium phosphate, ordinary superphosphate and triple superphosphate were equally effective in increasing yields of perennial ryegrass (Munro and MacKay, 1968). Richards and B61anger (1989) examined the movement of P applied to an acidic soil cropped to timothy for twenty-six years. They found that fertilizer P penetrated to the subsoil of a highly acidic, medium textured New Brunswick soil under long-term hay production, even when it was applied at low rates.

Potassium (K) is required in fairly large quantities by most forages, especially legumes, and is vital to many plant functions such as the formation of sugars and starch, the translocation
of these within the plant, protein synthesis, stomatal action and the neutralization of organic acids (Woodhouse and Griffith, 1973). A study by MacLeod and Bradfield (1964) showed that K fertilization decreased alfalfa plant mortality significantly and increased dry matter yields of alfalfa tap roots and of fibrous roots of grass and alfalfa. These results agreed with MacLeod et al. (1964) who found that alfalfa stand maintenance was influenced by the rate of K fertilization.

Nitrogen is often the first limiting factor in the growth of forage grasses, but the efficiency with which it can be utilized is very much dependent upon the presence of adequate quantities of other nutrients (Woodhouse and Griffith, 1973). The majority of work conducted on K in the Atlantic Provinces has been on the effect of N-K balance on plant growth. The effects of N and K fertilization have been investigated for: alfalfa (MacLeod, L.B., 1965a and b; MacLeod, L.B. and Carson, 1965; MacLeod, L.B. and Suzuki, 1967), orchardgrass (MacLeod, L.B., 1965a and b; MacLeod, L.B. and Carson, 1965, 1966; MacLeod, L.B. and Suzuki, 1967), timothy (MacLeod, L.B., 1965a and b; Grant and MacLean, 1966; MacLeod, L.B. and Carson, 1966; Grant, 1971; MacLeod, L.B. and MacLeod, 1974a), brome grass (MacLeod, L.B., 1965a and b; MacLeod, L.B. and Carson, 1966; MacLeod, L.B. and MacLeod, 1974a) and alfalfa-grass mixtures (MacLeod, L.B., 1965c).

The interrelationship of N and K is more important in species such as forages which are heavy consumers of N and K. Potassium plays a role in the conversion of soluble N fractions in the plant to protein N (MacLeod, L.B., 1965b). A deficiency of K in a plant may result in the accumulation of soluble N compounds, of which some are known to cause stress in plants and are harmful to animals (Teel, 1962). Adequate K is especially important to grass species that are heavily fertilized with N, especially as production is intensified and rates of N fertilization
continue to increase (MacLeod, L.B., 1965b). MacLeod (1965b), in a greenhouse experiment, found that percent of protein N, non-protein N and nitrate N increased with N fertilization and decreased with K fertilization for grasses and alfalfa. In later field studies, however, MacLeod and MacLeod (1974a) found that high levels of K did not prevent the accumulation of soluble reduced N at high rates and possibly increased the accumulation of nitrate N.

The supply of K must also be sufficient to meet the needs of legumes in grass-legume mixtures. MacLeod (1965c) found that fertilization with N increased the ability of grasses to compete for K and decreased the ability of alfalfa associate to compete for K. Potassium is also important in the accumulation of food reserves for winter survival and inadequate levels may reduce the persistence of forage species. Macleod (1965a) reported that in alfalfa-grass mixtures, K increased regrowth of alfalfa and decreased that of the grass associate while N increased regrowth of the grass species and reduced regrowth of the alfalfa associate. He concluded that supply of N and K should not be limiting during the hardening and overwintering stages.

Sulfur (S) was a standard impurity in many fertilizers in the past, but today’s production techniques have improved so that little or no S is now present. The ongoing trend for increased crop yields has also increased the removal of S from soils (Gupta and MacLeod, J.A., 1984). Cereals and forages are known to remove 18-45 kg S/ha -annually ' (Terman, 1978) while precipitation in Atlantic Canada only adds about 15 kg/ha (Coote et al., 1982). Unless S-containing fertilizers are used to maintain soil S levels, agricultural soils in the Atlantic Provinces may become deficient, especially considering the trend towards more intensive production (Gupta and MacLeod, J.A., 1984).

Sulfur is a constituent of protein and is therefore important for use by plants in protein synthesis. Gupta and MacLeod (1984) conducted a study to determine the effects of various
sources of S (Agri-Sul, gypsum and Urea-Sul) on S concentration of tissue and yields of forages and cereals. None of the sources increased the yield of either cereals or forages but gypsum was effective in increasing the S concentration in plant tissues. It was concluded that the S requirement of forages is likely presently met by S in precipitation and available S in the soil. Rodd and Richards (1988), however, suggested that S may not be as available to crops as was once thought, as atmospheric deposition has declined by 50%. They initiated a study in 1988 to determine if alfalfa and barley are receiving sufficient S from atmospheric deposition.

Micronutrients such as B, Mo, Zn, Mn, Cu and Fe are generally lacking in the Atlantic region (Gupta, 1979; Gupta and Lipsett, 1981). Specific studies on residual effects of micronutrients on plant growth, herbage yield and livestock production have been extensively reviewed (Smeltzer et al., 1962; Gupta, 1979; Gupta and Lipsett, 1981). The Atlantic Advisory Committee on Soil Fertility has prepared a booklet outlining the symptoms of micronutrient deficiencies, the available sources and the methods and rates of application (A.A.C.S.F., 1986).

The availability of micronutrients to plants from soils depends upon the elemental composition of the parent bed rock and on the soil developed on these materials (A.A.C.S.F., 1986). Many Atlantic Canada soils are classified within the podzolic order and are susceptible to intensive chemical decomposition, physical weathering and high precipitation which leaves them deficient in many essential elements for plant growth (A.A.C.S.F., 1986). Deficient micronutrients can be made available to crops by soil applications, foliar sprays and seed treatment. Micronutrients are available commercially from inorganic, organic and fritted sources as well as from manure. Manure is readily available in Atlantic Canada and is also useful for improving soil physical properties by increasing organic matter content but it is also a potential
source of ground water and stream contamination and proper use is essential (A.A.C.S.F., 1986).

The concentration of micronutrients in manure varies considerably as shown in Table 11.

Lack of boron (B) is one of the most common micronutrient deficiencies in forages in Atlantic Canada. A comprehensive review for a large number of field and vegetable crops that respond to B has been compiled by Gupta (1979). Boron is essential for several metabolic processes in forage legumes. Symptoms of deficiency include yellowing of the upper leaves only in alfalfa, and a red coloration on the margins and tips of younger leaves or yellowing and shrivelling of leaves in red clover; no symptom were observed on birdsfoot trefoil (Gupta, 1979).

A number of field trials have been conducted on the B requirement of forage crops to determine the effect of B and liming on yield and quality. Dr. U.C. Gupta (1971, 1972, 1973, 1984, 1991a), of the Charlottetown Research Station, examined boron nutrition of alfalfa, red

<table>
<thead>
<tr>
<th>Manure</th>
<th>No. of samples</th>
<th>DM (%): Average (Range)</th>
<th>Boron (ppm): Average (Range)</th>
<th>Copper (ppm): Average (Range)</th>
<th>Manganese (ppm): Average (Range)</th>
<th>Zinc (ppm): Average (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid Dairy</td>
<td>11</td>
<td>8 (5-12)</td>
<td>4 (2-6.5)</td>
<td>4 (1-17)</td>
<td>14 (8-31)</td>
<td>19 (8-78)</td>
</tr>
<tr>
<td>Solid Dairy</td>
<td>12</td>
<td>20 (14-34)</td>
<td>6 (2-14)</td>
<td>3 (1-7)</td>
<td>23 (10-77)</td>
<td>25 (10-64)</td>
</tr>
<tr>
<td>Liquid Hog</td>
<td>8</td>
<td>5 (1-11)</td>
<td>3 (1-5)</td>
<td>4 (tr-9)</td>
<td>18 (1-62)</td>
<td>35 (3-125)</td>
</tr>
<tr>
<td>Solid Poultry</td>
<td>2</td>
<td>57 (56-59)</td>
<td>24 (21-27)</td>
<td>14 (13-16)</td>
<td>136 (132-139)</td>
<td>175 (170-178)</td>
</tr>
<tr>
<td>Solid Beef</td>
<td>2</td>
<td>21 (15-26)</td>
<td>4 (4-5)</td>
<td>4 (2-7)</td>
<td>31 (16-46)</td>
<td>30 (9-51)</td>
</tr>
</tbody>
</table>

*Reproduced from A.A.C.S.F. (1986).*
clover, birdsfoot trefoil and timothy and found that legumes, especially alfalfa, were much more susceptible to B deficiency than were grasses. He concluded that 2 kg B/ha should last for 2 years for alfalfa and red clover and B should be applied in alternate years for continuous forage legumes (Gupta, 1984). Clare (1985a) examined the effect of boron on alfalfa in trials in New Brunswick. Liming caused greater reductions in the B concentration in timothy at high rates of added B than at low rates of added B (Gupta and MacLeod, J.A., 1973). Boron deficiency was also aggravated by high rates of lime on alfalfa and red clover (Gupta, 1972). It was found; however, that interaction between B and lime is more significant at high pH levels; B concentrations decreased more sharply when the pH was raised to 7-7.3 than when it was raised to 6.1-6.4 (Gupta and MacLeod, J.A., 1981). Renan and Gupta (1991) examined methods for predicting the B availability to plants and recommended the use of a 0.05 M HCl extraction method.
Molybdenum (Mo) is an important micronutrient for forage legumes as it is required in symbiotic nitrogen fixation. Robinson et al. (1957) found that seed treatments of Mo increased yields of early red clover on three soil types in Prince Edward Island (-2 to 97%). While yield was not affected by application of lime to molybdenum-treated clover, the uptake of molybdenum by plants increased with increasing lime applications. A greenhouse study also showed that Mo application of 40 to 160 g Mo/ha increased yield (83 to 102%) and tissue concentration (800% and higher) in red clover on peat soils (Gupta et al., 1990).

High levels of Mo are known to deplete reserves of Cu in animals, producing a deficiency called molybdenosis (Rayment and Gupta, 1984). Sulfur has been shown to reduce the Mo uptake by plants (Gupta and Munro, 1969) and Gupta and MacLeod (1975) conducted field and greenhouse studies to determine the levels of S required to alleviate Mo toxicity and the relationship of S, Mo and Cu in timothy, alfalfa and red clover. They found that applications of 50 to 200 ppm S, where 0.5 to 1.0 ppm of Mo were added, alleviated the Mo toxicity problem by decreasing the Mo concentration of forage tissue below the undesirable level of 5 to 10 ppm. The relationship between Mo and S was found to be independent of pH. Copper levels in crop tissues increased with added S but remained within safe levels for livestock consumption.

Most soils contain adequate levels of available manganese (Mn; which is involved in chlorophyll synthesis) so that Mn applications are generally unnecessary. In fact, the acidic nature of most soils in Atlantic Canada contributes to Mn toxicity. It is for this reason, however, that soils are routinely limed, as lime lowers the availability of Mn in the soil. A study by Gupta (1986) on the effects of Mn applications on cereals and forages on Prince Edward Island found
no Mn deficiency in either crops but Mn in plant tissue was reduced by liming. He recommended that tissue Mn levels in crops be monitored periodically because of the possible depletion of soil Mn from continuous liming practices.

Copper (Cu) is essential to plants as it is a constituent of chloroplast proteins which play a role in photosynthesis. Deficiency is well known in a number of different crop plants; it occurs most commonly in cereals but has also been reported in forages (Gupta, 1989). Gupta (1989) conducted a study to determine the effect of Cu applied as a foliar spray and soil amendment. Foliar spray increased the plant Cu concentrations in first-cut alfalfa and timothy but no increase in yield was reported. He suggested that Cu levels in P.E.I. crops should be monitored periodically and that any deficiencies could be overcome by foliar or soil applications of Cu.

Iron (Fe) is involved in cell respiration and is essential to the synthesis of chlorophyll. The iron content of most soils is very high but it is not always available to plants as it tends to form insoluble compounds with calcium, especially in highly limed soils. A study to determine the iron status of crops in Prince Edward Island and the effect of soil pH on plant iron concentration found that soil additions of FeSO4 7H2O did not increase Fe concentration in alfalfa and timothy but foliar application did for the first cut (Gupta, 1991b). Soil pH of up to 6.9 did not affect availability of soil Fe to plants.

Chlorine (Cl) is present in sufficient quantities in most soils to meet the requirements of most crops (A.A.C.S.F., 1986); deficiencies are rare. It is not considered to be a limiting factor to crop growth in Atlantic Canada and so has not received much attention. Its function in plant metabolism is still obscure.

Zinc (Zn) is essential to normal water uptake and cell division and is also related to iron metabolism. Deficiencies are not common and very little work has been done on this nutrient.
A study was conducted by Bishop and MacEachern (1973) to provide information on the Zn status of a number of Nova Scotia soils and crops. They found that Zn levels in plant tissues were adequate for all field crops tested except for corn from one location; corn is known to be sensitive to Zn deficiency. They stressed, however, that the acidic nature of Maritime soils and the ability of lime to reduce Zn availability could lead to Zn deficiency in the region.

Most agricultural soils in the Atlantic region are naturally acidic and liming is essential if they are to be productive. Soil acidity is caused by the presence of hydrogen ions from organic and inorganic acids. Soil acidity increases as soil nutrients such as Ca, Mg and K are leached from a soil and replaced by hydrogen ions or taken up by plants. Other factors that contribute to soil acidity are the use of N fertilizers, crop removal of nutrients and lack of natural lime in the soil. The addition of lime neutralizes acid soil conditions by converting toxic elements such as aluminum (Al) and Mn to less soluble forms (Clark, R.B., 1982). Lime also supplies calcium (Ca) and magnesium (Mg) to plants; increases the activity of soil bacteria which release nutrients from organic compounds; improves soil structure by stabilizing soil aggregates and reducing soil erosion; and improves fertilizer efficiency (A.A.C.S.F., 1986).

Aluminum toxicity has been identified as a dominant chemical factor associated with soil acidity in Atlantic Canada. A major study by MacLeod and Jackson (1965) examined the effect of concentration of the Al ion on root development and establishment of legume seedlings, in soil and nutrient solution experiments. They found that concentrations of ionic Al as low as 0.5 ppm restricted root growth and 1.5 to 2.0 ppm prohibited growth almost completely. Top growth was restricted at less than 1.0 ppm Al. Top and root growth on unlimed acidic soil were 73 and 71 respectively of growth on limed soil. Alfalfa and red clover established better than ladino clover, alsike clover and birdsfoot trefoil. Papadopoulos et al. (1992a) assessed the performance
of alfalfa cultivars under acidic subsoil and Al nutrient culture. They found that results from the soil study were positively correlated with nutrient culture results; 75 [imol Al L\(^{-1}\)] nutrient culture was effective in assessing the tolerance of varieties to acidic subsoil conditions; and current alfalfa cultivars varied considerably in their susceptibility to acidic subsoil and high levels of tolerance can be obtained through selection.

Calcium has many functions in plant growth including its importance as a component in cell walls. Deficiency symptoms include poor root growth and death of the growing point. Magnesium is an essential component of the chlorophyll molecule, it is associated with P in seed formation and it activates photosynthesis and certain enzyme reactions (A.A.C.S.F., 1981).

Deficiency symptoms include interveinal yellowish, bronze or reddish colour patches in old leaves which later die and turn brown or black. Dolomitic lime contains both Ca and Mg but routine use of calcitic lime may require the addition of Mg through fertilizers or foliar spray. Winter and Gupta (1987) analyzed alfalfa and red clover for Ca and Mg content, as well as several other macro- and micronutrients.

The overall effect of liming soils is increase in crop yields. A great deal of early work was conducted on the effects of liming and fertilization. MacLeod et al. (1964) found that yields of a forage mixture practically doubled with the application of 5.6 t/ha of limestone during a 4 year study. Blair and Leefe (1939), in a study on lime in crop rotation, concluded that lime had been the greatest single factor influencing the yields of all crops in the rotation.

The effects of liming have also been examined in conjunction with fertilization (Blair and Leefe, 1939; MacLeod, L.B. et al., 1964); adding lime to the soil has been shown to increase fertilizer efficiency (MacLeod, L.B., 1969b). MacLeod (1969b) found that the alfalfa component in a timothy-alfalfa mixture had disappeared almost completely on unlimed plots but an excellent
stand persisted on limed plots. MacLeod and Bradfield (1964) found that alfalfa yields increased up to a pH of 5.9 under several K treatment levels; subsequent increases in pH gave increased yields only when high levels of K were applied. Survival of alfalfa on soils with a pH of 5.9 or higher appeared to be more dependent on potassium fertilization than on increases in pH.

