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FORAGE CROPS
in the Aspen Parklands of Western Canada

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FORAGE CROPS
in the Aspen Parklands of Western Canada

·PRODUCTION·

Research Station Melfort, Saskatchewan

Research Branch
Agriculture Canada

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1991

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MELFORT RESEARCH STATION

Ken Bowren, B.Sc.	1947-87 (Retired) Forages in Crop Rotations, Use of Animal Manure
W.F. Nuttall, Ph.D.	1965-present Fertilizer for Forage Crops
D.A. Cooke, M.Sc.	1950-1977 (Deceased) Forage Variety Testing & Agronomy
J. Waddington, Ph.D.	1968-1984 (now at Swift Current) Forage Agronomy & Weed Control
S. Bittman, Ph.D.	1978-1987 (now at Agassiz) Forage Agronomy
N. Malik, Ph.D.	1985-1990 (now at FP&I, Ottawa) Weed Control in Forage Crops
W. Berkenkamp, Ph.D.	1987-present Plant Pathologist; Crop Diseases; Annual Crop Production
P.R. Horton, Ph.D.	1989-present Forage Agronomy and Range Management

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Dr. L.D. Bailey	1966-present Forage Crop Nutrition and Soil Fertility
A.T.H. Gross	1952-1979 (Deceased) Forage Agronomist
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INTRODUCTION

La production de plantes fourragères vivaces a un rôle crucial à jouer pour ce qui est de diversifier l'économie agricole et de maintenir la productivité des sols dans les Prairies. La plupart des exploitations agricoles de la prairie-parc de l'ouest du Canada (fig. 1) auraient grandement intérêt à faire plus de place aux plantes fourragères dans leurs assolements. Cela est particulièrement vrai dans les cas des terres difficiles à travailler, régulièrement inondées au printemps, caractérisées par une courte période exempte de gel ou aux prises avec de graves problèmes d'érosion. Il y a également des avantages à cultiver des plantes fourragères sur les terres qui conviennent aux cultures annuelles.

En semant des légumineuses telles que le mélilot, le céréaliculteur peut améliorer la fertilité et les propriétés physiques de ses sols. La production de foin comme culture commerciale améliore l'utilisation de la main-d'oeuvre disponible et diversifie les sources de revenus. Les naisseurs et les engraisseurs de bovins de boucherie peuvent acquérir une plus grande marge d'indépendance en produisant leurs aliments du bétail. Des options plus nombreuses s'offrent pour la formulation des rations, ce qui permet de tirer parti des aliments les plus économiques, car le foin de qualité supérieure peut la plupart du temps être vendu avec profit.

La rentabilité des cultures fourragères a souffert par le passé et continue de souffrir d'une réticence à appliquer la technologie disponible à tous les aspects du système de production. Souvent, les cultures fourragères sont reléguées aux terres les moins productives, les pâturages sont mal aménagés et la production fourragère jouit d'une faible priorité. Même lorsque le foin est récolté, on déplore souvent une forte baisse de sa valeur nutritive imputable à une altération au cours de la période séparant la récolte de l'utilisation. Jusqu'à tout récemment, les possibilités d'incorporation des fourrages dans les rations d'engraissement étaient largement méconnues. Cette technologie permet de remplacer les céréales par des plantes fourragères sur des terres mieux adaptées à ce type de production. Une telle substitution ne se traduirait pas nécessairement par une forte croissance du cheptel d'élevage dans l'hypothèse où les fourrages remplaceraient les grains comme principal ingrédient des rations. Toutefois, lorsque les grains se vendent à des prix dérisoires ou sont difficiles à écouler, l'intensification des productions animales pourrait avoir des retombées favorables sur l'économie, pour peu que des marchés normaux ou en croissance existent.

La présente publication résume les recherches menées à la Station de Melfort sur la production fourragère, et elle intègre de l'information provenant d'autres sources situées dans la prairie-parc, en particulier la Station de recherches de Brandon. L'accent est mis dans une large mesure, mais non exclusivement, sur les plantes fourragères vivaces cultivées, à cause de leur rôle dans les systèmes agronomiques de conservation. Il est reconnu que les cultures annuelles jouent un rôle important comme sources de pâturages, de foin et d'ensilage pour les ruminants, mais leur production a fait l'objet de beaucoup de recherches et de publicité. La présente étude s'inscrit dans une série de publications visant à promouvoir une production, une récolte et une utilisation plus efficaces des plantes fourragères. Elle est d'abord conçue à l'intention des agronomes et des étudiants en agriculture.

Fig. 1. The Aspen Parklands of Western Canada (lightly shaded area).

INTRODUCTION

The production of perennial forage crops has a vital role to play in diversifying the agricultural economy of the prairies and maintaining the productivity of the soil. Most farms in the Aspen Parklands of Western Canada (Fig. 1) would benefit considerably if more forage was included in the cropping program. This is especially true for land that is difficult to work or that regularly experiences spring flooding, a short frost-free period or serious soil erosion. There are also advantages in growing forage crops on land suitable for the production of annual crops.

By growing legumes such as sweetclover, the grain farmer can benefit through improved fertility and physical condition of the soil. Hay produced as a cash crop, will better utilize the available labor supply and diversify income possibilities. The cow-calf operator and cattle finisher can benefit by being more independent of others for their feed supply. More options are available for formulating rations to take advantage of the cheapest feeds available and high quality hay can be sold profitably in most years.

The economics of forage crop production has suffered in the past, and still does because of failure to apply available technology covering all aspects of the forage system. Forages on many farms are grown on the least-productive areas, pastures are often mismanaged and haying operations are given a low priority. Even when hay is harvested, it often seriously deteriorates in feeding value because of weathering during the period from harvesting to feeding. Until recently, the technology of utilizing forages in finishing rations for beef cattle has been largely overlooked. This technology allows forage crops to replace cereal crops grown on land that is better suited for forage crop production. Such a shift would not necessarily mean a large increase in livestock numbers if forages replaced cereals as the main component of the feed supply. However, when grain is low priced or difficult to market, increasing livestock production could have a positive impact on the economy provided normal or increased markets were available.