Increased crop yields as a result of liming and fertilization have contributed to the rapid removal of micronutrients from the soil. Gupta et al. (1971) examined the effects of 5 rates of limestone and 4 rates of fertilizers on the levels of Mo, Cu, B, Mn and Zn in mixed forage tissue and soil, and on forage yield. They found that levels of B, Mn and Zn in the soil were reduced at increasing pH levels while Mo and Cu were not affected by limestone at any level. Increases in soil pH resulted in increases in Mo and Cu levels in plant tissues (0.183-0.621 ppm. of Mo and 5.6-6.7 ppm of Cu when pH increased from 4.9 to 6.8) while B, Mn and Zn decreased (8.55-6.24 ppm B, 322.8-85.9 ppm Mn, and 19.5-17.3 ppm Zn). Fertilizer application did not affect the micronutrient content in plant tissue or soil. Decreases in the availability of B under limed conditions was also reported by Gupta and MacLeod (1977) and Calder and Langille (1963). The increase of Mo in plant tissue as a result of liming was also examined by Gupta (1969) and Gupta and Kunelius (1980).

Lime and fertilizers have been traditionally applied only, to the cultivated crops in a rotation while hay crops remained dependent on residual nutrients. As grassland farming became more intensive, the fertility requirements of hay and pasture crops were examined (Cameron and Hamilton, 1960; MacLeod, L.B. et al., 1960; Calder et al., 1965a; Calder and Warren, 1967; Bishop et al., 1969). Surface application of limestone and fertilizers was preferable as it was not necessary to break the sod; this was often difficult on the rocky terrain of pasture lands (Calder et al., 1965a) and undesirable on permanent hayland. Although some studies have shown that
incorporation of lime and fertilizers is superior, surface application was found to be almost equally effective on open textured soils with light sods (Calder et al., 1965a; Calder and Warren, 1967).

Most field research is necessarily of short duration although several long-term field studies have been reported in the Atlantic Provinces. These studies have been mostly concerned with long-term hay production, liming and fertilization. MacLeod et al. (1960) reported on the effects of 27 years of surface applied lime and fertilizers on permanent hayland. Yields were shown to decline with time indicating the need for occasional ploughing and reseeding. Yield response to P was greater than that to N or K although N was very important for the persistence of grasses.

A series of experiments were conducted at the Nappan Experimental Farm from 1936 to 1961 on the effects of commercial fertilizers and manure on the fertility levels, crop yields and nutrient levels of various crops in rotation. MacLeod et al. (1960) looked at a rotation of swedes, oats and hay. At the onset of the study, swedes were valuable as winter feed for livestock. Bishop et al. (1962) examined a rotation of potatoes, oats and hay; Bishop et al. (1964) reported on a rotation of corn, oats and clover.

A long-term field experiment which studied the effects of 25 years of N, P, and K fertilization on yield, persistence and nutritive value of timothy was conducted at the Fredericton Research Station. Belanger et al. (1989) found that only N and K were required for optimal yield and persistence during the first 3 years; P requirement increased over time (44 kg P/ha was required for maximum yield during the last 3 years); long-term persistence of timothy was solely dependent on K fertilization; and after 25 years, the productivity of the timothy sward was dependent upon a balanced application of all three macronutrients. Table 3 reports the quantities of N, P and K required for maximum and most profitable forage yields.
Papadopoulos et al. (1991) reported on the effect of fertility management on changes in yields and timothy persistence over a 65 year period of continuous (without ploughing) hay production on dykeland soil. They concluded that the surface application of manure and commercial fertilizers resulted in a substantial increase in timothy yield and persistence over the unfertilized control. Gradual yield decline associated with commercial mineral fertilizer applications was attributed to the depletion of other nutrients which were not replenished and the decreased nutrient availability induced by lowering pH. In contrast to other studies (Manger et al., 1989), the application of K did not affect DM yield or long-term persistence of timothy in this study. The authors attributed this discrepancy to the fact that K was not applied to the soil during the first 40 years following establishment.

4.1.4 Weed Control

Weed control can be accomplished by mechanical, cultural, biological and chemical methods. Workers in the field stress the importance of integrating several of these methods and not relying on one method only. Clipping weeds to allow forages to grow, periodic cultivation and reseeding, and planting vigorous crops that outcompete weeds are recommended to maintain low weed levels (A.A.C.C.P.C.F.C., 1991). In a weed control experiment on birdsfoot trefoil (which is difficult to establish in Atlantic Canada), handweeding plus N fertilization was found to increase yields but the herbicide 2,4-DB-dalapon suppressed growth of both weeds and trefoil (Kunelius, 1974b). Ivany and Kunelius (1981) examined the effectiveness of various herbicides on annual ryegrass. Herbicide rate application is very important, especially in alfalfa; recommended rates are not always adequate but higher rates can injure plants (Kunelius, 1974a). Ivany (1980) studied the effect of the herbicide EPTC and two antidotes and found that neither
antidote protected alfalfa from injury. Residues from fluazifop-P, a quack grass (Elytrigia repens L. Nevski) control, were found to be within a tolerable range for alfalfa (Doohan et al., 1992).

Tansy ragwort (Senecio jacobaea L.) although commonly found in waste places is also found in fertilized hay and pasture lands in Atlantic Canada (Black, 1971). The presence of alkaloids in its tissues makes it especially toxic to grazing livestock. Work by Black (1971, 1976) has shown that both cultural practices and applications of 2,4-D are effective in controlling populations. Some weeds can be controlled by natural insect predators and deliberate introductions have been made in some areas. The larva of the Cinnabar Moth (Tyria jacobaeae L.), feed on tansy ragwort; colonies of the moth were established in the Maritimes by 1975 and first noted in Newfoundland in 1980 (Larson and Jackson, 1980). Another pasture weed, St. Johnswort (Hypericum perforatum L.), is affected by populations of the beetle Chrysolina hyperici L. which were first released in Nova Scotia in 1969 (Robinson, D.K., 1990).

Herbicides applied to a crop can have negative impacts on subsequent crops grown in rotation. Some recent work has been conducted to determine the effects of various herbicides on subsequent forage and cereal crops. Atrazine, a weed control for corn, restricted growth of red clover, timothy, winter rye, barley and alfalfa, in that order of severity (Ivany et al., 1985). Metribuzin is used to control broadleaf grass and barnyard grass (Echinochloa crusgalli L. Beauv.) in potatoes in Atlantic Canada. Ivany et al. (1983) found that residue levels from normal application rates did not have any serious adverse effect on red clover and winter rye, and that some loss could be expected in timothy and barley when high rates are applied or when rate of breakdown is slow.

4.1.5 Inoculation of Legumes
Legumes, with the assistance of specific soil bacteria, have the ability to convert nitrogen from the air into a form that is available for their growth. This symbiotic relationship can fix approximately 100 to 200 kg N/ha/yr (Barnes et al., 1985 in Lirette et al., 1993). Inoculation of legumes with their associated bacterium may be necessary when the bacterium is not present in the soil. *Rhizobium meliloti* L. is the recommended bacterium for alfalfa in the Atlantic Provinces. Suzuki (1981a) tested a new strain of the alfalfa bacterium *R. meliloti* and found that the recommended Balsac strain resulted in higher yields. Kunelius (1979a) and Kunelius and Gupta (1975) examined the effectiveness of inoculated, lime-coated seeds on the establishment of alfalfa in acidic soils. Lime coating was found to be beneficial to establishment of alfalfa when soil pH was 5.6 or less.

4.2 Stand Maintenance and Management

4.2.1 Harvest Management

Harvesting should be timed to obtain maximal forage yield and quality and to provide for stand survival for a period of years. The stage of maturity at harvest and frequency of harvest are the most important factors which must be considered when harvesting forage crops in our region. Frequent cutting or grazing at immature stages, especially during periods of low food reserves, can weaken plants and make them more susceptible to drought, heat, winter injury, and invading diseases (Smith, D., 1973). Harvesting systems have been reviewed extensively for their effects on factors associated with yield, quality and persistence of forage legumes and grasses.

Although quality of forages is often greater in the immature herbage associated with frequent cutting, such intensive management can significantly affect total yield and persistence of forages in Atlantic Canada (MacLeod, L.B. et al., 1972). Although alfalfa and birdsfoot trefoil
can be harvested 2 to 3 times per season, researchers have found that frequent cutting led to reduced yields in subsequent years (Langille et al., 1968; MacLeod, L.B. et al., 1972; Belanger et al., 1992) and lack of persistence (Langille et al., 1965; Calder and MacLeod, 1966; Langille and Calder, 1971; MacLeod, L.B. et al., 1972; Suzuki, 1990a) due to the inability of the plant to accumulate adequate food reserves. Digestibility and crude protein have been shown to be greater in the early stages of growth (Langille and Calder, 1971; MacLeod, L.B. et al., 1972), which are characteristic of maturity with frequent cutting.

In the management of perennial grasses, which require large amounts of N for optimal growth, the effect of harvest systems is dependent on N fertilization. High rates of N can reduce persistence while low N rates contribute to weed invasion (Kunelius et al., 1976). With adequate N supplies, timothy produced highest DM yields and persisted well under a 2 harvest system (Kunelius et al., 1974, 1976). Harvesting at more mature stages generally improves the persistence of timothy and bromegrass (Kunelius et al., 1974; Kunelius, 1979b), although harvesting primary growth at various stages of maturity did not reduce, persistence of timothy under a 2 harvest system provided adequate recovery (Kunelius et al., 1974; Kunelius and McRae, 1986a). Intensive management may reduce persistence and promote premature deterioration of swards (Kunelius and McRae, 1986a). Grant (1971) found that delaying harvest beyond the boot stage and providing a proper N:K balance would improve vegetative reproduction and persistence of timothy. Forage quality of timothy decreases with age (Kunelius and McRae, 1986a; O'Reilly, 1988), particularly following full head stage (Grant and Burges, 1978).

The persistence of orchardgrass may be less influenced by frequent cutting and 3 and 4 harvest systems have performed well in the region (Kunelius and Suzuki, 1977a and b). Kunelius
(1990a) and Kunelius and Halliday (1989) examined the production, nutritive value and plant characteristics of cultivars of timothy, meadow fescue, tall fescue, orchardgrass and ryegrass X fescue hybrids under 3 and 4 harvest systems. It is generally recommended to harvest grass-legume mixtures at the bud to 10% o bloom stage of the legume component. Kunelius et al. (1975) found that harvesting the first crop before this time resulted in the disappearance of alfalfa from mixtures. Frequent cutting has also been shown to reduce total yield for grass-legume mixtures (Langille and Warren, 1961, 1962).

With proper management, annual ryegrasses can provide excellent forage for use from mid-summer to late fall in Atlantic Canada. Westerwolds ryegrass has been shown to produce good yields and quality of forage when grown under a 3 harvest schedule with adequate N (Kunelius, 1980). Italian ryegrass requires 4 week regrowth intervals, which allows for 3 to 4 harvests, for optimal production (Kunelius and Calder, 1978).

In the Atlantic region, grasses should be harvested at early heading and legumes at early flowering for maximum yield of total digestible nutrients (A.A.C.C.P.C.F.C., 1991). Early cutting generally increases the quality of forages but can decrease total DM yield. Bootsma (1984) conducted a study in which he used data from field trials in this region to estimate the growing degree day (GDD) requirements of alfalfa, red clover and timothy. Growing degree days above 5°C were used to estimate the time of maturity (Table 12). A maturity zonation map was produced containing eight distinct classes for the Atlantic region (Figure 1). A description of these maturity zones is found in Table 13.
<table>
<thead>
<tr>
<th>Accumulated growing degree-days above 5°C (GDD)</th>
<th>Approximate stage of maturity in postseeding years</th>
<th>Alfalfa&lt;sup&gt;ⅴ&lt;/sup&gt;</th>
<th>Red clover&lt;sup&gt;ⅰ&lt;/sup&gt;</th>
<th>Timothy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Clair</td>
<td>Champ</td>
<td>Climax</td>
</tr>
<tr>
<td>350 Early bud</td>
<td></td>
<td>Early head</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>400 Late bud</td>
<td></td>
<td>50% head</td>
<td>Early head</td>
<td>-</td>
</tr>
<tr>
<td>450 Early bloom</td>
<td>Early bloom</td>
<td>Full head</td>
<td>50% head</td>
<td>Early head</td>
</tr>
<tr>
<td>500 -</td>
<td></td>
<td>-</td>
<td>-</td>
<td>Full head</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>50% head</td>
</tr>
</tbody>
</table>

<sup>ⅴ</sup> Reproduced from Bootsma
<sup>ⅰ</sup> Average, based on Saranac and Iroquois cultivars. (1984).
<sup>ⅰ</sup> Average, based on Lakeland and Ottawa cultivars.
### Table 13. Critical accumulated GDD dates for maturity zones in the Atlantic region

<table>
<thead>
<tr>
<th>Maturity Zone&lt;sup&gt;v&lt;/sup&gt;</th>
<th>Average date when 350, 400 and 450 degree-days above 5°C have accumulated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>350 DD&lt;sup&gt;w&lt;/sup&gt;</td>
</tr>
<tr>
<td>M1</td>
<td>15 June or earlier</td>
</tr>
<tr>
<td>M2</td>
<td>16 – 20 June</td>
</tr>
<tr>
<td>M3</td>
<td>21 – 25 June</td>
</tr>
<tr>
<td>M4</td>
<td>26 – 30 June</td>
</tr>
<tr>
<td>M5</td>
<td>1 – 5 July</td>
</tr>
<tr>
<td>M6</td>
<td>6 – 15 July</td>
</tr>
<tr>
<td>M8</td>
<td>26 July or later</td>
</tr>
</tbody>
</table>

<sup>z</sup>Reproduced from Bootsma (1984).
<sup>v</sup>Correspond to zones in Figure 1.
<sup>w</sup>Expected dates when alfalfa (Saranac and Iroquois) is in early bud stage and Clair timothy in early head
<sup>x</sup>Expected dates when alfalfa is in bud stage, Champ timothy is in early head and Clair timothy is 50% headed.
<sup>y</sup>Expected dates when alfalfa is in early bloom, red clover (Ottawa and Lakeland) is in early bloom, Climax timothy is in early head and Champ timothy is 50% headed.
Figure 1. Maturity zones for first cut of forage (Reproduced from Bootsma, 1984)
4.2.2 Fall Management

Food reserves are accumulated and stored in the root tissues of grasses and legumes during the critical fall harvest period (A.A.C.C.P.C.F.C., 1991). Cutting during this period is not recommended as it lowers root reserves, weakens plants and increases the chance of winterkill. Alfalfa is particularly dependent on this period to undergo hardening. In the early 1980s, agronomists recommended not cutting alfalfa between September 1 and October 15 in the Atlantic Provinces. Due to the limited information on which these dates were based, Bootsma and Suzuki (1985) conducted a study to determine critical harvest periods based on growing degree days. Air temperature normals over a 30 year period were used to estimate spatial and temporal variations in the critical autumn period for alfalfa in the Atlantic region. A zonation map was prepared showing the starting date of the critical autumn period for the various regions and is presented in Figure 2. The dates ranged from 10 August in Newfoundland and northwestern New Brunswick to 4 September in southwestern Nova Scotia. Harvesting or grazing 3 weeks after the starting date was suggested to pose the greatest risk of winter injury.

Bélanger et al. (1992) suggested that harvest management of alfalfa in the fall should be based on the duration of the growth period between the second and third harvests, instead of the critical fall rest period, to ensure long-term stand survival and yield. They found that DM yield was not reduced in a 3 harvest system, with the last harvest taken during the critical fall rest period, when there were at least 500 GDD between the second and third harvests. No major winterkilling was observed during the course of their study.

Kunelius (1990b) examined the effect of harvesting in September and October on the growth and herbage composition of five perennial grasses and white clover. The forages were
Figure 2: Start of the critical fall harvest period
cut in June and August and then stockpiled until mid-September to mid-October. White clover had the highest crude protein (CP) while orchardgrass and tall fescue had the highest dry matter yields (Table 14). In vitro digestibility was still acceptable; concentrations of P, Ca and Mg in all species were adequate for grazing cattle; but Cu levels were low. Fall harvesting was shown to decrease first cut and total yield in perennial ryegrass (Bubar et al., 1988).

4.3 **Physiological Considerations in Forage Management**

4.3.1 **Mechanisms of Regrowth and Winter Survival**

Regrowth of forages is dependent upon the levels of food reserves that have accumulated in the plant prior to harvesting or the onset of winter. Legumes and grasses store excess carbohydrates in storage organs such as roots to provide energy for regrowth after cutting, for respiration during the winter months, to develop coldhardiness and to start growth in the spring (Calder et al., 1966; Smith, D., 1973). These reserves accumulate according to a seasonal cycle with levels dropping in the spring as they are utilized for initial growth then increasing to maximum levels at maturity. Regrowth potential is greater when plants are harvested at more mature stages (Smith, D., 1973).