This publication summarizes research carried out at the Melfort Station on the production of forage crops and includes information from other sources in the Aspen Parkbelt, particularly the Brandon Research Station. The material focuses largely, but not exclusively, on cultivated perennial forage crops because of their role in soil conserving agronomic systems. It is recognized that annual crops play an important role in providing pasture, hay and silage for ruminant livestock, but their production has been well researched and publicized. This publication is one of a series of publications aimed at promoting more efficient production, harvesting and utilization of forage crops. The publication is designed to provide information primarily to agrologists and agriculture students.

WHY GROW FORAGE CROPS?

Including perennial forage crops, (particularly legumes) in crop rotations in the Aspen Parkland can have the following beneficial effects.

1. The year-round stand provides physical protection to the land from wind and water erosion and may prevent the development of soil salinity.

2. Alternating cereal, oilseed, and pulse crops with perennial forages crop can help to break insect and disease cycles and to control weeds.

3. The deeper rooted perennials can use moisture and leached nutrients that lie below the reach of annual crops.

4. The more extensive root system of forages helps to improve soil structure and to hold the soil more firmly against the forces of wind and water.

5. By building up the organic matter content of the soil, water holding capacity is increased, favorable microflora activity is increased (helping to make more nutrients available to the plant), soil temperature fluctuations are moderated and the soil is much easier to work (for example, power required to till soil at Melfort was reduced by 25% when legumes were included in the crop rotation).

6. Perennial legumes interact with microorganisms to fix nitrogen from the air to meet up to 100% of their N requirements. The process can be managed to improve soil fertility.

7. Forage crops properly grown, harvested, stored and fed can supply high quality feed to ruminant livestock, and, in a competitive market, often return greater profits to the farmer in addition to benefitting his soil.

8. Forage crops are less weather dependent with respect to seeding, frost, hail and drought damage than are cereal and oilseed crops.

9. Forage crops for hay and silage can help make more effective use of available labor and equipment (swathers, tractors), as peak requirements do not coincide with those of either cereal or oilseed production.

10. Harvesting, storing, and feeding mechanization have greatly reduced the labor required to produce hay and silage.

SELECTING A FORAGE CROP

The key factor in the choice of a forage crop is the environment (soil and climatic conditions) prevailing in the area. A suitable forage species must be able to produce high yields of good quality forage if it is to be profitable to the grower. Because new forage crop species or varieties are constantly being introduced and/or developed for specific purposes, it is recommended that growers check with their nearest forage crop agronomist before seeding land to perennial forages, which could be in production for many years.

When assessing characteristics of forage crop varieties, remember that unlike cereal, oilseed and pulse crops, the primary purpose of a forage crop is to produce hay, silage and pasture. Dry matter yield (and quality) are much more important than ability to produce seed. Obviously, a high dry matter producing forage variety that also has a good seed yield, is preferable to one that produces little seed, but a high seed-producing variety that doesn't have good dry matter production under any environmental situation is of no real economic value.

Usually, there are several species or varieties of forages that are well adapted to a specific environmental condition. Within these, the following factors should be considered when choosing a forage.

1. What use is to be made of the forage? Will it be harvested for hay, silage, dehydrated alfalfa or seed, or will it be used for pasture or perhaps for several uses?

2. To what class of livestock will it be fed?

3. What harvesting method will be used?

4. How will the crop be stored prior to feeding to livestock?

5. Ease of establishment? Will it compete with the weeds present in the soil?

6. Does it have resistance to disease and insects likely to be a problem in the area?

7. If not used on the farm, is there a ready market for the crop?

8. How long will the stand be expected to produce?

9. How important are the soil improving capabilities of the crop?

Many species and varieties of perennial forage crops are adapted to one or more of the environmental conditions prevailing in the Aspen Parkbelt. The following are some of the more important forages currently produced. Their general description and their suitability for various conditions and purposes are briefly described. (The companion bulletin "Pasture Production and Utilization in the Aspen Parkland of Western Canada" contains information on perennial forages which are well suited for pasture purposes.) A summary of various characteristics of some species commonly grown in the Aspen Parkland is found in Table 1.

Characteristics of Some Perennial Forage Species Grown in the Aspen Parkland

Forage species	Soil preference	Life span	Winter hardiness	Drought tolerance	Tolerance to flooding	Tolerance to		Tolerance to salinity	Best Seeded		Ease of haymaking	Preferred Use(s)*			
						Acidity	Alkalinity		Alone	In mixture		Pasture	Hay	Silage	Green manure
Legumes															
Alfalfa	well drained, deep loam, high-lime	medium	good	very good	none	low (> ph 6)	some	fair	x	x	fair	1**	1	2	1
Alsike clover	low-lying, moist soils, organic soils, Gray soils, heavy, moist alkaline soils	short (2-3 yr)	excellent	none	6 wk	good	good	low	x	x (timothy)	difficult	1	2	2	4
Birdsfoot trefoil	Gray luvisol and Black soils	short (2-3 yr)	poor	low	3-4 wk	some	good	some	x	-	fair-difficult	1	2	3	4
Red clover	moist, semi-moist, Gray luvisol and Black soils	short (2-3 yr)	good	low	2 wk (spring)	good (> pH 5)	low	none	x	-	difficult	1	3	2	1
Sainfoin	well-drained, alkaline soils and productive clay loam soils	short (2-4 yr)	fair	good	low	none	good	none	x	-	fair	1	1	2	4
Sweetclover	fertile, well-drained clay or clay loam, sandy or Gray wooded	short (1-2 yr)	good	good	poor	low	very good	fair	x	x (short-lived grasses or cereals)	difficult	2	3	1	1
Grasses															
Bromegrass	moist, well-drained Black and Gray luvisol soils	very long	very good	good	2 wk (spring)	some	fair	fair	x	x (alfalfa)	easy	1	1	3	4
Crested wheatgrass	drier parts of Black soil zone, Gray wooded and sandy soils	very long	very good	excellent	low	fair	fair-good	low	x	x (alfalfa)	easy	1	1	2	4
Intermediate wheatgrass	well-drained, high lime soils, ample moisture	short (5-7 yr)	good	good	low	low	good	none	x	x (alfalfa)	easy	1	1	2	4
Meadow bromegrass	similar to bromegrass	long	good	good	low	slight	slight	slight	x	x (alfalfa)	fair	1	1	3	4
Meadow foxtail	cool, moist, Gray luvisol and peaty soils	long	good	none	very good	good	good	?	x	x	fair	1	2	3	4
Reed canarygrass	cool, moist soils, high water table	very long	good	fair	excellent (2 months)	fair	fair	none	x	-	fair-easy	2	1	3	4
Russian wild rye	widely adapted, fertile loams, clays, drier parts of Black soil	very long	very good	very good	none	low	fair	slight	x	x (alfalfa)	not recommended	1	4	4	4
Slender wheatgrass	sandy loams	short (3-4 yr)	good	fair	none	low	good	good	x	x (other grasses or sweetclover)	easy	1	1	3	4
Tall wheatgrass	poorly drained alkalies and saline soils	long	good	low	5 wk	low	very good	very good	x	x (alfalfa, sweetclover)	easy	1	1	2	4
Timothy	cool, moist, Gray luvisol, clay silt, sandy soils	short-medium	good	low	5 wk	good	none	none	x	x (alfalfa, red clover, alsike clover	easy	1	1	3	4

*In order of suitability: 1 - recommended use; 2 - good use; 3 - possible use; 4 - not recommended or normally not used.
**Seeded with a grass.

GRASSES (See Tables 2 and 3)

Bromegrass

A leafy grass reaching a height of around 1 meter and spreading rapidly by means of underground rhizomes. The creeping tendency varies in degree from variety to variety but eventually results in such a heavy mat of rhizomes that plant vigor is affected and yields are reduced. The grass is long-lived and with good management will produce satisfactorily for many years.

Adaptation:	- widely adapted, prefers cool, moist conditions and a well-drained soil
Drought resistance:	- moderately good
Spring flooding tolerance:	- about 2 weeks with cool temperatures
Competitive ability:	- moderate to high, depending on vigor of the creeping habit
Pests and diseases:	- several leafspots may reduce quality
Salinity tolerance:	- moderate
Palatability:	- very good, both as pasture and hay
Productivity:	- hay 2-4 tonnes/ha, seed 300-400 kg/ha
Varieties:	- Carleton, Magna, Rebound, Signal
Time to harvest:	- best-quality hay: cut no later than flowering stage - poorer but acceptable hay: cut immediately after seed crop is removed - seed: swath when stem just below seed head has turned brown

Crested wheatgrass

A long-lived bunchgrass growing 60 to 90 cm tall, with wide-spreading root system, fine stems and fairly narrow leaves. It is well adapted to Brown soil zones but has performed extremely well at Melfort. Spring growth commences very early. The grass should be grazed or mown before seed heads develop as they are unattractive to stock. It tends to go dormant in dry, hot weather and to recommence growth when moisture conditions improve.

Drought resistance:	- very good

Spring flooding tolerance: - about 7 days

Competitive ability: - good, combines well with alfalfa and is a good weed competitor

Pests and disease: - no serious problems

Salinity tolerance: - fair

Palatability: - excellent when young; seed heads unpalatable as pasture. Good feed conversion efficiency.

Productivity: - hay 2-4 tonnes/ha; seed 300-650 kg/ha

Varieties: - Parkway, Fairway, Kirk

Time to harvest:
- hay: cut before flowering
- seed: swath when heads are brown but stems still green (seed in medium-dough stage)
- pasture before heading

Russian wild rye

A long-lived bunchgrass, producing an abundance of bluish-green basal leaves 30-45 cm high, topped by a seed stalk about a meter high. This grass is the first to start growth in spring and continues to grow until late fall. The leaves remain palatable at all times and provide excellent pasture. For adequate and sustained seed production, the grass must be mown or grazed to the ground immediately after seed harvest; otherwise, growing points develop too far above ground and future seed production is imperilied. Maximum production is not reached until the 3rd or 4th year after establishment.

Adaptation: - loam and clay loam soils in drier parts of the Black soil zone

Drought resistance: - excellent

Spring flooding tolerance: - very low

Competitive ability: - weak, slow-growing seedlings are hard to establish when weed competition is strong; once established, it is very competitive, and will suppress most weed growth for at least 30 cm distant

Pests and diseases: - leaf diseases on some varieties, e.g., Sawki

Salinity tolerance: - excellent tolerance once established

Palatability:	- moderately good at all stages of growth
Varieties:	- Swift, Mayak, Tetracan
Productivity:	- forage for pasture: about 2 tonnes/ha (not grown for hay) - seed: 300-550 kg/ha common in 2-4-year-old stands when grown in rows 45-90 cm apart
Time to harvest:	- pasture: best to graze early in spring and late in fall with a mid-summer rest if possible - seed: swath just above basal leaves when straw has turned yellow (seed at firm-dough stage) and combine as soon as seed is dry

Intermediate wheatgrass

A tall-growing perennial often exceeding a height of 120 cm. It produces a stemmy growth, with fewer basal leaves than bromegrass, and looks like quackgrass. It is usually considered a moderately short-lived grass (3-4 years), but at Melfort, in mixtures with alfalfa, has persisted for 7 years. It is well adapted to the Parkland area and with alfalfa provides good pasturage.