Winter survival of forage grasses and legumes is dependent on a number of factors, including soil characteristics and condition, climatic factors such as wind, temperature and precipitation, and the physiological responses of plants to these environmental conditions. The susceptibility to injury of many forage species under winter conditions in the Atlantic Provinces has led to a great deal of research being conducted. Suzuki et al. (1975) reviewed available data on the frequency of occurrence of winter injury to alfalfa and clovers over 28 and 75 seasons respectively on Prince Edward Island. From 1901 to 1975, they found that forage legumes...
Table 14. Dry matter yields and composition of grasses and white clover in the fall

<table>
<thead>
<tr>
<th>Species</th>
<th>Dry matter t/ha</th>
<th>Crude protein %</th>
<th>Digestibility %</th>
<th>ADF %</th>
<th>P %</th>
<th>Ca %</th>
<th>Mg %</th>
<th>Cu ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tall fescue</td>
<td>2.3</td>
<td>11.6</td>
<td>77</td>
<td>27</td>
<td>0.3</td>
<td>0.4</td>
<td>0.36</td>
<td>6</td>
</tr>
<tr>
<td>Meadow fescue</td>
<td>2.0</td>
<td>13.8</td>
<td>76</td>
<td>26</td>
<td>0.3</td>
<td>0.4</td>
<td>0.29</td>
<td>7</td>
</tr>
<tr>
<td>Reed canarygrass</td>
<td>1.8</td>
<td>17.1</td>
<td>74</td>
<td>23</td>
<td>0.4</td>
<td>0.3</td>
<td>0.32</td>
<td>8</td>
</tr>
<tr>
<td>Orchardgrass</td>
<td>2.5</td>
<td>13.2</td>
<td>72</td>
<td>28</td>
<td>0.4</td>
<td>0.3</td>
<td>0.28</td>
<td>8</td>
</tr>
<tr>
<td>Timothy</td>
<td>1.7</td>
<td>13.8</td>
<td>77</td>
<td>26</td>
<td>0.3</td>
<td>0.3</td>
<td>0.21</td>
<td>7</td>
</tr>
<tr>
<td>White clover</td>
<td>1.8</td>
<td>21.6</td>
<td>80</td>
<td>18</td>
<td>0.4</td>
<td>1.0</td>
<td>0.27</td>
<td>8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cutting date</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>10 September</td>
<td>1.7</td>
<td>18.1</td>
<td>78</td>
<td>25</td>
<td>0.4</td>
<td>0.4</td>
<td>0.31</td>
<td>8</td>
</tr>
<tr>
<td>1 October</td>
<td>2.2</td>
<td>14.5</td>
<td>76</td>
<td>24</td>
<td>0.3</td>
<td>0.5</td>
<td>0.29</td>
<td>7</td>
</tr>
<tr>
<td>21 October</td>
<td>2.1</td>
<td>13.0</td>
<td>74</td>
<td>25</td>
<td>0.3</td>
<td>0.5</td>
<td>0.27</td>
<td>6</td>
</tr>
</tbody>
</table>

*Reproduced from Kunelius (1990).*
suffered winter injury on average of 1 in 5 years (Table 15). They reported that Prince Edward Island had the most severe winterkill in 1972 (Suzuki, 1972). Timothy survived best, followed by bromegrass, birdsfoot trefoil, orchardgrass, alfalfa and red clover. Red clover plants were killed in February or earlier, orchardgrass in April, birdsfoot trefoil in May and bromegrass gradually lost vitality throughout the winter. Winter survival surveys conducted across the Maritime provinces annually since 1976 (Suzuki, 1990b) found significant improvement over the previous 75 years (Table 16). This was attributed to more favourable winter climate, hardier varieties and improved management practices.

Overwintering forage species develop cold resistance with the onset of the shorter days and colder temperatures of autumn. This "hardening" process involves physiological cellular changes that prepare the plant for the environmental stresses brought on by winter; these changes are dependent on high levels of food reserves (Smith, D., 1973). Researchers use a number of techniques for assessing the development of coldhardiness in forages in Atlantic Canada. Understanding the factors that are associated with this process may improve the ability of forages grown in this region to produce and persist.

The measurement of total available carbohydrates (TAC) has shown that high percent TAC in the roots in the fall is associated with better winter survival and higher forage yields in the following year (Calder et al., 1965b; Langille et al., 1965). The level of TAC in storage tissues depends on plant species, cultivars, stages of plant development, management practices and environmental conditions (Suzuki, 1971b). Carbohydrate reserves in birdsfoot trefoil remain relatively low throughout the growing season and are restored in the fall (Langille et al., 1968). Suzuki and McKenzie (1978) found that food reserves in the basal top and crown tissues were
Table 15. Frequencies of occurrence of winter injury to clovers, alfalfa, winter wheat, winter rye and strawberry plants in P.E.I. (1901-1975)\textsuperscript{z}

<table>
<thead>
<tr>
<th>Injury Ratings\textsuperscript{y}</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>(C+D)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clovers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of seasons</td>
<td>39</td>
<td>20</td>
<td>10</td>
<td>6</td>
<td>16</td>
<td>75</td>
</tr>
<tr>
<td>Frequency</td>
<td>1/1.9</td>
<td>1/3.8</td>
<td>1/7.5</td>
<td>1/12.5</td>
<td>1/4.7</td>
<td></td>
</tr>
<tr>
<td><strong>Alfalfa</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of seasons</td>
<td>13</td>
<td>9</td>
<td>5</td>
<td>1</td>
<td>6</td>
<td>28</td>
</tr>
<tr>
<td>Frequency</td>
<td>1/2.2</td>
<td>1/3.1</td>
<td>1/5.6</td>
<td>1/28.0</td>
<td>1/4.7</td>
<td></td>
</tr>
<tr>
<td><strong>Winter wheat</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of seasons</td>
<td>3</td>
<td>4</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Frequency</td>
<td>1/3.3</td>
<td>1/2.5</td>
<td>0/10.0</td>
<td>1/3.3</td>
<td>1/3.3</td>
<td></td>
</tr>
<tr>
<td><strong>Winter rye</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of seasons</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Frequency</td>
<td>1/1.6</td>
<td>1/4.0</td>
<td>1/8.0</td>
<td>0/8.0</td>
<td>1/8.0</td>
<td></td>
</tr>
<tr>
<td><strong>Strawberry</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of seasons</td>
<td>1 1</td>
<td>16</td>
<td>4</td>
<td>3</td>
<td>7</td>
<td>34</td>
</tr>
<tr>
<td>Frequency</td>
<td>1/3.1</td>
<td>1/2.1</td>
<td>1/8.5</td>
<td>1/11.3</td>
<td>1/4.9</td>
<td></td>
</tr>
</tbody>
</table>

\textsuperscript{z}Reproduced from Suzuki et al. (1975).

\textsuperscript{y}Injury ratings: A, little or no injury; B, some but not extensive; C, considerable, D, severe.
Table 16. Frequencies of occurrence of winter injury to alfalfa, red clover, winter wheat and fall rye in the Maritime Provinces from 1976-1990

<table>
<thead>
<tr>
<th>Crop/Province</th>
<th>Survival rating(^y)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td><strong>Alfalfa</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N.S.</td>
<td>1.7</td>
<td>3.0</td>
<td>15.0</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>N.B.</td>
<td>2.3</td>
<td>2.0</td>
<td>14.0</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>P.E.I.</td>
<td>1.5</td>
<td>5.0</td>
<td>15.0</td>
<td>15.0</td>
<td></td>
</tr>
<tr>
<td><strong>Red clover</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N.S.</td>
<td>1.9</td>
<td>2.5</td>
<td>15.0</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>N.B.</td>
<td>1.7</td>
<td>3.8</td>
<td>15.0</td>
<td>15.0</td>
<td></td>
</tr>
<tr>
<td>P.E.I.</td>
<td>1.5</td>
<td>5.0</td>
<td>15.0</td>
<td>15.0</td>
<td></td>
</tr>
<tr>
<td><strong>Winter wheat</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N.S.</td>
<td>1.4</td>
<td>5.0</td>
<td>15.0</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>N.B.</td>
<td>2.0</td>
<td>2.0</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>P.E.I.</td>
<td>2.5</td>
<td>2.5</td>
<td>5.0</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td><strong>Fall rye</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N.S.</td>
<td>1.2</td>
<td>65</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>N.B.</td>
<td>1.3</td>
<td>4.0</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>P.E.I.</td>
<td>1.8</td>
<td>2.8</td>
<td>14.0</td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

\(\text{\textsuperscript{z}}\) Reproduced from Suzuki (1990).

\(\text{\textsuperscript{y}}\) Injury ratings: A, little or no injury; B, some but not extensive; C, considerable; D, severe.

\(*\text{>15.} \)
more important than those in tap roots for winter survival of alfalfa. Knowledge of the role of carbohydrate reserves in regrowth may aid in the selection and subsequent breeding of plants with increased tolerance to frequent cutting and winter conditions.

Total nonstructural carbohydrates (TNC) consist of sugars, fructosan and a small amount of starch (Suzuki and Stout, 1983). Fructosan is synthesized from sucrose and is accumulated in temperate grasses during the fall (Suzuki, 1989b). A study by Suzuki and Stout (1983) found that fructosan was the major component of TNC in timothy and that the concentration and molecular size of fructosan in storage tissues of perennial grasses were related to resistance to defoliation or grazing. Suzuki (Suzuki, 1968b, 1971a, 1989b) has investigated fructosan biochemistry and its relation to coldhardiness in forage grasses.

A cold stress test, which involves inducement of hardening in environmental control chambers, has been utilized by some researchers to evaluate the coldhardiness of forage species and the effect of harvesting practices and fertilizer treatments on this tolerance (Calder et al., 1965b; Calder and MacLeod, 1966; Langille and Calder, 1971; Choo and Suzuki, 1983a). Calder et al. (1964a) developed an in situ technique to study the hardening process in legumes. This technique did not require destruction of the plant tissue as did previous methods and was used to follow the hardening process over time. Electrodes implanted in the soil measured changes in the electrical resistance in plant roots induced by variations in temperature and light. This resistance has been used to verify the physiological cellular changes associated with hardening (Calder and MacLeod, 1965; Calder et al., 1966). Suzuki has used an auto-analyzer to determinate the levels of TAC in root tissues of alfalfa (Suzuki, 1971b) and triphenyltetrazolium chloride (TTC) to evaluate the regrowth potential of buds on storage organs of alfalfa, birdsfoot
trefoil, timothy and bromegrass (Suzuki, 1968a). A colorific reaction of TTC in the meristematic
tissue of the storage organs provides a visual evaluation of regrowth potential. Quantitative
estimates of the colour density were determined with a spectrophotometer and a significant
correlation was found between the color density of the resulting triphenylformazan in the tissues
and the regrowth pattern of individual species grown in pots and subjected to the same cold
treatments as the plants that were tested with TTC.

Tissue culture techniques can be very useful for the genetic improvement of plant species.
These techniques require germplasm that is capable of regenerating entire plants from callus and
cell suspension and the ability of regenerated plants to establish and set seed under greenhouse
conditions (Matheson et al., 1990). Researchers at the Nova Scotia Agricultural College have
been investigating in vitro regeneration in red clover and alfalfa (MacLean and Nowak, 1989;
callus culture of zigzag clover. Researchers have also examined the role of polyamines in
regeneration and coldhardiness of red clover (Nowak, 1989) and white clover (MacLeod, K. and

Studies have indicated that in vitro regenerative ability may be related to coldhardiness
in plants. Nowak et al. (1992a) found that regenerative genotypes of alfalfa and red clover
survived better than did non-regenerative genotypes where exposed to cold hardening conditions.
Nowak et al. (1992a) were able to select alfalfa plants with higher tolerance to proline analogues
(used as a selection pressure) and will test these plants for cold tolerance. The in vitro selection
of plants with increased coldhardiness may help plant breeders to improve the persistence of
existing forage species in the Atlantic Provinces.
The flowering characteristics of various types of red clover has been investigated as an indication of winter survival ability. Choo (1984) suggested that the absence of flowering in the seeding year was a possible criterion for selecting winter hardy plants. Christie and Choo (1991a) suggested that this scheme would be useful if yield in the seeding year was not important, but if it was, plants which flowered in the seeding year should be evaluated in the second and third year for survival, vigour and bloom date.

Plant age can have an effect on its ability to tolerate cold. Choo and Suzuki (1983b) found that red clover younger than 12 weeks had very little chance of withstanding freezing and could not be used for screening red clover germplasm for coldhardiness. They also suggested that red clover should be seeded so as to provide at least 12 weeks of summer growth to ensure some degree of survival. Calder et al. (1965b) found that increased maturity prior to hardening increased winter survival of alfalfa. Suzuki (1991) found that alfalfa plants that survived the seeding year did not lose cold tolerance over time; no differences in coldhardiness were found among different stand ages.

Besides cold temperatures, a major environmental factor associated with winterkilling is soil moisture and the effects of freezing and thawing on forages. The wet fall and winter climate, along with freezing temperatures, causes many soils to heave throughout the winter in the Atlantic Provinces. Alfalfa is particularly susceptible to heaving as the crown and roots may be exposed as a result. Calder et al. (1965b) found that extremely high soil moisture content at the time of hardening and freezing hindered the development of hardiness, storage of TAC and increased the risk of damage caused by heaving. Grant and Saini (1973) found that moisture equivalent (the approximate amount of water a soil will hold at field capacity) was closely related
to frequency and severity of heaving. This factor could be used to predict the susceptibility of soils to heaving.

The formation of ice sheets often occurs on soils with poor drainage and can easily be predicted. Suzuki (1975) found that survival of alfalfa was not affected by ice cover but that yields were 13% lower than plants not covered. Suzuki (1981b) investigated the effects of mid winter thaw on alfalfa survival and found that waterlogging, an associated problem, resulted in accumulation of ethanol and methanol, solubilization of proteins and a decrease in carbohydrates. He suggested that the ability to maintain freezing resistance during the thawing period and to remove ethanol quickly after waterlogging were important physiological characteristics for surviving mid-winter thaw.

Alar-85 (N-dimethyl amino succinamic acid) has been shown to retard growth of a wide variety of plants as well as increase drought tolerance of certain species (Calder et al., 1973). Calder et al. (1973) examined the effects of Alar spray on the drought and frost hardiness of alfalfa and Ladino white clover. Carbohydrate content of plant tissues increased (0.65 to 1.03%) and changes in electrical impedance and visual recovery ratings indicated increased resistance to drought or frost for up to 25 days following spraying.

4.3.2 Germination and Growth Inhibition

Extensive research has shown that many plants contain substances which are inhibitory to the germination and growth of other plants and sometimes to themselves (Grant, 1965). This phenomenon may be an important consideration in the compatibility of forage mixtures. Grant and Sallans (1964) reported on a study to assess the effect of the aqueous extract of eight
common forage plants upon germinating seed of the same species. They classified the species in the following order of decreasing inhibition: alfalfa, birdsfoot trefoil, Ladino clover, red clover, reed canarygrass, bromegrass, timothy and orchardgrass. Alfalfa and timothy were the species least affected by the extracts while reed canarygrass was the most susceptible.
5.1 **Hay Production**

Climatic and soil conditions in Atlantic Canada require that a great deal of the forage production for livestock be conserved as hay or silage. These same conditions also dictate what species are best suited to production in the region. Timothy is by far the most important grass species grown for hay in this region and is recommended as part of most hay and haylage mixtures. Other grasses commonly seeded are bromegrass, orchardgrass and reed canarygrass. Langille (1977b) compared several western Canada grasses, including several wheatgrass species and creeping red fescue, with locally grown species. Alfalfa has become an important hay species and is recommended in mixture with timothy, bromegrass and orchardgrass (A.A.C.C.P.C.F.C., 1991).

The choice of forage conservation system is usually based on economics, local climate and on-farm requirements. Haymaking systems continue to be the main conservation method for Atlantic farmers. Although silage systems are less weather-sensitive and increase the likelihood of harvesting forage crops at optimum maturity, the high cost and difficulties associated with trading tend to restrict their use to large livestock operations.

5.1.1 **Production and Harvest Methods**

The importance of fertilization of hayfields has not been traditionally recognized in this region and hay is often one of the most neglected farm crops (Comeau, 1959). MacLeod (1969a) conducted a study to determine the effect of fertilization on yield and costs per tonne of alfalfa/timothy hay and found that liming and then fertilizing produced substantial increases in
yield and reduced the cost per tonne over unfertilized fields. Cost per tonne was lowest when 181 to 272 kg 5-10-30/ha was applied to limed soil (pH 6.2). - The effects of lime and fertilizer elements and micronutrients on grass and legume species for hay was discussed in the section entitled "Fertility Management".

Advances in mechanization, such as the mower-conditioner, have made operations more efficient, accelerated the drying process and improved the quality of conserved forages. A great deal of work has been done to evaluate the efficiency and suitability of mower-conditioners (Jackson, 1967; MacIntyre, 1971; Sibley, 1987; Desir, 1988) and other harvest equipment (Ramsay, 1989; Walsh et al., 1989; Carmichael, 1990) for Atlantic agriculture. The modification of conditioners and other forage harvesting machinery by fitting them with flotation tires or "muskeg" tracks has adapted them for use on peat soils in Newfoundland (Rayment, A.F. and Heidel, 1972).