Adaptation:	- prefers well-drained soils with adequate moisture
Drought resistance:	- fair
Spring flooding tolerance:	- poor
Competitive ability:	- fair; combines well with alfalfa, but is not a vigorous creeper
Pests and diseases:	- no severe problems
Salinity tolerance:	- poor
Alkalinity:	- tolerant
Palatability:	- excellent
Productivity:	- hay 2-4 tonnes/ha; seed 300-400 kg/ha
Varieties:	- Chief, Clarke, Greenleaf
Time to harvest:	- hay: cut when seed head appears - seed: swath when most seed heads have turned light brown (earliest heads will be shattering)

Slender wheatgrass

A short-lived bunchgrass (3 years) producing a stemmy growth 60-90 cm high. Seedlings are vigorous, easily established and under good growing conditions a crop can be taken in the seedling year. Hay is of fairly good quality, provided the crop is cut at the early heading stage.

Drought resistance: - good

Spring flooding tolerance: - 1-2 weeks

Pests and diseases: - good

Salinity tolerance: - good

Palatability: - fairly good

Productivity:
- hay: 2-3 tonnes/ha (4-year average, including year of seeding)
- seed: 450-675 kg/ha

Varieties: - Revenue

Reed canarygrass

A long-lived, creeping-rooted grass, growing 1-2 meters tall. It produces large amounts of leafy forage, which varies in palatability from plant to plant because of differing levels of alkaloids. Palatable forage can be obtained if grass is harvested before flowering. Adapted to long periods of flooding, but also produces good yields under dryland conditions. Because of shattering, this grass is difficult to harvest for seed. It can be straight combined, but timing is very critical.

Adaptation: - prefers adequate moisture and a cool climate. Thrives in areas with a high water table or subject to flooding.

Drought resistance: - fair

Spring flooding tolerance: - excellent

Competitive ability: - good

Pests and diseases: - no severe problems

Salinity tolerance: - low

Palatability: - variable, but is satisfactory if harvested early

Varieties: - Rival, Venture (all low alkaloid)

Productivity:
- hay: 4-6 tonnes/ha
- seed: 200-250 kg/ha

Time to harvest:
- for best hay: cut between boot and early flowering stages (not always possible because of soil moisture where this grass grows)
- coarse hay: cut as soon as possible after seed crop is harvested
- seed: swath when seeds at top of panicles have turned brown or gray; or straight combine as soon as seeds in top of panicle start to fall out when struck

Timothy

A long-lived bunchgrass, producing good-quality hay. The grass is quite shallow rooted and produces high yields of hay only where moisture is plentiful.

Drought resistance: - poor

Spring flooding tolerance: - very good

Competitive ability: - good with adequate moisture; fairly good on dryland once established

Pests and diseases: - rusts and leaf spots may occur in some years

Salinity tolerance: - very low

Palatability: - good. A popular hay for horses if put up free of dust prior to the fully-headed stage.

Productivity: - hay 1-2 tonnes/ha; seed 300-450 kg/ha

Varieties: - Climax, Champ, Basho, Itasca, Timfor

Tall wheatgrass

A long-lived, coarse bunchgrass. It is useful because it is the most saline tolerant of the better quality grasses. Hay is of good quality, provided it is made before the grass flowers. The grass matures too late for reliable seed production in the Parkland area of Western Canada. It is usually grown only on saline soils where other grasses are unsatisfactory. Yields vary, depending on moisture and degree of salinity.

Drought resistance: - fairly poor

Spring flooding tolerance: - 3 weeks

Pests and diseases: - no severe problems

Salinity tolerance: - very good

Palatability: - good, when harvested before fully headed

Varieties: - Orbit

Productivity: - hay; 2-3 tonnes/ha. Three years after establishment on a moderately saline black soil at Melfort, a yield of 5.6 tonnes/ha was obtained, in two cuts, when fertilized with 90 kg N and 45 kg P_2O_5/ha.

Meadow bromegrass

A long-lived perennial bunchgrass, similar in appearance to smooth brome but with less creeping ability. Produces considerable root and crown material and provides good protection against soil erosion. Plant material has a higher proportion of leaf than smooth bromegrass. Seed stalks are 60-90 cm tall. Seed matures earlier than does that of smooth bromegrass.

Adaptation: - well suited to areas where smooth bromegrass thrives. Requires at least 350 mm precipitation annually for good production. Prefers soils ranging from slightly acidic to mildly alkaline. Winter hardiness may be a problem under some conditions and is still being evaluated.

Drought resistance: - good

Flooding tolerance: - up to two weeks in the spring before growth begins. None after that

Competitive ability: - compatible with alfalfa

Pests and diseases: - susceptible to aphid infestations

Palatability: - vegetative growth very palatable

Salinity tolerance: - somewhat tolerant

Persistence: - long term persistence still unproven in the Aspen Parkland. Some winter killing has occurred at Melfort.

Yield: - similar to, or slightly higher than, smooth bromegrass, with better recovery following cutting or grazing, thus greater late season production

Varieties: - Fleet, Paddock, Regar

Table 2. Comparative Yield of Forage Grass Species for Hay and Pasture at Melfort (kg DM/ha) 2 year average (1980-1981)*

Species	Hay Two-cut	Simulated Pasture (3-4 cuts)
Crested wheatgrass	10180	8480
Intermediate wheatgrass	8660	9300
Meadow bromegrass	8170	7260
Altai wild rye	8170	8820
Pubescent wheatgrass	7870	8060
Slender wheatgrass	7450	7700
Russian wild rye	7050	6130
Smooth bromegrass	6380	7620
Green stipa grass	5920	6410
Creeping red fescue	5830	5170
Tall wheatgrass	5720	6710
Meadow foxtail	5330	4930
Timothy	4920	4140
Hard fescue	3000	3450
Kentucky bluegrass	2770	2710

*Including first harvest year

Table 3. Comparative Yields of Fertilized and Unfertilized Grass Species in a Two Cut System at Melfort (kg DM/ha) 2 year average (1983-1984) - Seeded 1980

Species	Unfertilized	Fertilized*
Smooth bromegrass	1150	2940
Crested wheatgrass	1360	3060
Intermediate wheatgrass	960	2570
Pubescent wheatgrass	1080	2400
Altai wild rye	1010	2290
Russian wild rye	700	1790
Meadow bromegrass	1270	3150
Green stipa	1220	2890
Kentucky bluegrass	950	2690
Creeping red fescue	620	2590

*100 kg 11-51-0/ha prior to seeding plus 100 kg N and 30 kg P_2O_5 annually.