5.1.2 Field Drying
A minimum of 3 good drying days are required to dry hay to the stage where it can be baled (below 25% moisture). A good drying day has been classified as one with less than 12.7 mm of rainfall on the previous day and a drying index value, based on potential evaporation, greater than or equal to 4.2 mm (Hayhoe and Jackson, 1974). Field drying takes place when moisture is evaporated from the leaves and stems of the mowed crop by ambient air, and the speed with which this occurs is dependent upon the moisture content of the crop, air humidity and the degree of surface exposure to the air (Sibley, 1987). Mechanical conditioning breaks down the waxy layer on the stems and leaves in order to hasten water evaporation from tissues.
A number of researchers have worked on the problem of predicting the field drying rates of hay and methods of scheduling harvest operations to minimize losses from weather exposure. Kemp and Roach (1968) suggested that latent evaporation (LE), or the drying ability of the air (Robertson, 1954), could be used as a single meteorological parameter in developing drying equations. Kemp et al. (1972) used LE to develop equations for drying alfalfa in the laboratory and suggested that since LE could be easily obtained from atmometers or calculated from meteorological data, it could prove very useful in field drying experiments. Hayhoe and Jackson (1974) proposed an index based on potential evaporation and precipitation as a measure of the suitability of weather data for predicting field drying rates and generated a table of "good drying day probabilities" for Nappan, Nova Scotia. They calculated the probability of 3 consecutive good hay drying days ranged from 0.068 in mid- to late August to 0.36 in early July. Kemp et al. (1977) found that drying rates of hay crops under field conditions can be adequately represented by exponential equations using cumulative latent evaporation with or without cumulative precipitation. Bootsma and Suzuki (1984) prepared a climatic zonation map which compares the climate for hay drying and the degree of moisture stress that may affect growth of forage crops during the summer months in Atlantic Canada (Figure 3). The legend is explained in TABLE 17a and 17b.
Figure 1: Moisture zones for hay drying and water deficits
(Redproduced from Bootsma and Suzuki, 1984)
Table 17a. Drying index values and general drying conditions in each zone

<table>
<thead>
<tr>
<th>Moisture Zone</th>
<th>Range in average drying index (mm)</th>
<th>Drying conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>D 1</td>
<td>360-325</td>
<td>Good</td>
</tr>
<tr>
<td>D2</td>
<td>325-280</td>
<td>Fair</td>
</tr>
<tr>
<td>D3</td>
<td>280-225</td>
<td>Fair - Marginal</td>
</tr>
<tr>
<td>D4</td>
<td>225-160</td>
<td>Marginal</td>
</tr>
<tr>
<td>D5</td>
<td>less than 160</td>
<td>Very Poor</td>
</tr>
</tbody>
</table>

*Reproduced from Bootsma and Suzuki (1984)*

Table 17b. Approximate average water deficits for each zone

<table>
<thead>
<tr>
<th>Moisture Zone</th>
<th>Average water deficit, June-August (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Soil Water-holding capacity</td>
</tr>
<tr>
<td></td>
<td>50 mm</td>
</tr>
<tr>
<td>D 1</td>
<td>115-70</td>
</tr>
<tr>
<td>D2</td>
<td>70-35</td>
</tr>
<tr>
<td>D3</td>
<td>35-5</td>
</tr>
<tr>
<td>D4</td>
<td>5-0</td>
</tr>
<tr>
<td>D5</td>
<td>Nil</td>
</tr>
</tbody>
</table>

*Reproduced from Bootsma and Suzuki (1984)*
5.1.3 Packaging Systems

Kemp (1980) prepared a publication entitled "Forage Handling Systems for Grass and Legumes" which provides information and suggestions on handling forages for hay and silage systems. This booklet was recently updated by Watts (1991). The main packaging systems in the Atlantic Provinces at the time of the first publication included standard small bales, large round bales and mechanically formed stacks. The current publication omits stack forming, which is not a common practice, but includes large rectangular bales. The small bale system has been the most popular in this region due to its versatility of handling and storage and the suitability of bales for transport over fairly long distances. Large round bales offer one of the lowest investments in a completely mechanized system and bales may be left in the field. Large rectangular bale systems are specialized for custom production of forage. These bales can be made at any moisture content and are easily transported, but initial cost is high (Watts, 1991).

Kemp et al. (1975) prepared a report on stack formers and examined the quality and operating costs associated with this forage handling system. Kemp et al. (1978) compared the dry matter and quality losses of stacks and low and high density, large, round bales. They found that low density bales were best for inside storage. With outside storage, stacks were found to be more susceptible to wind damage, and bales to moisture damage. Hay stacking has not been practised to a large extent in the Atlantic region.

5.1.4 Artificial Drying

Climatic conditions in Atlantic Canada are not conducive to long periods for field drying. The probability of 3 consecutive dry days during the summer months is very low in all provinces, making it extremely difficult to dry hay to the 18% moisture content recommended for large
bales. Baling at higher moisture content (30-35%) with subsequent drying would reduce the chance of moisture damage and also the leaf loss associated with a dry crop (Barclay et al., 1989a). Investigators have examined the potential of artificial hay drying through the use of bam dryers and chemical drying agents. Misener et al. (1990) used an experimental hay dryer to conduct drying experiments on large round bales. They found that soft-core bales tended to dry at a faster rate than the uniform density bales, where a higher moisture content was retained in the top outer portion. Several methods of applying heat were tested and all found to effectively dry large round bales with initial moisture content of up to 34% (Misener and McLeod, 1992). Misener et al. (1990) found that the energy requirement for drying bales was 33 kWh/tonne dry matter/moisture point reduction. Webster et al. (1991) evaluated hay dryer designs on 2 local farms. The Sub-committee on Structures and Equipment of the Atlantic Agricultural Engineering Committee prepared a booklet on forced air drying and its use in improving forage quality in the Atlantic region (Henderson et al., 1979).

Desiccants are drying agents applied at time of cutting to reduce drying time of legumes (Anonymous, 1990a). They consist of potassium carbonate and/or a mixture of methyl esters of fatty acids and operate by altering the waxy cuticle of leaves and stems to allow moisture to escape at an accelerated rate. Barclay and Misener (1990) found that drying time of alfalfa was reduced an average of 21% when treated with desiccant and that acid detergent fiber and total nitrogen content were adversely affected in second cut alfalfa but not in a subsequent trial with third-cut alfalfa. Red clover, a succulent and slow wilting crop, was found to dry faster when treated with 5 kg a.i. ha potassium carbonate, based on moisture to dry matter ratio (Narasimhalu and Choo, 1983).
Many chemicals have been tested for their potential to preserve moist baled hay. Manger et al. (1987) evaluated urea, a readily available ammonia source, as a preservative for moist grass hay. They found that the addition of urea at a rate of 40 g/kg forage and above reduced microbial activity, which reduced heating and spoilage, improved digestibility and increased nitrogen content. Inoculants are sometimes added to hay when baled at 20-25% moisture to prevent mould formation and reduce heat damage (Anonymous, 1990a). These bacterial inoculants promote the growth of beneficial bacteria and prevent the growth of harmful bacteria and mould.

5.1.5 Storage Conditions

Large round baling systems are economically attractive and provide farmers with totally mechanized forage systems with low labour requirements. The larger mass of bales, however, is more susceptible to spoilage than the smaller rectangular bales and a moisture content of 18% is recommended before storage (Barclay and Misener, 1990). Laflamme (1989) reported major quality changes in the first 15 cm layers of large round bales (LRB) that were not covered during storage. He suggested that LRBs were an acceptable system for this region but that plastic bags or shelter should be used to prevent damage from precipitation.

5.1.6 Transportation

In addition to on-farm use, some operations produce enough forage to enable them to sell additional material. The main problem, however, for hay export is the excess transportation costs due to characteristic low density of the material. Hay compacting equipment can be used to adjust the density of forages and Swinkles (1984) reported on several systems in operation in the
Atlantic region. Watts and Bilanski (1991) examined the effects of moisture content, leaf content, loading rate and maximum density of bales on stress relaxation of alfalfa under compression. This may be of significant importance when determining strapping requirements for high density bales.

5.1.7 Feeding Systems

Large round bales pose a difficulty for some farmers who operate tie-stall barns and barns with insufficient area for operating bale handling and feeding equipment. Bales fed to livestock outdoors can simply be placed in round bale feeders or chopped with machinery such as a bale buster. The bale buster can eliminate wasted forage and the excess energy required by cattle to pull forage from tightly packed bales (Lawton, 1990). Misener et al. (1991) developed a stationary large round bale shredder and examined its effectiveness for use in tie-stall barns.

5.1.8 Nutritive Value

Loss of hay quality, such as digestibility of dry matter, is due to the loss of leaf material, plant respiration, leaching of carbohydrates by rainfall, and spoilage in storage. Hay quality is also affected by stage of maturity at harvest, weather conditions during the growing season and the species grown. Halliday et al. (1992) reported on the chemical composition and animal performance of hays made from several grass species. Crude protein values ranged from 8.4 to 10.8%, and in vitro digestibilities, 57.0 to 66.6%. Deficiencies in Cu and Zn were reported for all hays. Feed efficiency ranged from 9.6 to 15.6, with "Basho" timothy performing best. A ryegrass X meadow fescue hybrid, "Prior", had the greatest intake (7.2 kg/day) and highest digestibility (66.6%) of all hays, but it required an extra day to dry. "Farol", a late maturing
timothy, was cut in the first week of July and contained a substantial amount of dead leaf material. It had the lowest CP levels (8.4%) and was lower in mineral content. "Mimer", an early maturing meadow fescue, required harvesting in late May to early June to produce acceptable animal gains (0.52 kg/day), which is not always possible. "Venture" reed canarygrass produced excellent quality hay but palatability was low (5.0 kg/day compared to a mean of 6.6 for other hays) (Halliday et al., 1992). Rayment and Heidel (1972) found that hays grown on peat soil in Newfoundland produced satisfactory yields and animal performance as compared to hays grown on mineral soil. Feed quality was represented by 0.56 and 0.62 kg ADG, 55A% and 53.6% o IV D, and 11.0% and 8.0% CP for peatland and mineral hays, respectively.

Changes in the chlorophyll content of red clover during hay making has an undesirable effect on the appearance of the hay. Herbage changes colour rapidly from green to dark brown and this is attributed to formation of brown pigments such as clovamides, which are conjugates of amino acids with polyphenols (Suzuki and Christie, 1991). This discoloration has not been found to affect nutritive value or palatability but there is little or no market for the hay because of its appearance.

5.2 Grass and Corn Silage

The climate in Atlantic Canada is not conducive to hay making for many parts of the region and despite great progress in hay making technology, some farmers cannot rely on this system to meet their forage requirements. In areas where field drying of forages for hay is difficult because of frequent precipitation, a good alternative is to store the crop as silage. A silage system should be considered if more than 250 tonnes of dry matter of forage per year are required (Kemp, 1980).
5.2.1 Types of Silage

Corn is an excellent forage crop for silage production as it produces more total digestible nutrients per unit area than any other locally-grown forage (A.A.C.C.P.C.T.C., 1991). Production of corn, however, is limited to areas with sufficient heat and a long growing season and climatic conditions in many regions of the Atlantic Provinces are not suitable. Calder et al. (1976) found corn silage to be superior to grass-legume and grass silages as feed for steers. Burgess and Nicholson (1984) found no advantage in growing male sterile corn for silage versus regular corn (which is subject to bird damage) as the male sterile corn had lower dry matter yield. Other research on corn for silage use has focused on seeding rates (Burgess et al., 1979; Nicholson et al., 1986) and timing of harvest (Calder et al., 1977; Narasimhalu et al., 1986).

"Grass" silage is made from cured forage crops that include grasses; grass/legume mixtures; and legumes. Grasses such as timothy, bromegrass and orchardgrass can make excellent silage if properly managed. Narasimhalu and Kunelius (1980) found timothy and Italian ryegrass contained suitable dry matter levels for ensiling (32% and 26%, respectively) after six hours of field drying and that annual ryegrasses contained higher moisture loads than timothy. Burgess and Grant (1974) found that a silage system based on timothy cultivars with variable maturities offered a reliable source of high quality forage for areas where corn and legume production is considered unreliable. These results were supported by findings of Lovering (1975). Severe infestation of timothy by quackgrass (Elytrigia repens L. Neoski) was found to have no significant effect on the quality of silage (Narasimhalu et al., 1989). Surplus herbage from late-season annual ryegrasses can also be conserved as silage. Narasimhalu et al. (1985) found timothy silage contained more cell wall and less digestible dry matter than annual ryegrass.
Italian ryegrass silage was superior to Westerwolds ryegrass with respect to composition, animal intake and digestibility (Narasimhalu et al., 1992b). Calder (1986a) found annual ryegrass silage to equal red clover/timothy silage for animal gain. Halliday et al. (1992) evaluated several grass and legume species for ensiling characteristics and found a great deal of variation due to variety, maturity and growing season.

Grasses are generally fertilized with high levels of N which are detrimental to the ensiling process. The breakdown of non-protein N to ammonia in grass silage neutralizes some of the acids which are produced to lower the pH and preserve the silage (Nicholson, 1982). This results in increased losses of dry matter, it encourages undesirable Clostridia bacterial activity and reduces intake by livestock. Preservatives such as formic acid can be used to offset these problems and produce good quality grass silage (Kunelius and Suzuki, 1978).

Legumes can be ensiled either as pure silage crops or in mixture with grasses. Halliday et al. (1992) found that alfalfa produced silage with high pH and high NPN. Legumes are more difficult to ensile than grasses because they generally have twice the buffering capacity, which means they require twice as much fermentation acid to attain the same pH. They also have low water soluble carbohydrate (WSC) levels, which are required by lactic acid bacteria to produce acids which lower the pH of the ensiled mass. Red clover silage, however, had low pH and low NPN (Halliday et al., 1992). It was suggested that hemicellulose was a possible alternate source of the acids produced and that rapid fermentation prevented excessive proteolysis (breakdown of protein). Nicholson and McQueen (1980) evaluated silage made with "Hungaropoli", a tetraploid red clover that was reported to be higher in WSC. They found the strain to outyield "Ottawa" red clover, a diploid cultivar, by 29 and 16% (first and second cut), but there were no differences
in WSC. Beef calves had superior gains on second cut Hungaropoli silage (0.97 vs. 0.83 kg/day gain).

Lirette et al. (1993) found pure white clover (WC) silage superior to alfalfa (AL) silage and comparable to red clover (RC) silage as feed for steers. Average daily gains of steers were 1.05, 0.98 and 0.62 kg/day for WC, RC and AL and were significantly lower for steers fed AL silage. Dry matter percent was 48.1±1.0%, 44.6±1.2%, and 38.2±1.3% and crude protein values were 25.7±0.3%, 22.4±0.2% and 21.3±0.3% for WC, RC and AL, respectively. Steers fed alfalfa silage had significantly lower dry matter intake and higher feed to gain conversion. They attributed lower production parameters produced by AL silage to poor fermentation and concluded that white and red clovers make good, high quality feed but that white clover is difficult to grow and to ensile.

The feasibility of ensiling other field crops with forages has also been investigated. Surplus potatoes are a plentiful resource in the Atlantic region and incorporating them into livestock feed programs would be economically attractive to area farmers. Nicholson et al. (1977) found that potatoes could be ensiled with chopped hay in a 2.5:1 ratio and provide comparable feed to corn silage. Potatoes were found to ensile well during the winter months when cull potatoes were most available, eliminating the need for storage until spring (Nicholson et al., 1982). Laflamme (1992) reported good quality silage from carrot/grass mixtures. Forage peas have been found to improve feeding value when grown with barley for silage (Thomas, 1991 a).

5.2.2 Production and Harvest Methods
Intensive production of forages has led to increasing levels of N applied to crops in an attempt to produce higher and higher yields. Recent interest in annual ryegrasses, which require large amounts of N to maintain their rapid growth, has also led to increased use of N (Nicholson, 1982). Levels of N fertilization, however, are a concern in the production of silage. Non-protein nitrogen (NPN), which develops when N is absorbed from fertilizer faster than it can be converted to protein in the plant, breaks down to ammonia during fermentation (Nicholson, 1982). Ammonia neutralizes the acids which are produced to lower the pH of the silage, prolonging fermentation and resulting in dry matter losses and unstable silage. Nicholson and MacLeod (1966) found that calcium nitrate applied as fertilizer to a grass- legume mixture resulted in higher NPN concentrations than did applied urea. The form of fertilizer, however, did not significantly affect chemical quality, steer performance or N balance of sheep.

Forages can be harvested for silage either immediately as direct-cut silage or after a period of wilting. The moisture content of forage when it is ensiled affects the quality of the silage because moisture affects the type of fermentation that takes place and the time required for fermentation (Logan and Lister, 1971). Direct-cut silage can result in poor fermentation and high seepage losses in vertical silos (Kemp, 1980) and although additives may alleviate this somewhat, their use is not generally recommended (Watts, 1991). Narasimhalu et al. (1983) found that voluntary intake by sheep was higher for wilted than direct cut silages. Russell et al. (1977) used a computer simulation model to study the effects on forage yield-quality and costs of a number of variables in direct-cut timothy silage harvesting.

Wilting forage to a moisture content of 60-70% is very effective in reducing losses and results in the least problems for storage. It can be used in all types of silos and is recommended for most operations (Kemp, 1980). Wilting forages before pick-up is the most common practice
in the Atlantic Provinces. Calder (1982) steam-treated grass prior to harvest with a mobile steamer to accelerate wilting and determine its effect on silage quality. He found that animal gains increased 57% but that this method was not economical.