Note: A comparison of Tables 2 and 3 reveals startling variations in production between years and that growing conditions can affect the relative yields of species.

LEGUMES

Alfalfa

A bloat-causing legume, growing to a height of 60-90 cm. Leaves are trifoliate with smooth or slightly toothed margins. Stems are fairly slender, either solid or hollow. Flowers grow from leaf axils and are usually blue, purple or variegated in color, although other colors are not uncommon. Seed pods vary in shape from crescent-shaped to several tight whorls, with several seeds per pod. Root systems vary from a branched taproot to a creeping-rooted type, all penetrating deeply. For pasture, alfalfa is usually grown with a grass. For seed production, use of leafcutter bees is essential for good pollination.

<u>Adaptability</u>: - wide, but prefers deep, well-drained loam with high calcium content (neutral to slightly alkaline)

<u>Drought resistance</u>: - very good

<u>Spring flooding tolerance</u>: - 1 week

<u>Competitive ability</u>: - good to very good, increasing with proportion of

creeping-rooted plants

<u>Pests and diseases</u>:
- forage fields seldom suffer seriously from pests and diseases
- the most prevalent pests are plant bugs that damage flower buds and reduce seed yields
- several leaf spots and stem blights can weaken plants by causing early leaf death but rarely kill plants
- winter crown rot weakens plants and makes them unproductive and shortens life of the stand
- most modern alfalfa varieties are resistant to bacterial wilt
- burning an alfalfa seed field in early spring helps control most diseases and insects

<u>Winterhardiness</u>:
- excellent for recommended varieties

<u>Salinity tolerance</u>:
- moderate

<u>Palatability</u>:
- very palatable; excellent pasture or hay, but may cause bloat under some conditions

<u>Productivity</u>:
- 2-5 tonnes (non-irrigated)
- seed: 200-400 kg/ha (dryland), up to 800 (under irrigation)

<u>Popular varieties</u>:
- Rambler, Roamer, Heinrichs, Drylander, Rangelander, Beaver and others. (See local forage agronomist for varieties best suited to your needs.) (See Table 4)

<u>Time to harvest</u>:
- pasture: do not overgraze; allow regrowth to reach early-bud stage; avoid heavy grazing between 1st week of September and freeze-up
- hay: cut between late-bud and 10%-bloom stages (usually late June - early July)
- seed: straight combine after severe frost dries out stems; or swath when 75% of seed pods have turned black or dark brown and combine when stems have dried out (swath when the crop is slightly damp from dew as seed pods are less likely to break off and be lost)

Sweetclover

An upright biennial (or occasionally annual) legume reaching a height of 1-2 meters. Leaves are trifoliate with toothed margin and bitter taste. Spikes of flowers grow from leaf axils and, after pollination, are replaced

Table 4. Characteristics of Some Recommended Alfalfa Varieties

Variety	Winter Hardiness*	Bacterial Wilt Resistance**	Soil Moisture Required	Recovery After Harvest	Root Type	Comparative Yields kg/ha at Brandon Hay	Seed
Algonquin	H	R	moderate-moist	average	tap	6800	745
Alouette	MH	R	moist	rapid	tap	--	--
Anchor	MH	R	moist	rapid	tap	6200	709
Apica	MH	R	moist	rapid	tap	--	--
Beaver	H	VR	moist	average	tap	7600	729
Dekalb 120	MH	R	moist	average	tap	--	--
Drylander	VH	R	fair	slow	sl. creeping	--	--
Heinrichs	VH	R	moderate	slow	creeping	--	--
Rambler	VH	MS	fair	slow	creeping	7000	561
Rangelander	VH	S	fair	slow	strongly creeping	--	735
Roamer	VH	R	fair	slow	creeping	--	--
OAC Minto	MH	R	moist	rapid	tap	--	--
Vernal	MH	R	moist	medium	tap	6600	625

*VH-very hardy; H-hardy; MH-moderately hardy
**VR-very resistant; R-resistant; MR-moderately resistant; S-succeptable

Source: Selecting Alfalfa Varieties for Manitoba by small pods each containing one seed. The stems are succulent at first, but turn woody as plants mature. Yellow-flowered varieties are finer-stemmed and better for hay or pasture. There is some danger from badly cured hay of some varieties due to the formation of a blood anticoagulating substance. To avoid this, try to ensure the crop is cured rapidly and stored to prevent spoilage (molding).