5.2.3 Fermentation Processes

When freshly cut forage is placed into air tight structures, oxygen is rapidly utilized through plant respiration (MacLennan et al., 1990). The anaerobic environment thus created favours the growth of lactic acid-producing bacteria which are present on the forage. The bacteria digest carbohydrates in the forage and produce lactic acid as a by-product in a process called fermentation. Large quantities of lactic acid are accumulated during fermentation, lowering the pH and producing a stable or "preserved" silage product (MacLennan et al., 1990). Rapid fermentation provides high quality forage by preserving protein quality and discouraging growth of spoilage organisms.

The level of water soluble carbohydrates (WSC) is important for the conservation of forages as silage as they are the main fermentable carbon source during ensilage. Six to eight percent WSC of DM is required to produce high quality silage (Suzuki et al., 1990). Suzuki and Kunelius (1989) reported that about 45% of forage crops grown in eastern Canada may have insufficient levels of WSC for making high quality silage. They suggested several methods to increase the availability of WSC in ensilage: use of silage additives; pre-treatments such as chopping; minimizing loss of WSC after harvest; improving crop management practices such as avoiding excess N application and modifying cutting schedules; selecting high WSC crops and mixtures; and developing high WSC cultivars (Suzuki and Kunelius, 1989). In a survey conducted in Quebec and the Atlantic Provinces, 32% of samples from the Maritime Provinces
showed 10% WSC of DM or higher while in Newfoundland, the majority of samples contained insufficient WSC levels and more than 30% of samples contained less than 5% WSC (Suzuki et al., 1990).

Fructan is one of the main components of forage grasses grown in temperate regions such as Canada. It is composed of a group of fructose polymers with various degrees of polymerization with one molecule of sucrose or glucose at the terminal (Suzuki and Kunelius, 1989). Fructans are present in various chain lengths and molecular sizes which affect the availability to silage bacteria. Suzuki (1989b) reported that each forage grass has a characteristic profile of molecular size distribution of fructans.

The amount of carbohydrates required to produce good quality silage depends on the buffering capacity and dry matter content of the forage crop. Buffering capacity is defined as the amount of acid required to bring a standard amount of forage material to a pH of 4. McQueen (1989) found red clover cultivars and annual ryegrass to have twice the buffering capacities of Climax timothy. This means that about twice as much lactic acid would be required for proper ensilage. Annual ryegrasses contain higher WSC levels than other forage grasses grown in Atlantic Canada (Table -18; -Suzuki, 1989b). These high levels of WSC would be required to offset the high buffering capacity of the species for successful ensiling.

5.2.4 Silage Additives

Silage additives help promote the rapid fermentation required to produce high quality silage. They are classified as: preservatives, such as acids and formaldehyde; nutrient supplements, such as molasses and barley; and biological additives, which contain cultures of bacteria and/or
enzymes. Limited research on these additives has been conducted in Atlantic Canada.

Kunelius and Suzuki (1978) found treating wilted and unwilted grasses with formic acid and formic acid plus formaldehyde reduced pH and ammonium-N levels in the silage but that untreated silages were still of acceptable quality. Narasimhalu et al. (1992a) reported that timothy could be ensiled without formic acid or a commercial enzyme additive and that formic acid treatment decreased silage digestibility in sheep. Calder (1977) reported that neither the addition of barley to the ration nor formic acid to the grass made into silage resulted in any increase in animal gain over grass silage alone. Hydrochloric acid applied at a rate of 4L 38% HCL diluted 1:1 with water per tonne of direct-cut forage produced good quality forage (Fredeen, 1986). Intake of treated silage was reduced but lower field losses from direct-cutting improved nutrient concentration. Nicholson and Cunningham (1964) added one and two percent high-calcium, ground limestone and shredded newspaper to corn and grass silages. The limestone did increase organic acid content as reported by others but digestibility of organic matter was not affected and intake was reduced. The addition of newspaper to reduce moisture content had no effect on organic acid production and reduced intake.

Table 18. Water soluble carbohydrates in forage grasses at Charlottetown, P.E.I.\textsuperscript{x,y}

<table>
<thead>
<tr>
<th>Crop Species</th>
<th>Cultivar</th>
<th>WSC (% of DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Aug. 5</td>
</tr>
<tr>
<td>Timothy</td>
<td>Climax</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td>Salvo</td>
<td>7.0</td>
</tr>
<tr>
<td>Reed canarygrass</td>
<td>Palaton</td>
<td>6.0</td>
</tr>
<tr>
<td>Orchardgrass</td>
<td>Frode</td>
<td>9.2</td>
</tr>
<tr>
<td>Bromeegrass</td>
<td>Saratoga</td>
<td>7.7</td>
</tr>
<tr>
<td>Grass Type</td>
<td>Variety</td>
<td>CP (%)</td>
</tr>
<tr>
<td>------------------------</td>
<td>----------</td>
<td>--------</td>
</tr>
<tr>
<td>Meadow fescue</td>
<td>Prior</td>
<td>10.3</td>
</tr>
<tr>
<td>Tall fescue</td>
<td>Kenhy</td>
<td>8.8</td>
</tr>
<tr>
<td>Perennial ryegrass</td>
<td>Norlea</td>
<td>13.8</td>
</tr>
<tr>
<td>Italian ryegrass</td>
<td>Bartolini</td>
<td>14.2</td>
</tr>
<tr>
<td>Westerwold ryegrass</td>
<td>Aubade</td>
<td>19.4</td>
</tr>
</tbody>
</table>

²Seeded and harvested in 1987.
³Reproduced from Suzuki (1989b).

The addition of 75 kg of barley per tonne of forage increased dry matter (22.9%, untreated to 27.2%, treated) and lactic acid content (3.77 to 5.83%); lowered CP, ammonia N, butyric acid and pH; and increased animal gain (Nicholson and MacLeod, 1966). High carbohydrate sources such as barley and molasses are thought to provide extra carbohydrates to stimulate the growth of lactic acid bacteria in the silage, particularly in forage species with low WSC. Halliday et al. (1989) added molasses, whey and potatoes to alfalfa before ensilage. Molasses and whey caused a rapid drop in pH and reduced ammonia and water soluble N (WSN). Molasses improved DM recovery and increased lactate levels. A study on Prince Edward Island found barley to improve fermentation in one out of four trials and molasses to improve protein recovery in one out of two
trials (MacLennan et al., 1990). The researchers attributed inconclusive results to variable application rates and quality of harvested forages.

Biological additives have the advantage compared to acid-type additives in not being corrosive or dangerous to handle. Reported research in the region found no conclusive benefits of these additives on silage quality nor any ill effects on animal performance (Fredeen et al., 1989, 1991a; Nicholson and St. Laurent, 1989; St. Laurent, 1989; Fredeen and McQueen, 1992). Fredeen et al. (1989) found that timothy silage treated with a bacterial inoculant containing added nutrients and enzymes was not of higher quality but it had the highest lactic acid concentration and was most acidic (lactic acid concentrations were 51.32, 60.70 and 42.04 g/kg DM; pH was 4.90, 4.88 and 5.07 for control, inoculant with nutrients and enzymes, and bacteria alone, respectively). A large number of commercial additives are available and they vary in quality and effectiveness.

5.2.5 Silage Systems

In addition to traditional vertical and horizontal silos (Nicholson, 1978), a number of techniques have been evaluated to facilitate the ensilage process including stacking systems (Everett and Kemp, 1976), chopping and packing silage into bags (Foster, 1986; Anonymous, 1990b; Esau et al., 1990), heap silos (Ramsay, 1990), and round bales covered with plastic (MacIsaac, 1983; Barclay et al., 1989b; Anonymous, 1991a and b). Farmers with lower forage requirements may be able to take advantage of some of these newer, low-cost ensiling systems.

Nicholson et al. (1991) compared baled silage and chopped, bagged silage as feed for beef calves and sheep. They found that bagged silage had a better fermentation pattern (pH below 5 by day 3 and 4.4 on day 60 vs. pH above 5 on day 60 in baled silage) and lower NPN (468 vs.
585 g/kg total N in baled silage). Beef calves fed bagged silage consumed more feed per day, gained weight faster and converted feed DM to gain more efficiently than those fed baled silage. Nicholson et al. (1992) also examined the effect of moisture level on ensiling characteristics of baled and bagged alfalfa. None of the silages produced were of good quality, although the chemical and microbiological parameters studied showed benefit for the drier (400 vs. 270 g DM/kg) silage under both systems.

Silage is still susceptible to loss of quality even when fermentation is complete. Unloading of horizontal-type silos has normally been done by front end loaders. This practice often leads to a crumbled pack face which is susceptible to spoilage. Work has been done in the region to evaluate other systems, such as the silage block cutter, which keep the pack face sealed and are more efficient at handling the removed silage (Kemp and Melanson, 1974; Robinson, G., 1986; Campbell, V. and MacEwen, 1990; VanGaal, 1992).

5.3 **Cereal Silage**

Ensiling cereals was initially investigated in the Atlantic region because short growing seasons prevented the production of high quality corn silage in many areas. Cereals are better adapted to our cool climate and can produce high yields. Burgess et al. (1973) ensiled "whole crops" of corn, barley, wheat and forage oats and fed them as the sole forage to lactating dairy cows. They found that corn silage was used more efficiently by cows and that the cereals were similar in feeding value. The whole cereal silages contained high fiber levels which reduced intake and milk yield. They recommended that dairy farmers grow silage corn and use cereals only for emergency crop situations. Nicholson et al. (1971) found that milling ensiled barley resulted in a 25 to 30% increase in the digestion coefficients for dry matter, organic matter and energy. Whole barley was not efficiently used by steers or yearling heifers and was not recommended
as feed. MacIntyre (1970) found whole barley silage to give satisfactory results but corn silage was better feed for growing heifers.

Burgess et al. (1989) investigated barley and wheat "head-chop" silages as feed for dairy cows. "Head-chop" silages are made by ensiling the cereal heads with only a limited amount of the straw. They found that reducing the amount of straw improved feeding value of the cereal silages; DM, CP and in vitro true digestibility (IVTD) of DM increased and ADF content decreased. Barley head-chop silage was better than wheat head-chop silage in terms of intake of total DM by dairy cows which resulted in higher uncorrected milk yields (Burgess et al., 1989). A Master's thesis is in progress at the Nova Scotia Agricultural College to examine the value of intercropping sweet white lupins and cereals for silage (Jannasch, Unpubl.).

5.4 **Economics of Hay and Silage Production.**

Timothy is the most commonly grown forage in Atlantic Canada. McIsaac and Lovering (1982b) used a forage-livestock computer model to compare three modes of harvesting and storing timothy: direct-cut silage, wilted silage and hay. They found that hay was the most profitable of the harvest modes when land was not a constraint or if both land and herd size were a constraint. Direct-cut silage was more profitable when land was a constraint but the herd size could be increased. These researchers also compared the cost and returns associated with corn silage, timothy hay and ryegrass silage as the principal forage on a dairy farm (McIsaac and Lovering, 1982a). They found that timothy hay was more profitable than corn silage and corn silage was more profitable than wilted ryegrass silage on dairy farms of 40-120 cows fed conserved forage 365 days/year.
5.5  **Forage Crop Fractionation**

The possible use of juice squeezed from forage crops as a high protein feedstuff for feeder pigs was investigated by Bubar (1978 and 1981). Ladino white clover was the most promising species studied; it was easier to pulp than other legumes and grasses, and it had uniform field production which was important for obtaining fresh juice over a longer period. Fresh juice could be satisfactorily fed to pigs when mixed with dry hog rations. Methods of preserving and concentrating this juice for on-farm use were examined. Fermentation alone gave erratic results, but addition of molasses (10% v/v) before and acetic acid (3.5% v/v) after fermentation resulted in the desirable protein coagulation. Acetic acid added to fresh juice was also found to give satisfactory results (Bubar, 1981).

5.6  **Pasture Production and Management**

Good pasture land is a valuable asset to livestock enterprises in Atlantic Canada. Approximately 80,000 ha are devoted to pasture in the region (Table 19). Climatic conditions such as abundant, well-distributed rainfall and moderate temperatures during the growing season favour high pasture productivity. Two major constraints, however, to maximizing utilization of Atlantic pastures are the location of many pastures on soils of low fertility (due to the traditionally held view that forage crops and pasture were low-value crops) and poor management of forage and grazing livestock. Papadopoulos et al. (1993) reviewed the factors that influence pasture productivity in Atlantic Canada.

5.6.1  **Types of Pastures**

5.6.1.1  **Permanent Pastures**
Most pasture land in Atlantic Canada is classified as permanent pasture. These pastures have remained more or less in their natural state and have not been changed by cultivation or improvement. They contain primarily naturalized grass and legume species such as bluegrass, bentgrass, creeping red fescue, quackgrass and white clover. Good permanent pastures can provide excellent animal gains (Kunelius et al., 1989a) and very economical livestock feed, while renovation can significantly improve production of neglected pastures (Calder and Warren, 1967).

A study on cow-calf management systems for beef cattle in Nova Scotia found that permanent pasture, supplemented with annual ryegrass or stubble turnips for emergency use, provided the optimum summer grazing system (Troelstra and Calder, 1987). In areas of Newfoundland, cattle are traditionally allowed to roam the countryside for "rough" grazing. Rayment (1966) reported

<table>
<thead>
<tr>
<th></th>
<th>N.S</th>
<th>P.E.I</th>
<th>N.B.</th>
<th>Nfld.</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>

ZAdapted from Statistics Canada (1991), as referenced by Papadopoulos et al. (1993)
on native browse plants that are consumed.

5.6.1.2 Sown Pastures

Sown pastures are seeded specifically for pasture use and are periodically reseeded to maintain a balance of species for nutritious and productive forage. They can be incorporated into rotations or maintained as long-term pastures. Interest in these pastures is increasing in Atlantic Canada as more productive, cultivated grasses and legumes become available and intensive production focuses on the importance of forages in livestock enterprises.

Grass species commonly used for pasture include timothy (Winter and Black, 1975; Kunelius and Fraser, 1992; Rodd et al., 1992; Kunelius and Narasimhalu, 1993), tall fescue (Calder, 1983a, 1986b; Laflamme and Papadopoulos, 1987), meadow fescue (Winter and Black, 1975; Thomas, 1990) and reed canarygrass (Black, 1970; Kunelius and Coulson, 1989a). Orchardgrass is a productive pasture species but it is one of the least winterhardy for this region.
(Winter and Black, 1975; Suzuki, 1989b). Thomas (1990) found that mixtures containing orchardgrass yielded the highest of all mixtures studied. A recent study examined the suitability of orchardgrass cultivars under intensive pasture management (Papadopoulos et al., 1992b). Bromegrass, although not generally utilized in sown pastures, is readily grazed by livestock (Black, 1970). Perennial ryegrass is not very winterhardy in the Atlantic region (Langille, 1973) but ryegrass X fescue hybrids produce high DM yields and exhibit intermediate persistence under severe overwintering conditions (Kunelius and Coulson, 1989a). Creeping red fescue, a short-growing grass, performs well in mixtures with white clover (Calder, 1986b; Laflamme and Papadopoulos, 1987).

The addition of legumes to pasture swards has been shown to significantly improve forage quality and animal production (Calder and Nicholson, 1970; Calder et al., 1970); grass/legume mixtures have higher CP content and palatability, and lower nitrate and fiber content (Papadopoulos et al., 1992b). "Wild" white clover is the most common legume in native pastures and recent work has examined the potential for it and larger-leaved cultivars for use in sown pastures (Fraser, 1984, 1988b; Papadopoulos et al., 1992b). Papadopoulos et al. (1992b) found that although grass/white clover swards yielded approximately 2 t/ha less DM than grass monocrop, they supported higher average lamb gain (960 vs. 819 kg gain/ha). In addition, 93% of lambs raised on grass/white clover swards were assessed as grade A at slaughter, while only 83% of lambs which grazed grass monocrop received grade A ratings. Rodd et al. (1992) found that alfalfa cultivars currently in use in Atlantic Canada are not suitable for pasture use as they do not withstand grazing.

The performance of various species in pasture mixtures has been investigated by many Atlantic researchers. Thomas (1990) reported on the performance of meadow fescue, tall fescue
hybrids, white clover, alfalfa, timothy and orchardgrass in various mixtures. White clover mixtures have received increasing attention in recent years (Smeltzer, 1968; Fraser, 1984; Fraser and Kunelius, 1989; Martin, R.C. et al., 1992a; Papadopoulos et al., 1992b). Laflamme and Papadopoulos (1987) compared red fescue/white clover, tall fescue/birdsfoot trefoil and tall fescue/white clover mixtures and found that best results were achieved on pastures containing the highest legume percentage.

Newly sown pastures have been shown to produce up to 10 t DM/ha (Papadopoulos et al., 1992b) and over 1000 kg/ha live weight gains (Papadopoulos et al., 1992b; Kunelius and Narasimhalu, 1993). While this is greater than results produced by permanent pastures (up to 6 t DM/ha and 700 kg/ha live weight gains; Winter and Black, 1975; Cooper and Bosveld, 1989; Neary, 1991; Kunelius and Narasimhalu, 1993), sown species tend to be replaced by native, volunteer species under intensive grazing. Currently available cultivars lack the needed persistence to sustain long-term production of these species (Papadopoulos et al., 1992b; Kunelius and Narasimhalu, 1993). The additional costs associated with maintaining sown pastures will continue to make well managed, permanent pastures more profitable for beef production in Atlantic Canada unless more persistent, high yielding cultivars are identified or developed (Cummings, 1992; Kunelius and Narasimhalu, 1993).

5.6.1.3 Supplementary Pastures

Supplementary pastures include crops grown to provide pasture at those times in the grazing season when regular pasture is in short supply. Langille (1961a, 1962a) reported on the value of sunflowers, corn, vetch, millet, peas, rape, kale and oats, grown alone and in mixtures, as supplementary pasture in late summer and fall. Burgess and Kunelius (1982) found Italian
ryegrass to perform well under intensive management systems with high levels of fertilization. It was readily consumed and withstood intensive grazing. A winter rye/clover mixture seeded in spring provided good late season grazing for dairy cattle (Vienot and Bridge, 1992).

Utilization of annual forage species, including annual ryegrasses, kale, rape and stubble turnips for late season grazing, was discussed in detail in the section entitled "Annual Forage Species and Their Characteristics".

5.6.2 Pasture Renovation

Pasture renovation is often necessary to increase the productivity of permanent pastures. Pasture renovation is any method of rapidly improving pasture without growing an intervening crop (Calder and Warren, 1967). Reseeding and/or lime and fertilizer applications can be achieved with or without cultivation. In Atlantic Canada, most permanent pastures are located on infertile and/or untillable soils. Surface application of lime and fertilizers has been shown to improve yields and botanical composition of permanent pastures (Cameron and Hamilton, 1960; Chiasson, 1960; Calder et al., 1965a). The effects of lime and fertilizers on pastures were also discussed in the section entitled "Fertility Management".

Periodic reseeding of pasture lands is necessary in Atlantic Canada to maintain a good balance of sown species and to increase the productivity of unimproved pastures. Minimum tillage renovation methods, such as sod-seeding, have been shown to be effective and were discussed previously in the section entitled "Forage Establishment". Rayment (1972) reported on rough pasture development on community pastures in Newfoundland. Surface seeding and addition of lime and fertilizers, along with modified equipment for difficult terrain, were successful in establishing forage species on barren lands and peat soils.
5.6.3 Pasture Management

Good pasture management, improved cultivars and species, an extended grazing season and animal health are the key factors in increasing the utilization of pastures in Atlantic Canada (Kunelius and Fraser, 1992). Good pasture management involves maintaining high levels of soil fertility; selecting productive, well-adapted grass and legume species and cultivars; and ensuring optimal sward yield and quality, and crop persistence by controlled grazing. Bates et al. (1979) prepared a publication which discusses the theory and practice of pasture production and utilization in the Atlantic Provinces.

5.6.3.1 Soil Fertility

Although grazing animals supply nutrients to pastures in the form of manure, fertilization is important to stimulate early growth, maintain good swards throughout the growing season and improve the yield of older, permanent pastures. Cameron (1953) found that application of 538 kg/ha of 20\% superphosphate and 112 kg/ha of 50\% muriate of potash every 3 years produced over 100\% more gain in live weight of heifers per hectare than was obtained on untreated fields. MacLeod et al. (1965a) reported that surface applications of N, P and K on pasture where cultivation is difficult could increase DM production from approximately 1-3 kg/ha. MacKenzie (1937) concluded that liberal applications of phosphoric acid and potash were responsible for the excellent condition of the Fredericton Research Station pastures.

Nitrogen fertilization is especially useful in improving the productivity of grass species and can stimulate dormant seed germination in older, neglected pastures. N fertilization increased dry matter yields by 3\% for legume swards, 16\% for grass/legume swards and 59\% for grass
alone (Calder and Nicholson, 1970). Total digestible nutrient (TDN) production, as calculated from animal gain and maintenance, showed the same relative ranking of treatments. Nitrogen fertilization of pastures was discussed in detail in the section entitled "Fertility Management".

5.6.3.2 Grazing Management

Grazing management is necessary to optimize forage yields and utilization; stimulate regrowth and maximize longevity of pasture species; and maintain desirable sward composition. Grazing differs from mechanical defoliation in that animals have an effect on the long-term productivity of a sward as well as their own performance by controlling which species of a mixtures are grazed as well as the proportion of the plant taken and the frequency with which it is removed; they also trample and foul the plant material (Bates et al., 1979). Grazing management is the most limiting factor to pasture productivity as improved fertilization and species selection are of little value if a pasture is not properly utilized. Two types of grazing practiced in Atlantic Canada are continuous and intermittent (Papadopoulos et al., 1993). These two types are classified according to sward height following grazing and the time interval between grazing periods.

The majority of pastures in Atlantic Canada are grazed continuously for the entire pasture season (Papadopoulos et al., 1993). Continuous grazing involves permitting livestock unrestricted access to a pasture for an extended period. Overgrazing and low fertility are the main problems seen on continuously grazed pastures in the region. Reduced animal gains (30% less beef calf gain/ha, (Cooper and Bosveld, 1989; Neary, 1991); 11-17% less Holstein steer gain/ha, (Kunelius et al., 1989a), low DM production, and poor persistence of improved forage species (Calder,
1970; Kunelius and Dickson, 1989) were reported with continuous grazing when compared with rotational grazing.

Intermittent grazing involves moving livestock periodically (from 1/2 day to weekly intervals) between pastures (rotational) or restricted sections of the field (strip) to allow for recovery between grazing periods (Papadopoulos et al., 1993). Rotational grazing involves moving livestock between several pastures as each pasture is grazed. It allows the farmer to adjust grazing to the growth habit of the forage species, the condition of pasture and animal needs (Bates et al., 1979). Strip grazing is an extreme from of rotational grazing where animals are given a new area to graze each day, usually controlled by an electric fence. This system is not widely practiced due to high labor input (Bates et al., 1979).

Rotational grazing on permanent pastures realized improved herbage and animal production on two Cumberland County, Nova Scotia farms (Cooper and Bosveld, 1989; Neary, 1991). In comparative studies of rotational and continuous grazing, rotational grazing resulted in higher animal and forage productivity (Kunelius and Dickson, 1989; Kunelius et al., 1989a; Cummings, 1992) as well as improved survival of legumes (Calder, 1970). Both rotational and daily strip grazing produced excellent animal gains (approx. 1 kg/day) as well as forage production in excess of herd requirements (2.2 and 1.2 t/ha, respectively), which was harvested for silage (Winter, 1985; Winter and Kunelius, 1986).

Additional management techniques for optimizing animal production and forage utilization ensure that livestock with high nutrient requirements (such as high-producing dairy cows and growing lambs) graze first at low-stocking rates and are followed by lower-producing animals grazing poorer quality forage at a higher stocking rate (Bates et al., 1979). Calder et al. (1962) found that creep grazing of lambs was advantageous when herbage was not abundant, such as
under high stocking rates or during the dry periods of summer. Average daily gains were 0.20, 0.23 and 0.26 kg (low stocking rate) and 0.17, 0.18 and 0.15 kg (high stocking rate) for rotational, creep, and creep grazing with creep feeding of concentrates, respectively. They also found that rotational and creep grazing of lambs reduced internal parasite build-up.

Forage species are currently recommended on the basis of DM production under a clipping management regime. It has been suggested that evaluating species under grazing pressure would more accurately assess their potential for pasture use (Calder, 1970; Calder et al., 1970; Papadopoulos et al., 1992b). Papadopoulos et al. (1992b) found that performance of orchardgrass cultivars was influenced by sward management and that evaluation of varieties under a hay management system was not effective for predicting their performance under a pasture system.

The kind of grazing animal has an effect on the swards being grazed (Calder, 1970). Sheep graze more severely than cattle, defoliating a greater portion of leaf material and leaving more stems. Overgrazing by cattle not only affects pasture production directly through trampling and grazing, but also indirectly by adversely affecting soil properties, such as compaction, and subsequent production (Rodd et al., 1992).

5.6.4 Animal Production

Good pastures provide the most economical source of nutrients for cattle in Atlantic Canada. Grazing animals are supplied with an abundance of highly digestible forage without the harvest costs and quality losses associated with conserved feed. Several concerns regarding animals on pasture include: providing a constant supply of high-quality forage to support milk production in dairy cattle and good gains for beef production; maintaining good herd health by reducing parasitism and forage toxicities; and managing grazing behaviour to maximize utilization.
Finishing of beef steers on pasture has normally been accomplished by utilizing pasture when quality was highest and by supplementing with grain. Calder (1983b, 1986b) found that steers could be grown to market weight as early as 14 months of age and finished to the A1 grade on pasture without any additional feed. Gorrill (1967) concluded that dairy calves could be reared on milk and good quality pasture prior to weaning, and pasture only after weaning. Holstein steers were shown to make rapid gains (approx. 1 kg/day) on pasture when high quality forage was abundant (Winter and Kunelius, 1986). Livestock on pasture may benefit from supplementary water when dry weather reduces that available in the forage. Grazing lambs and ewes that were provided with drinking water performed slightly better than did animals given no supplementary water (Calder et al., 1964b).

Additional minerals are sometimes required for animals on pasture. Cobalt-iodized (blue) salt is a general recommendation in Atlantic Canada to prevent cobalt and iodine deficiencies (Bates et al., 1979). Salt mineral mixtures are also available to provide extra nutrients such as calcium and phosphorus to grazing livestock. Rayment and Winter (1976) found that additional cobalt was required by sheep grazing peatland pastures in Newfoundland and that more research was required to determine levels of copper required to offset molybdenum-induced copper deficiency.

Animals on pasture are particularly susceptible to gastrointestinal parasites which rely on grazing to complete their life cycle. Smith (1970) and Smith and Archibald (1968a and b, 1969) reported on the acute parasitic syndrome that developed on susceptible calves and yearlings grazing on residually infected pastures. Smith and Calder (1972) found that steers treated with an antihelminth gained from 0.13-0.36 kg/day more than those not treated. They also found that
irrigation may play a role in the development of parasitism during dry periods or in areas with
drought conditions; irrigation provides adequate moisture for survival of parasites and accelerates
disintegration of faecal material and spreading of eggs. Populations of helminths
(Oesophagostomum sp.) affecting swine did not overwinter on pasture but were maintained in the
hosts under housed conditions until the next grazing season (Smith, H.J., 1979). Forward-creep
grazing of lambs was found to reduce although not prevent build-up of internal parasites (Calder
et al., 1962). Smith and Fulton (1989) assessed ovine nematode (Ostertagia spp., Cooperia
oncophora, Nematodirus spp., Chabertia ovina and Trichuris spp.) populations affecting sheep
on pasture.

Decline in growth of lambs on pasture in mid-summer was noted for many years at the
Nappan Experimental Farm (Brewer et al., 1971). Ingestion of certain microfungi was believed
to be inhibiting the metabolism of rumen bacteria; a significant increase in the number of these
microfungi at the end of July coincided with a sizable decrease in the numbers of viable rumen
bacteria in the lambs. Normal growth usually resumed when animals were removed from pasture.
Brewer and Taylor (1980) conducted a quantitative study of the fungal flora in permanent pasture
soils at Nappan, Nova Scotia.

The grazing behaviour of livestock can affect pasture sward composition and improve
utilization of pasture. The transition from indoor feeding to pasture can sometimes depress initial
production of young livestock. Ramos and Tennessen (1992) demonstrated that unweaned lambs
exposed to short grazing experiences with their dams had longer grazing bouts and grazed for
almost twice as long (192%) after weaning than did unexperienced lambs. Experienced lambs
also displayed a preference for the forage species to which they were initially exposed. Calder
(1970) found that different classes of livestock produce different effects on sward composition. Sheep grazed more severely than cattle, defoliating the leaf portion of the plants and leaving more stem standing.

5.7 Dehydration

In Atlantic Canada, the production of dehydrated feeds has been minimal and based almost exclusively on alfalfa (Kemp, 1974). Alfalfa is chopped; processed in dehydrators, which consist of rotating drums that separate the moisture from the plant material; ground; and then pelleted' to facilitate handling and feeding. Dehydration represents the ultimate in preservation but it is also the most costly due to the high cost of fuel (Grant and McQueen, 1978). The feasibility of operating dehydration plants in the Annapolis Valley, Nova Scotia, was investigated by the Nova Scotia Department of Agriculture and Marketing; Plant Industry Branch, at the request of farmers in the mid-1970s (C. Gunn pers. common. Truro, N.S.). The process was not considered economically viable at the time with available technology.

Increasing the use of locally grown forages would provide economical feed for milk production and reduce the reliance of the Atlantic dairy industry on imported grain. Burgess et al. (1981) investigated the effects of pelleted alfalfa on the intake of silage and composition of the milk. Feeding of alfalfa pellets was generally effective in increasing forage and total DM intake and addition of pellets at a level of 9.0 kg/day did not depress milk fat levels. Although not significant, a definite trend developed toward increased actual and 4% fat corrected milk with higher levels of DM intake.
5.8 **Seed Production**

Considerable quantities of timothy, red clover and bentgrasses were harvested for seed prior to the 1960s (Bubar, 1975). Seed production in the Atlantic region has declined since this time, due mainly to intensive production of commercial seed and changes in farm mechanization and technology, particularly the replacement of binders. Bubar (1975) examined seed production potential of timothy, bromegrass, meadow and tall fescue, red fescue, orchardgrass, ryegrasses and birdsfoot trefoil. Experiments at the Napan Experimental Farm examined seed production of alfalfa, timothy and birdsfoot trefoil (Anonymous, 1965; Langille, 1966b). Researchers at the Charlottetown Research Station harvested seed of Westerwolds ryegrass (283-1556 kg/ha; Kunelius and Coulson, 1983c) and red clover (Christie and Choo, 1990). Nicholson (1984) reviewed the uses of forage straw which is available in large quantities when forages are harvested for seed.

The effects of harvest time and the growth regulator Alar-85 on seed yield of Dollard and Hungaropoli red clover were examined by Christie and Choo (1990). Second crop yields were greater in the first year, and equal in the second year of study, to first crop yields. Alar-85 increased seed yields of the second crop by more than 100% by increasing the number of heads and number of seeds per head. Alar-85 also shortened corolla tubes and reduced plant height. Choo and Thompson (1982) monitored the number of insect pollinators on red clover on Prince Edward Island. Bumblebees (Bombus fervidus, B. borealis, B. vagans, B. rufocinctus and others) were the predominant insect pollinator, outnumbering honeybees (Apis mellifera L.) by 4 to 1 in Dollard red clover and by 3 to 1 in Florex red clover. Greater numbers of bumblebees in fields treated with Alar-85 were likely due to the higher number of heads/m' on treated plants.
6.1 Forages in Crop Rotation Schemes

Using forages in crop rotations is useful for maintaining soil fertility, adding N to the soil (with legumes), improving soil structure, preventing erosion, and reducing the effects of plant diseases and pests. Sweet clover is an excellent soil conditioner and is becoming more popular in rotations; it can be incorporated into the soil to add organic matter, it has roots up to 2 feet in length to improve soil condition, and it provides erosion control when left standing through the winter (MacMillan and Buchanan, 1987). Forages and cereals are commonly grown in rotation with potatoes in Atlantic Canada. Most forages, however, are susceptible to damage by plant-parasitic nematodes (Pratylenchus, Paratylenchus, Helicotylenchus, Meloidogyne and Tylenchorhynchus spp.; Willis et al., 1976b; Kimpinski et al., 1984) which can infect the following potato crops. Kimpinski and Kunelius (1982) found that Italian and Westerwolds ryegrasses were not good hosts for the root lesion nematode (Pratylenchus penetrans L.) and could be used instead of the commonly grown timothy and red clover in rotations.

Some soilborne potato pathogens can survive on rotation crops and re-infect future potato crops. Celetti et al. (1989, 1990) found that cereals and forages differed in their susceptibility to pathogens and choice of crop grown prior to potatoes affected the incidence of some pathogens but not others. Soil acidity controls the incidence of scab (caused by Streptomyces scabies (Thaxter), Waksman and Henrici) in potatoes but is detrimental to the production of forages.
Bishop et al. (1954) found that limestone applied periodically on a 3 year rotation of potatoes, barley and clover hay resulted in significant increases of barley and clover but not potatoes, and incidence of scab increased with increasing levels of applied limestone.

### 6.2 Forages as Cover Crops

Cereal crops grown alone do not provide soil conservation and restoration. Underseeding cereals with forage grasses or legumes, however, can help conserve soil moisture, physical characteristics and fertility, although grain yield may be reduced. Kunelius et al. (1992) evaluated the effect of undersowing Italian ryegrass and red clover on barley. The forages reduced grain yield by 10-41% depending on growing conditions and 'cultivar of ryegrass; herbage DM yield and root biomass were greater for the ryegrass; and leaf disease severity was similar for barley grown alone or with either forage species. Warman (1987) evaluated annual ryegrass, kale, Austrian winter pea (Pisum sp.) and vetch as cover crops for sweet corn. Vigorous forage species underseeded to grain can interfere with combining if the grain lodges and the forage grows above it. Several varieties of subterranean clover, a low-growing annual, were evaluated with red and Persian clovers and showed promise as an underseeded legume with barley (Kunelius and Coulson, 1983b).