Adaptation:	- prefers well-drained clay and loam soil but can be successfully grown on sandy and heavy clay loams, and on gray wooded soils
Drought resistance:	- good
Spring flooding tolerance:	- very poor (less than 1 week)
Competitive ability:	- as seedling, fair; as mature plant in 2nd year, good.
Pests and diseases:	- no serious diseases - main pest is sweetclover weevil, which can eat seedlings to the ground in a short time (2nd-year plants usually grow fast enough to withstand infestation)
Winterhardiness:	- excellent in recommended varieties
Salinity tolerance:	- moderate
Palatability:	- fairly palatable when young and succulent, can cause bloat
Productivity:	- hay 2-4 tonnes/ha; seed 500-700 kg/ha
Varieties:	- Norgold, Polara (low coumarin varieties)
Time to harvest:	- pasture: graze in 2nd year when growth reaches 30-45 cm - hay: cut at early bud stage - seed: when 2/3 of seed pods have turned brown - green manure: preferably when the plant is in full bloom

Sainfoin

A tall, perennial legume reaching a height of about 1 meter. The plant has pinnately divided leaves, which resemble those of vetch without tendrils; and coarse, succulent, hollow stems, which are terminated by long spikes of pink flowers. The seeds are smooth, kidney-shaped, olive to dark brown, about 0.3 cm long and usually enclosed in pods the shape of a flattened hemisphere with a raised network of veins on the surface. A deeply penetrating, branched taproot makes the plant drought resistant. Spring growth starts very early. Regrowth after a harvest is usually slow. Leaf retention is good and quality loss with increasing age is slower than for alfalfa. This legume does not cause bloat.

Adaptation:	- prefers dry calcareous soils, but does well on thin and gravely soils
Drought resistance:	- very good
Spring flooding tolerance:	- very poor
Competitive ability:	- because of its open growth, weeds can become established easily but are tolerated well because the crop is tall. In pasture mixtures sainfoin does not persist because of its excellent palatability.
Pests and diseases:	- no problems at present
Salinity tolerance:	- none
Palatability:	- very palatable, both as hay and pasture
Winterhardiness:	- good, provided crop is well established (do not harvest in year of establishment until after freeze-up)
Varieties:	- Melrose, Nova
Productivity:	- hay: 2-4 tonnes - seed: 500-900 kg/ha
Time to harvest:	- pasture: graze at bud or early bloom stage to allow good regrowth - hay: cut at 10-50% bloom for optimum yield and quality - seed: swath when lowest seed pods on heads have turned brown and are about to break off; combine several days later (seed should not be threshed free of pod)

Red Clover

A short-lived perennial with many stems arising from a crown, which has a fairly deep, branched taproot. The stems are succulent and bear trifoliate leaves with a distinct pale V marking on each leaflet. The flowers are pink and are in compact heads at the tips of the stems. The whole plant is often very hairy. Red clover is not grown for forage in northeastern Saskatchewan because alfalfa and sweetclover produce higher yields.

Drought resistance: - fairly poor

Spring flooding tolerance: - 1-2 weeks

Competitive ability: - fairly good, but deteriorates as stand thins after 3rd year

Pests and diseases: - several diseases (mildews, leaf spots, northern anthracnose, clover sclerotinia rot) alone do not kill plants but together weaken them too much to survive winter

Salinity tolerance: - very low

Winterhardiness: - fair under dryland conditions; good when soil moisture plentiful

Palatability: - very palatable, but may cause bloat

Varieties: - Altaswede, Norlac - produces one hay crop and some regrowth

Productivity: - hay 2 tonnes/ha; seed 280-675 kg/ha

Alsike clover

A bloat-causing perennial, tillering profusely from the crown and producing slender, somewhat prostrate stems 60 to 90 cm long. Leaves are trifoliate and heads of pinkish-white flowers are produced in leaf axils. The plant is completely hairless. Alsike clover is often grown for seed in northeastern Saskatchewan, but seldom for forage as alfalfa and sweetclover outyield it. The legume combines well with timothy or reed canarygrass in areas too wet for more productive legumes.

Adaptation: - cool, moist growing conditions, well suited to acidic organic soils, Gray Luvisol soils and heavy, moist, alkaline soils. Low tolerance to salinity.

Drought resistance: - fairly poor

Spring flooding tolerance: - several weeks (5-6)

Competitive ability: - good

Pests and diseases: - no serious problems

Salinity tolerance: - low

Palatability: - very palatable, but can cause bloat

Winterhardiness: - poor, but generally reseeds itself

Varieties: - Dawn, Aurora

Productivity: - seed: 500 kg/ha

Birdsfoot trefoil

A perennial, producing many fine stems 30-60 cm long. Leaves have five leaflets, two close to the stem and three on a short stalk. Flowers are fairly large and bright yellow in clusters of 5-7. The plant does not cause bloat. It yields less than alfalfa in northeastern Saskatchewan and so is not usually grown for forage.

Drought resistance: - fair

Spring flooding tolerance: - several weeks

Competitive ability: - poor

Pests and diseases: - no serious problems

Salinity tolerance: - low

Palatability: - very palatable

Winterhardiness: - fair

Varieties: - Cree, Leo (also Empire in Manitoba)

Productivity:
- hay: 2.0 tonnes/ha (where moisture is good)
- seed: potential 700-800 kg/ha, but likely to get 200-300 kg/ha (seed set usually good but shattering can quickly reduce yields)

A summary of characteristics of various species of perennial forages is presented in the following chart.

COMMENTS

Yields of all forage crops are extremely variable, depending on many factors, especially moisture supply and level of available soil and fertilizer nutrients. In general yield figures cited are for average to above average growing conditions and are not intended to provide valid "between species" comparisons.

ESTABLISHING A FORAGE STAND

Soil moisture conditions are critical to the establishment of perennial forage crops. Because forage seeds (except Sainfoin) are quite small compared to seeds of cereal and pulse crops, they must be seeded shallowly (1 to 2 1/2 cm) in order to reach sunlight before their energy supply is exhausted. It is essential that the moisture supply near the soil surface be ample to meet the need of the germinated seed until its roots can reach moisture at lower levels.

Seeding into a properly prepared seedbed is required for successful establishment of a forage crop. Weeds should be controlled prior to seeding to the extent practical, by the use of cultivators or appropriate herbicides to eliminate competition for water, sunlight and soil nutrients. Packing or rod-weeding before seeding helps to firm the seedbed. A firm, level seedbed makes it easier to control the depth of seeding. Although a finely worked soil is best for the seedlings, it can predispose to erosion and crusting problems in some soils, hence some lumpiness may have to be tolerated.

With the advent of zero-tillage it may be satisfactory to seed the forage crops directly into standing stubble. Provided weeds are absent or can be controlled with a non-residual herbicide, this will help to protect both the soil and the developing seedling from the adverse effect of wind (erosion and loss of moisture) and may in some conditions provide beneficial shade.

In the Aspen Parkbelt perennial forages are usually seeded in 30 cm (12") rows for hay production (see section on seeding rates).

When the forage stand is used for hay or silage production, the weed problem can be considerably reduced during the initial year or two by harvesting the crops before weeds produce seeds (See section on Weed Control).

TIME TO SEED FORAGE CROPS

Seeding Time	Overall Rating	Comments
Late April-mid-May	Fair to very good	Excellent moisture and cool temperatures are good for forage establishment. Limited opportunity for preseeding weed control may lead to problems later. Frost hazard.

Mid-May-mid-June	Very good to fair	Good moisture and cool temperatures are good for forge establishment. Opportunities exist for preseeding weed control. Probably the best time of year for seeding, especially last half of May.
Mid-June-mid-August	Poor	Moisture can be variable, leading to patchy germination. High day temperatures can desiccate seedlings. Rapid growth of annual weeds can cause problems in control.
Mid-August-September	Good, except legumes	Moisture can be good, and cool temperatures, especially at night, are good for grass establishment. Legumes may winterkill due to insufficient time for them to become properly established. Weeds not usually a problem.
Late October	Fair	Seeds germinate the following April when moisture is excellent, temperatures are cool and frost damage may occur.

SEEDING RATES (Northeastern Saskatchewan)

Sow at the following rates, kg/ha (lb/ac), in rows 30 cm (12") apart, except where otherwise indicated:

Forage	For hay	For pasture	For seed
Grasses			
Bromegrass	9 (8)	9 (8)	5.6 (5) 3.5 (3) (90 cm rows)
Crested wheatgrass	8 (7)	8 (7)	3.5 (3) (60-90 cm rows)
Intermediate wheatgrass (pubescent wheatgrass)	14.5 (12-14)	14.5 (12-14)	5.5 (5) (90 cm rows)
Meadow bromegrass	11 (10)	11 (10)	7 (6)
Russian wild ryegrass	Not recommended	8 (7); 4.5 (4) (60 cm rows)	2* (2) (90 cm rows)
Tall wheatgrass	13 (12)	13 (12)	Not recommended
Slender wheatgrass	11 (10)	11 (10)	11 (10)
Reed canarygrass	6-8 (5-7)	6-8 (5-7)	2 (2) (90 cm rows)

Timothy	5-6 (5)	5-6 (5) (15-18 cm rows)	5-6 (5) (15-18 cm rows)
Meadow fescue	Not recommended	Not recommended	8 (7)
Legumes			
Alfalfa	6.8 (5-7)	Not recommended	1-2 (1-2) (909 cm rows)
Sweetclover	11 (10)	11 (10)	6-7 (5-6)
Birdsfoot trefoil	Not recommended	4.5 (4)	4.5 (4)
Sainfoin	22-45 (20-40)	22-45 (20-40)	11 (10) (60-90 cm rows)
Red clover	Not recommended	Not recommended	4.5 (4)
Grass-legume mixtures			
Bromegrass-alfalfa	9 + 2-4 (8 + 2-4)	9 + 2-4 (8 + 1-2)	n/a
Crested wheatgrass-alfalfa	8 + 2-4 (7 + 2-4)	8 + 2-4 (7 + 2-4)	n/a
Intermediate wheatgrass-alfalfa	14 + 2-4 (12 + 2-4)	14 + 2-4 (12 + 1-2)	n/a
Reed canary-alsike clover	7 + 2 (6 + 2)	7 + 2 (6 + 2)	n/a
Meadow bromegrass-alfalfa	10-3	10-2	n/a
Timothy-alsike clover*	2 + 3 (2 + 3)	2 + 3 (2 + 3)	n/a

*Recommended in hay and pasture mixtures on moist, non-saline, non-alkaline, acidic soils

COMPANION CROPS FOR ESTABLISHING PERENNIAL FORAGES

A companion crop, sometimes misleadingly called a nurse crop, is often sown with forage. A companion crop provides grazing, hay or grain in the year of forage establishment, protects the land against wind and water erosion to some extent, and offers some protection to the forage seedlings against extreme weather. Annual cereal stubble will also have the added benefit of trapping snow, both for water and for insulation during winter. On the other hand, companion crops compete with the forage seedlings for water, light, and nutrients, and make weed control more difficult because suitable herbicides for the combination of companion crop and forage are often not available.

Flax is considered to be the least competitive annual companion crop, followed by spring wheat, barley and oats in that order. Flax is sometimes not competitive enough: green growth in the swath can be a problem if the flax is seeded with a very vigorous forage such as sweetclover. Annual cereals can be used for pasture, hay, or allowed to mature, depending on the grower's requirements and judgment of his changing needs as the growing season progresses. The advice that cereals be seeded at half the usual rate is recognition that companion crops compete with forage seedlings, to the detriment of the forages. Recently canola (rapeseed) has been used as a companion crop with some success. Between 1972 and 1986, several experiments were conducted in the Melfort and Tisdale areas on the effects of wheat and canola on underseeded forages.