Winter cover crops are generally recommended in the Atlantic Provinces, particularly following fall harvest of annual row crops such as potatoes. Cereals can be seeded in the fall but forages can not establish sufficiently after fall planting to survive the winter. In a study comparing several crop species as fall-seeded winter cover, winter rye was found to outperform barley by 38%, oats by 80% and Italian ryegrass by 130% (Edwards and Sadler, 1992). Relay intercropping involves underseeding a companion crop following the establishment of the host
crop. Several studies have examined spring-seeding a forage crop to a fall-seeded cereal. This system can provide continuous ground cover for several years. Edwards (1986, 1989, 1992) evaluated red clover and Italian ryegrass spring-seeded into fall-seeded winter rye (Secale cereale L.) and winter wheat (Triticum aestivum L.) and found red clover to have higher yields; neither crop affected grain yield (3.4 to 3.5 t/ha); and winter rye outyielded winter wheat by 70%.

Broadcasting and drill seeding the forages were equally effective. Nitrogen-fertilized Italian ryegrass outyielded red clover in monoculture by 64% (Kunelius and Narasimhalu, 1983) but lack of spring fertilization and competition from a rye crop could depress ryegrass yield.

6.3 **Forages as Green Manure**

Green manure crops are incorporated into the soil to provide additional organic matter and nutrients for subsequent crops. They are becoming increasingly popular in alternative and sustainable agricultural systems. Legumes are often preferred for ploughdown species due to their N fixation capabilities. Warman (1990a and b) investigated the effects of several legume species intercropped with cabbage (Brassica oleracea L. capitata), cauliflower (B. oleracea L. botrytis), tomato (Lycopersicon esculentum L.) and asparagus (Asparagus officinalis L.). The intercrops had variable effects on vegetable crop yields, and were not recommended during the first few years following transplanting of asparagus. The intercrops absorbed considerable quantities of nutrients which would be incorporated into the soil following ploughdown. Alsike, sweet and red clover green manure crops provided the equivalent nutrient value of an N-P-K fertilizer application of 30-36-36 to subsequent oats (Warman, 1991). Soil P and K were limiting, however, when the forages were grown on infertile soils and mineral nutrition was lower than for crops grown on fertile soils.
6.4 Forages for Land Revegetation

Warman (1988) examined the possibility of using forage species to revegetate the tailings pond at the lead-zinc mine at Gays River, N.S. (Canada Wide Mines, a subsidiary of Esso Resources Canada Ltd.), which closed in 1982. Mine tailings are waste products which arise from the grinding and chemical treatment of ores during the milling process. These tailings are normally deposited as a water slurry into artificial damned ponds and are devoid of organic matter, N and P and are high in lead and zinc. These ponds may eventually revegetate if plant species are introduced. The following species were evaluated for establishment potential: alfalfa, buckwheat (Fagopyrum esculenturn L.), couchgrass (Agropyron repens L.), ladino clover, meadow fescue, orchardgrass, red clover, reed canarygrass, annual ryegrass, sweet clover, timothy and yellow foxtail (Setaria glouca L.). Alfalfa, couchgrass and red clover were the most successfully introduced species to revegetate the tailings site. The researcher suggested that high levels of N-P-K fertilizer would have to be maintained; and grass species collected from old metal mine sites with a tolerance to heavy metal contaminations would also be effective.

CHAPTER 7

FEED VALUE OF FORAGES
Forage quality is defined by how well a forage meets the nutritional and physiological needs of livestock. It can be influenced by factors such as forage species, fertility management practices, stage of development at harvest, preservation methods, as well as animal factors. Quality of forages for animal use is ultimately measured in animal performance (average daily gain or milk yield and health status), which is a function of the rate and amount of forage consumed, the digestibility of the forage and the utilization of the nutrients absorbed from the forage (Fredeen, 1991).

7.1 Factors Influencing Feed Quality

Regardless of the apparent nutrient content of forages, the quality and quantity of nutrients that are actually digested and absorbed by livestock is more representative of its value. It is well known that animals exhibit preferences for different forage species and will feed on them regardless of other species available. Reed canarygrass contains alkaloids which adversely affect its palatability and decrease subsequent intake (Johnson, 1976; Grant, 1964a). Forage species and cultivars exhibit some differences in nutrient content and the availability of these nutrients to livestock (Narasimhalu et al., 1982a, 1985, 1992b) although these differences may not significantly affect intake and utilization. Preliminary results of a study by Fredeen et al. (1991b) found that alfalfa varieties resistant to lodging had more hemicellulose, less cellulose and were less digestible than entries susceptible to lodging. Dairy cows fed alfalfa silage produced milk that was more susceptible to undesirable SOF (spontaneous development of oxidized flavour) than the milk of those fed corn silage (Nicholson and St. Laurent, 1991).
Fredeen (1991) reviewed the effects of fertility management on forage crop composition and the implications of these changes on the nutrition of animals. It is generally believed that while fertility management improves productivity per hectare, it has a neutral effect on animal performance per se. He suggested, however, that while digestible energy and total dry matter consumption are the main limiting factors to animal performance, some components of the forage that are affected by fertility management may also be limiting. High levels of N fertilization often result in a build-up of non-protein nitrogen (NPN) in forage grasses. Nitrates, which are composed of NPN, can be toxic to livestock if present in sufficiently large amounts (Nicholson, 1982). Non-protein nitrogen slows fermentation in silage, and intake and subsequent utilization of high NPN silages may be reduced (Nicholson, 1982). Digestibility of timothy was not affected by increasing rates of N fertilizer (Kunelius et al., 1976).

Selenium (Se) is an essential trace element for animals that is generally deficient in feedstuffs grown in Atlantic Canada. Studies to determine the Se content of forages grown in the region found very few samples to contain the 0.1 ppm required by livestock (Winter et al., 1973; Winter and Gupta, 1979). On the region's acid soils, Se complexes with iron, making it less available to plants (Gupta and Winter, 1975). Additional Se can be supplied through injection (which is expensive) or added to the feed of certain classes of animals. Foliar spray (Gupta et al., 1983a, 1988), soil application (Gupta et al., 1982) and seed treatment (Gupta et al., 1983b) have been found effective in preventing Se deficiency symptoms in livestock. Gupta and Winter (1989) found that source of Se varied in effectiveness; selenate resulted in 5-18 times more Se in timothy, alfalfa and barley than did selenite. Many soils in Atlantic Canada are deficient in cobalt and ruminant animals may require supplementation (Nicholson, 1986). High
levels of molybdenum combined with low levels of copper in forages may cause molybdenum-induced copper deficiency in livestock (Rayment, A.F. and Gupta, 1984).

Voluntary intake and digestibility of forages decrease rapidly as plants mature (Nicholson and Langille, 1965; Calder and MacLeod, 1968), and the rate of this decline varies among species (Calder and MacLeod, 1968; Langille and Calder, 1968; Kunelius et al., 1974). Calder (1977) found that grass silage harvested at the vegetative stage produced better animal gains (1.17 kg/day) than grasses harvested at later stages (0.78-1.08 kg/day), even those treated with formic acid or supplemented with barley. He reported, however, that yield of a crop in the vegetative stage must also be economical to harvest. Broadleaf (Spartina pectinata Link) can be a nutritive feed when harvested early but in late summer, when it has traditionally been harvested on marshlands, it is very low in digestibility and is not consumed in sufficient quantity to meet the energy requirements of sheep (Nicholson and Langille, 1965).

Concentration of Ca is greater in immature forages and although actual availability may diminish with advancing maturity, early harvested forages may not provide significantly more Ca to the animal than forages harvested later (Fredeen, 1989). Langille and Calder (1968) found that crude protein content of timothy decreased steadily throughout the growing season and the rate of decline varied only slightly among varieties. Similar results were reported for timothy (Kunelius et al., 1974; O'Reilly, 1988), bromegrass and orchardgrass (Kunelius et al., 1974).

Kunelius and Suzuki (1978) concluded that good quality silages could be made from perennial grasses in this region even though they are low in soluble carbohydrates. Addition of formic acid with and without formaldeyde lowered pHs and ammonium-N contents and improved quality of both wilted and non-wilted silages. Narasimhalu et al. (1982a) determined the intake and digestibility of wilted grass silages and found close correlations between silage
intake and in vitro digestible DM (rVDDM). Nicholson and Parent (1957) fed silage supplemented with hay to dairy cows and reported progressive increases in total digestible nutrients and DM consumption as the rate of hay feeding increased. Bush (1991) found that intake of hay and silage by young calves was comparable and varied only with quality of the forage.

Digestibility of forages can also be affected by the animal itself and conditions under which it is kept. Nicholson (1979) reported on an experiment to determine the effect of cold weather on the digestibility of pelleted hay and chopped hay. He found that digestibility decreased from 64.3% to 61.2% for chopped hay and 59.3% to 56.1% for pelleted hay when sheep were housed in warm (12°C) and cold (0 to -18°C) buildings (Nicholson, 1979). He suggested this was one reason why cattle do not usually gain as well in winter as in summer.

7.2 Anti-quality Factors

Nutritional disorders can result from several anti-quality factors present in some forages and particularly for animals on pasture. Bloat is a very common condition that has been associated with pastured legumes. Sweet clover contains coumarins (aromatic compounds which give the plant its characteristic odour) which may cause "sweet clover bleeding disease" and so is not recommended for livestock feed. When the plant is chewed by animals, coumarin is liberated and produces an undesirable tast which reduces intake (Gorz and Smith, 1973). During heating and spoilage in sweet clover hay or silage, coumarin is converted to a toxic substance which reduces blood clotting. Animals who ingest this toxin may bleed to death from small wounds or internal haemorrhages. Low coumarin cultivars have been tested but do not survive well in the Atlantic Provinces (A.A.C.C.P.C.F.C., 1991).
Plant estrogens have been linked to reproductive problems in livestock. Most estrogenic activity is found in legumes, the main compounds involved being isoflavones (Reid and Jung, 1973). Robinson (1980) reported previous results of low concentrations of formononetin, an isoflavone, for alfalfa, birdsfoot trefoil and alsike clover (0.003-0.005%) and a relatively high concentration in one sample of zigzag clover (1.36%). In his study, he found concentrations of 0.753% for red clover and 0.051% for white clover. Some plants, such as reed canarygrass, contain high levels of alkaloids which reduce palatability and intake (Johnson, 1976; Grant, 1964a) and can be toxic to livestock. Mycotoxins are produced by fungi that are present on forages and can adversely affect the health of livestock. Gray (1988) evaluated mouldy silage samples for the presence of mycotoxigenic moulds and mycotoxins.

Some plants contain compounds known as cyanogenic glucosides which have the ability to produce hydrocyanic acid (prussic). Hydrolysis of cyanogenic glucosides can occur when normal growth has been checked by adverse environmental conditions or from bacterial activity in the rumen (Reid and Jung, 1973). The resulting cyanide is rapidly absorbed into the blood of livestock where it combines with haemoglobin to form cyanohemoglobin, which does not carry oxygen. Respiratory distress can be followed by death from respiratory paralysis. Fraser (1986a, 1987a) examined the frequency of cyanogenic and acyanogenic phenotypes in naturalized populations of white clover in Nova Scotia, New Brunswick and Prince Edward Island. She found that variation of cyanogenic phenotypes ranged from 1.7% on Prince Edward Island up to 35% in Grand Falls, New Brunswick. Fluctuating temperatures may cause changes in the phenotypic expression of individual plants which is reflected in population structure. Fraser and Nowak (1988) examined growth habits and the effect of temperature on cyanogenesis in "Huia" white clover and a highly regenerative variant, "Huia No. 5". They found great variation in
cyanogenic glucoside content of leaf laminae in Huia plants but low levels dominated in the
variant plants. They concluded that response to environmental changes regarding cyanogenesis
are likely genetically determined.

CHAPTER 8

TECHNIQUES OF FORAGE ANALYSIS

Accurate assessment and prediction of the nutritional value of forages is a major concern
for animal nutritionists. McQueen (1986) reviewed the importance of some of the major
laboratory procedures and discussed their role in improving forage utilization by livestock.
Researchers at the Charlottetown Research Station used an improved gas-liquid chromatography method to determine volatile fatty acids (VFA) and lactic acid simultaneously (Suzuki et al., 1979; Suzuki and Lund, 1980). These acids are analyzed to determine silage quality; previous determinations were more time consuming as the acids had to be determined separately.

A rapid method of determining DM in grass silage using a microwave was reported by Narasimhalu (1982). This method would be useful for digestibility experiments which require DM consumption to be relatively constant over time. Kunelius (1984b) reported on the use of perforated polypropylene bags as an economical, labour-saving method of collecting and drying herbage samples. McQueen (1987) found that ceramic fiber was suitable for replacing asbestos, a carcinogen, in the determination of acid-insoluble lignin in grasses and legumes by the AOAC official final action method 7.074-7.077. Use of a near infrared reflectance analyzer (Technicon Model 500 InfraAlyzer) for quality analyses of forages was investigated at the Fredericton Research Station (McQueen, 1988). This instrument is expensive to incorporate into a feed testing laboratory but its speed, non-destructiveness, ability to perform simultaneous analyses and reduce use of chemicals and other laboratory supplies make it an attractive, long-term investment.

Knowledge of the quality and quantity of hays and silages can help farmers plan their feed rations and schedules. Narasimhalu et al. (1982b) found that lignification in first-cut grass hays and acid detergent fiber (ADF) or in vitro dry matter digestibility (IVDMD) of second-cut hays could be used to predict dry matter digestibility (DMD). Acid-pepsin solubility (APDMD) of each cut of hay and IVDMD of second cut hay could predict intake of digestible energy (DEI). Laflamme et al. (1989) developed an accurate, portable, electrical meter for determining the dry matter content of forages. This device could be very useful for livestock farmers concerned with harvesting and storage of quality forage and for the hay-selling industry. MacAulay (1979)
compared devices which measure bulk density of silage within a silo and developed an improved surface sampling instrument.

CHAPTER 9

DISEASES AND PEST MANAGEMENT

9.1 Fungi and Viruses

Verticillium wilt, caused by the fungus Verticillium albo-strum (Reinke and Berthold) is one of the most potentially destructive diseases of alfalfa. Until 1988, verticillium wilt had not been identified in Prince Edward Island or New Brunswick (Martin et al., 1991). A survey in 1980-81 detected the disease initially in Nova Scotia (Michaud et al., 1988) while a 1989 survey showed that infestation was concentrated in the North Sydney and Truro areas (Mellish and Gray, 1991). The most effective means of controlling verticillium wilt is the identification and development of varieties that are resistant to the disease. Demonstration plots established in New Brunswick in 1989, 1990 and 1991 to evaluate alfalfa varieties for verticillium wilt resistance (McLean et al., 1991) have not yet exhibited symptoms of infestation (C. McLean, pers. Commun.). Twenty alfalfa cultivars with improved levels of verticillium wilt resistance are being evaluated at the Nappan Experimental Farm (Papadopoulos and Thomas, 1990).

In a survey conducted on Prince Edward Island, Willis (1965a) found common leaf spot (Pseudopeziza trifoli L.) to be the most destructive leaf spot disease on red clover and alfalfa. Sooty blotch (Cymadothea trifoli (Pers. ex Fr.) Wolf) was destructive on alsike clover. Suzuki and Willis (1982) found the alfalfa variety "Peace" incurred the severest defoliation of several
varieties tested for resistance to common leaf spot disease. Resistance to clubroot, a very common disease of Swedes; formed the basis of many breeding efforts in past years when swedes and other root crops were the main component of livestock winter diets.

The growth and persistence of forages such as red clover can be severely restricted by crown and root-rot complexes. Several fungi species have been found to be associated with these rots. Willis (1965b) found that Fusarium spp. were more prevalent on roots of first-year plants, particularly on young plants (3-months), while Cylindrocarpon spp. were prevalent on older plants. Roots of red clover examined for root rot also showed signs of internal breakdown (IB) in crown tissues (Willis, 1966a). Fusarium spp. were the fungi most frequently recovered from IB tissues (27%), followed closely by Chaetomium spp. (25%), Phoma spp. (19%), and Gliocladium, Penicillium and Rhizoctonia spp. (18%). The number of crowns affected increased with plant age.

Willis and Thompson (1975b) found that both nematicide (carbofuran) and fungicide (benomyl) were required to both control Fusarium numbers and increase yield (14%, seeding year; 51% and 36% for 1st and 2nd cut in second year, respectively) of birdsfoot trefoil. Depressed yields from fungicide-only treatment (8 to 31% reduction) may have been due to phytotoxicity of the benomyl or increased numbers of nematodes in these plots. Nowak (1992) found in vitro selection of red clover did not reveal any improved tolerance to fusaric acid while several alfalfa selections were identified for use in future germplasm development for improved persistence.

Willis (1966b) examined the pathogenicity of Sclerotinia trifoliorum Erikss., which causes sclerotinia crown rot, on several forage legume species on Prince Edward Island. He found red clover to be most susceptible to infection (mean of 99.3%) when inoculated with the fungus
under greenhouse conditions, while birdsfoot trefoil was least susceptible (56%). Alfalfa infection averaged 89.5% followed by alsike clover, 83%, and white clover, 77% (Willis, 1966b).

Alfalfa mosaic virus (AMV) has been identified on Prince Edward Island (McDonald and Suzuki, 1983), and AMV, clover yellow mosaic virus and white clover mosaic virus have been identified on plants in Nova Scotia (Thibault and Gray, 1991). The occurrence of lucerne transient streak virus (LTSV) on one farm in New Brunswick was reported in 1983 (Paliwal, 1983). Barley yellow dwarf virus (BYDV) reduced yield of forage oats by 36.9% and percent dry matter by 6% (Gill et al., 1971).

9.2 Plant-parasitic Nematodes

Plant-parasitic nematodes from at least nine genera are associated with forage legume crops in Atlantic Canada (Townshend et al., 1973) Some species reproduce well on grasses, particularly in grass/legume mixtures (Willis, 1973), but there is little evidence of pathogenicity (Willis, 1978). Kimpinski et al. (1984) found that red clover, birdsfoot trefoil, alfalfa and timothy were better hosts for root lesion nematodes (Pratylenchus penetrans) than were Italian and Westerwolds ryegrasses, perennial ryegrass, orchardgrass and bromegrass, during a 3 year study. Other infested crops investigated include alsike clover and white clover (Willis and Thompson, 1967), soybean (Kimpinski, 1992), turnip and fodder radish (Kimpinski and Kunelius, 1987a), and sainfoin (Willis, 1976b). Pratylenchus crenatus, another species of root lesion nematode, was also common in forage legumes and grasses (Willis et al., 1982), and cereals (Kimpinski et al., 1982). Pratylenchus penetrans reduced yield of birdsfoot trefoil, alfalfa and red clover, in that order, while P. crenatus did not affect the yield of grasses or legumes (Willis et al., 1982). Sainfoin was the most susceptible forage species studied to infestation of the northern root-knot
nematode (Meloidogyne hapla) while common vetch was the least susceptible (Willis, 1981). Nematode infestation of forage crops in rotation with carrots and potatoes was also investigated (Kimpinski and Kunelius, 1987a; Diamond et al., 1991).

Townshend et al. (1973) found that 100% of fields sampled in New Brunswick and Prince Edward Island between 1967 and 1972 were infested with nematodes. Root lesion and pin nematodes (Paratylenchus spp.) were the most common species (45.3%). Several factors have been shown to affect reproduction of root lesion nematodes. Foliage yields of birdsfoot trefoil were reduced much more at higher soil moisture levels (70-100% saturation) than at lower levels (50%), while cutting at early flower, and at 2.5 cm above the soil every 3 weeks, significantly reduced root and foliage yields (Thompson and Willis, 1970b).

Willis (1972) found P. penetrans decreased forage yields of alfalfa at pH 5.2 and 6.4 but not at pH 4.4 and 7.3. Yields were not significantly affected until 26 weeks after seeding. The optimum soil pH for P. crenatus reproduction was 5.0 to 7.0 (Kimpinski and Willis, 1981). Numbers of P. penetrans in alfalfa and timothy, and to a lesser extent, P. crenatus in timothy, increased significantly as soil temperature increased from 10°C to 30°C. Kunelius et al. (1988) reported that soil populations of root-lesion nematodes were higher with conventional establishment than for direct seeding, although there were no significant differences in numbers in the plant roots. Willis and Thompson (1975a) reported that different crops have varying effects on populations of P. penetrans. Soil nematode numbers increased by approximately 500% in a red clover/timothy mixture and by approximately 200% in timothy monocrop. Nematode numbers increased slightly with a barley crop in the first season, then decreased in the second season; numbers decreased in both years when no crop was sown (fallow; Willis and Thompson, 1975a).
Herbage yield reductions have been reported as high as 40-90% in birdsfoot trefoil (Willis and Thompson, 1968, 1972), 20-50% in alfalfa and red clover (Willis and Thompson, 1968, 1969) and 7% in white clover (Willis and Thompson, 1969). Legumes in grass/legume mixtures were less competitive when grown in nematode-infested soil; legume yields were reduced 21-58% when grown alone and 46-70% when grown with timothy or bromegrass in greenhouse experiments, and 1-5% and 13-29%, grown alone and in mixture, respectively, in field experiments (Willis et al., 1976a). Suzuki and Willis (1974a) found that P. penetrans infestation did not affect concentrations of total N or total available carbohydrates in alfalfa. It also produced yellowish-green fluorescent compounds in the roots that began in the upper tap roots and extended through the inner tap root tissues and downward with increasing plant age. Root lesion nematode damage has also been linked to decreased cold tolerance (Suzuki and Willis, 1974b).

Nematicides have been shown to be effective in reducing numbers of nematodes and increasing forage-yields. Aldicarb applications were found to increase alfalfa yields by 24% in the seeding year (Kimpinski and Kunelius, 1987b) and 13% in the post-seeding year (Kimpinski et al., 1988b), but effects diminished by the third year (Kimpinski and Kunelius, 1991). Seven nematicides (fensulfothion, dozomet, aldicarb, Mocap, methomyl, carbofuran and mesural) were found effective in increasing yields of red clover by 22%, alfalfa by 22% and birdsfoot trefoil by 40% in the seeding year (Thompson and Willis, 1970a). Other studies have reported the effectiveness of nematicides in the first year or two after application (Willis and Thompson, 1973, 1975b, 1979; Thompson and Willis, 1975, 1976). Soil fumigation, which has been used to kill pathogenic microorganisms and nematodes in the soil prior to planting, has also been shown to increase the availability of some nutrients (P, S, Mo, Mg and Zn) to timothy and alfalfa. The
increased nutrient concentrations, particularly of P and Mg, were attributed to the solubilization of compounds containing these minerals following fumigation. Nematicides have not been used commercially to reduce nematode numbers due to the high associated cost. Alternative methods would involve the use of resistant varieties and appropriate crop management. Christie and Townshend (1992) reported that progress maybe possible for breeding for root-lesion nematode resistance in alfalfa; initial resistance trials were conducted on red clover by Kimpinski et al. (1992).

9.3 Insects

A large number of insect species are known to cause extensive injury to forages in Atlantic Canada. Thompson (1964) identified 40 insect species, from the orders Orthoptera, Homoptera, Homoptera, Coleoptera and Lepidoptera, commonly found on forage grasses and legumes in Prince Edward Island.

The alfalfa blotch leafminer (Agromyza frontella Rondani) was first identified in the Maritime region in 1974 (Thompson, 1974a and b). Suzuki and Thompson (1978) reported that crude protein levels in leaves were reduced approximately 30% by severe larval damage. Although alfalfa blotch leafminer (ABL) was not found to reduce forage yield or levels of N, P or K in alfalfa, it may reduce water soluble carbohydrate levels which affect the plants' resistance to stress (Suzuki and Thompson, 1981). Thompson (1981) found that insecticides tested reduced ABL damage but did not increase herbage yields. He suggested that early, cutting and the use of resistant varieties would be a more practical means of reducing ABL damage.
The clover root curculio (Sitona hispidula F.) is a widely distributed weevil that causes significant damage to some forages, particularly red clover. Observations by Thompson and Willis (1967) revealed that 90% of roots studied had suffered insect injury. Root decay was found to be related to increased root curculio injury (Thompson and Willis, 1967); Fusarium spp. became better established and root decay was more extensive in infested plants (Thompson and Willis, 1968). Sitona hispidula was found to prefer red, white and alsike clover roots over alfalfa and birdsfoot trefoil (Thompson and Willis, 1971 a). Initial screening trials showed little promise for resistance in any of the varieties tested. A hymenopterous parasitoid (Pygostolus falcatus Nees.) was present in 37% of curculips examined by Thompson (1989) on Prince Edward Island although it was not known if populations of curculios were reduced by this parasitism.

Stewart and Kunelius (1991) examined the response of stubble turnips to simulated insect damage in an attempt to accurately assess plant response to insect attack. They found that 1.30% and 1.38% defoliation resulted in a 1% decrease in dry weight of roots and first cut leaves, respectively. A study by the same authors showed that damage to kale by the imported cabbage worm (Pieris rapae L.), the diamondback moth (Plutella xylostella L.) and the cabbage looper (Trichoplusia ni Hübner) were not severe enough to reduce yield (Stewart and Kunelius, 1989). The chemical insecticides methomyl, carbaryl, carbofuran, trichlorfon, NRDC-143, WL-43467 and WL-43775 gave rapid and effective control of Thylmelicus lineola (Ochsenheimer) on timothy while the biological insecticides DipelTM, Thuricide' and a nucleopolyhedrosis virus, gave effective but slower response; dry matter yields were increased by all treatments (Thompson, 1977). Retallack and Willison (1988) examined the glandular trichomes of several clover species. These glands on alfalfa produce substances that are toxic to the alfalfa weevil (Hypera postica Gyllenhal). Species and cultivars of clovers differed in the distribution and density of these
glands but similarities to the alfalfa glands suggest that they may also play a role in pest resistance.

CURRENT TRENDS AND FUTURE DIRECTIONS

Improving forage productivity in Atlantic Canada requires a collaborative effort on the part of producers, researchers and agricultural extension personnel to respond to the regional needs of the livestock industry. Cooperation between public and private research agencies is even more important with present budgetary constraints. Research efforts must be directed toward developing production and utilization systems which take full advantage of regional growing conditions and available species and cultivars, and are viable on commercial enterprises. Forages, animals, soils and climate all play an integral role in productivity and must be considered together to provide meaningful research. The viability of the agriculture industry in this region is dependent on development and rapid adoption of innovative and economical, sustainable technologies.

Current research efforts have been centered on the identification and development of persistent and high yielding forage species and cultivars. Major emphasis of the forage program at the Nappan Experimental Farm (NEF) is to extend the adaptability of legume species to the
majority of arable land in the Atlantic region through studies aimed at identifying the factors responsible for increasing persistence on land with few soil limitations. Persistent legumes are important to improve yield and quality of grass/legume mixtures and to reduce reliance on nitrogen fertilizer. Persistent legumes would also increase the value of sown pastures by improving quality and decreasing the frequency of reseeding. New breeding techniques, such as in vitro selection, and an improved system for evaluating persistence of cultivars will prove useful.

In addition to ongoing regional trials, cultivar evaluation is currently being conducted across the region on various forage grasses and legumes. Maximizing alfalfa yields and quality, and determining potential leaf elongation, biomass accumulation and optimum N concentration in timothy are two current concerns at the Fredericton Research Station (FRS). Performance of several varieties of switchgrass (Panicum virgatum L.) is being compared to timothy and reed canarygrass. Current clover research at the Charlottetown Research Station (CRS) includes development of more persistent alsike clover from tetraploid types; development of white clover with increased petiole length, more flowers and greater fall production; and utilization of tissue culture and protoplast fusion in hybridization experiments of red clover. The Nappan Experimental Farm is evaluating numerous legume species and cultivars for improved persistence. The Provincial agriculture departments are currently concerned with forage establishment techniques and equipment. Fall seeding and seeding rates of forages (Nova Scotia Department of Agriculture and Marketing; NSDAM), frost seeding (Prince Edward Island Department of Agriculture; PEIDA), and no-till seeding (New Brunswick Department of Agriculture; NBDA) are currently being examined.
Proper fertility management is essential to maintain and improve forage productivity. This is becoming increasingly important with the recent trend towards more intensive forage production and recent research findings which identified nutritional imbalances that could develop by following the current fertility recommendations for forage crops. More effort must be made to improve fertilizer recommendations to producers based on soil analysis interpretation. Current research on nutrient requirements of forages includes: N requirement of pasture grasses grown alone and in mixture with white clover (NEF); the effect of K rates on alfalfa/timothy mixtures (St. John's West Research Station; SJWRS); a survey of K levels in crops and soils (NSDAM); the micronutrient status of cereal and forage crops in Nova Scotia (NEF); subsoil lime application (FRS); and the S requirement of alfalfa (NEF), alfalfa/orchardgrass mixtures (SJWRS), and a number of grasses and legumes (CRS).

Pasture is an important and economical resource for the livestock industry in Atlantic Canada. Research must be designed to consider all factors which influence productivity and utilization. Evaluating cultivars under grazing pressure will more accurately assess their performance under pasture conditions. Recent work at the Nappan Experimental Farm has examined the performance of orchardgrass and white clover under intensive pasture management. The compatibility of different species in complex pasture mixtures (NEF) and the productivity of white clover mixtures for pasture (NEF, CRS) are also under investigation. Research on pasture renovation techniques and grazing management is crucial to maximizing production of herbage and utilization by livestock. The Charlottetown Research Station is currently investigating no-till pasture renovation techniques such as sod-seeding. A current trend in the dairy industry is year-round feeding of conserved forages; more research is needed on the role of pastures in dairy cow nutrition and the use of various pasture dairy supplements to insure the
stability of milk production throughout the grazing season. Evaluation of fall pasture species for yield, quality and animal performance can extend the grazing season and reduce reliance on conserved forages which are more costly and labour intensive.

Improvements in planting, harvesting and storage techniques and equipment are required to reduce producers' dependence on climatic conditions, to maintain high quality of forages and to make conservation more economical. The P.E.I. Department of Agriculture is working on developing high quality timothy suitable for hay export to Japan. Silage systems are less climate dependent than hay systems but generally require large capital investments; economical techniques which accelerate harvesting and storing, and minimize nutrient loss would facilitate silage use by smaller enterprises. Researchers at the CRS are investigating the effect of inoculant/enzyme preparations on fermentation quality and feeding value of round bale silage timothy, and establishing feed values of locally grown forages to identify optimum combinations of forages, grains and protein feeds for this region. The NEF is evaluating wheat silage and the effect of urea-treated, whole plant moisture wheat silage on beef cattle growth.

Establishing efficient information and technology transfer between industry and research personnel and fostering cooperation among the various research agencies is essential to maintaining and improving the livestock industry in Atlantic Canada. The Atlantic Provinces Agricultural Services Coordinating Committee (APASCC), which is affiliated with the Canadian Agricultural Services Coordinating Committee (CASCC), coordinates agricultural and food research, and extension activities in the Atlantic Provinces. An Advisory Committee on Crops, and Sub-committee on Forage Crops, report to the APASCC and are responsible for the forage sector. The N.S. Crop Development Institute was established in 1990 by the NSDAM to coordinate and conduct investigative studies associated with forage, grain and vegetable products.
Goals of this organization include: education; coordination of federal/provincial and interprovincial cooperation; facilitating information transfer between industry and research/extension personnel; and responding to producers' needs by conducting short-term, problem-oriented research. Recent activities include: sponsoring crop rotation and resource management workshops; coordination of cereal, oilseed, forage and vegetable crop cultivar evaluation; upland/dyke land forage evaluation; and commissioning the Atlantic Forage Cultivar Evaluation System (AFCES), and literature reviews of crop research on dykeland, and Atlantic Canada forage research.

Researchers, producers and extension personnel must work together to respond to consumer preferences to maximize product demand and the industry's ability to meet regional needs. Finishing beef on pasture, for example, is possible but may result in carcasses with yellow fat which have lower market value. A preliminary study of this constraint was conducted at the Nappan Experimental Farm under the direction of Dr. L.F. Laflamme, however, results are not yet available. More research is needed on livestock performance on locally generated feeds to minimize reliance on imported feeds. It is also essential that workers continue to stress the importance of forage-based livestock systems in Atlantic Canada and foster good communication and cooperation to maximize efficient use of existing resources.

Additional research efforts should be channelled to resolve current limitations of weed control in grass/legume swards direct-seeded or underseeded to cereal nurse crops, and hay stands grown for export. More research is needed to develop economically viable pasture system options for dairy herds with special emphasis on the nutritional management of lactating dairy cows. Forage productivity in the Atlantic region will be maximized through careful consideration of factors considered in previous and current research investigations. However, these factors
must be assessed in combinations on a field scale since effective forage cropping systems likely result from a proper balance of these factors.

LITERATURE CITED


Bubar, J.S. 1978. Ladino juice as pig feed. Forage Notes. 23(2):60.


Calder, F.W. 1983a. Comparison of Kenhy tall fescue, Basho timothy and Deborah sweet bromegrass as pasture grasses. Pages 80(a)-80(b) in Research Summary 1983. Agriculture Canada, Experimental Farm. Nappan, N.S.


Langille, J.E. 1961b. Number of days required for heading and anthesis on six synthetic timothy varieties at Napan. Forage Notes. 7(2):50.


Weaver, G.M. 1986. Forage Crops. Pages 40-51 in 100 Years of Agricultural Research, the History of the Experimental Farm, Nappan, Nova Scotia. Agriculture Canada, Research Branch. Ottawa, Ont.