WHEAT

At Melfort, a harvestable amount of brome or alfalfa was obtained in the seedling year when they were clear-seeded on fallow. When they were underseeded in wheat, there was little growth in the seedling year, and yields were reduced by about one-third in the following year (Table 5). Thereafter, alfalfa produced about the same, whether seeded with or without wheat, but bromegrass yield showed a rebound effect. Areas seeded with wheat produced more hay after the first harvest year than areas clear-seeded. Weeds were not a major component in either forage. Wheat produced about 2900 kg/ha whether seeded at 50 or 100 kg/ha, and seeding rate had little effect on forage establishment. In the Tisdale and Choiceland areas, applications of nitrogen in amounts based on soil testing, increased wheat yields but depressed alfalfa hay yields the year after seeding (Table 6). Phosphorus also increased wheat yields but had very little effect on the alfalfa.

CANOLA

Both canola species showed effects similar to wheat on underseeded forages (Tables 7 and 8). Volunteer canola was a major problem with the Polish varieties. Control using 2,4-D on grasses or 2,4-DB on legumes is effective but represents an added cost. Russian wild ryegrass established poorly under Polish canola. Sweetclover seemed quite compatible with Polish canola. Normal seeding rates for both crops were satisfactory (Table 9).

There are two major considerations when deciding whether to use a companion crop when establishing forages. First, is the gain in companion crop greater than the loss in forage? Second, is a big yield the year after seeding preferable to a more uniform but lower productivity over several years? The big yield the year after seeding is largely a result of seeding on fallow, and is not as evident following seeding on stubble. Reducing the seeding rates of either wheat or rapeseed did not have much effect on the underseeded forages when compared with the major reduction of growth from using a companion crop. Taken together, tests show that establishment of the commonly-used forages, bromegrass and alfalfa, will be satisfactory most years whether a companion crop is used or not. Individual circumstances should dictate which option to use.

Table 5. Forage Crop Yields (3-yr average, kg/ha) After Establishment with a Wheat Companion Crop

Forage Crop	With/Without Companion Crop	Year from Seeding			
		Seedling Yr. (one cut)	First Year (two cuts)	Second Year (two cuts)	Third Year (one cut)
Alfalfa	without	1969	7650	5456	3262
	with	112	4781	5344	3206
Bromegrass	without	2756	8325	5175	2756
	with	225	4894	5962	3600
Weed % in alfalfa	without	17	9	12	26
	with	10	15	13	24
Weed % in bromegrass	without	7	2	1	8
	with	3	3	0	3

Source: J. Waddington

Table 6. Yields After Seeding With a Wheat Companion Crop Fertilized With Nitrogen (average of five tests)

Nitrogen rate on wheat kg/ha	Alfalfa Yields (kg/ha)		
	First Year after seeding	Second Year after seeding	Third Year after seeding (average of 4 tests)
0	4556	4669	4219
62	3600	4275	4050
113	3544	4500	4163

Source: S. Bittman
D.A. Pulkinen

Table 7. Forage Crop Yields (3-yr average, kg/ha) After Establishment With an Argentine Canola Companion Crop.

Forage Crop	With/Without Companion Crop	Year after seeding			
		Seedling Yr. (one cut)	First Year (two cuts)	Second Year (two cuts)	Third Year (one cut)
Alfalfa	without	956	7031	4894	3488
	with	56	4275	4275	3488
Bromegrass	without	2025	9113	5343	3825
	with	225	5006	5119	4331
Weed % in Alfalfa	without	18	6	11	14
	with	20	34	15	16
Weed % in Bromegrass	without	11	0	0	3
	with	3	1	1	1

Source: J. Waddington

Table 8. Forage Crop Yields (3-yr average, kg/ha) After Establishment With a Polish Canola Companion Crop.

Forage Crop	With/Without Companion Crop	Seedling Year (one cut)	First Year (one cut)	% Weeds in First Year
Alfalfa	without	2306	5175	2
	with	169	2588	39
Bromegrass	without	3319	6525	2
	with	394	3769	3
Sainfoin	without	2588	4613	10
	with	281	2475	51
Russian Wild Rye	without	450	2869	28
	with	56	1688	65

Source: J. Waddington

Table 9. Sweetclover Dry Matter Yields (3-yr average, kg/ha) After Establishment With a Polish Canola Companion Crop.

Rapeseed seeding Rate (kg/ha)	Sweetclover seeding rate (kg/ha)			
	1	4	7	10
3	3094	3600	3713	3825
5	2588	3319	3431	4050
7	1744	2700	3375	3938

Source: J. Waddington

PERSISTENCE OF ALFALFA VARIETIES WHEN GROWN WITH SMOOTH BROMEGRASS

Most of the alfalfa on the prairies used for hay or pasture is grown in mixture with a grass (to reduce the hazard of bloat, to facilitate field drying when harvesting as hay, to improve the feeding value of the grass, and to reduce losses should alfalfa winterkill). Based on variety tests at Melfort and elsewhere on the prairies, the varieties recommended in Saskatchewan include Beaver, Rambler, Rangelander, Algonquin, Anchor, and more recently, Heinrichs. However, an apparent contradiction exists between results of variety tests and the experience of producers, pasture managers, and pasture specialists. Whereas most recommended varieties usually survive well year after year in variety tests, these varieties when grown with grasses, diminish and often disappear in farmers' hay fields and pastures. Under test conditions in northeast Saskatchewan two harvests of alfalfa can be taken safely each year, yet local producers very often take only one harvest for fear of losing the stand.

An experiment was established in 1980 on gray-wooded soil near Melfort to compare alfalfa varieties under conditions which closely resemble those on farms, implementing the following variations from conventional variety tests:

a) Both low and high levels of P maintained.
b) Both simulated pasture and hay cutting managements were used.
c) All varieties were grown in mixture with smooth bromegrass.

Plots were harvested in 1981 but yields were not determined. In 1982, the strain SCMF3713 yielded less than other varieties. In 1983, yield of all varieties was similar. However, in 1984-1986 SCMF3713 yielded significantly more than all other varieties tested. In 1984-1986, Beaver was the lowest yielding variety. Phosphorus level and cutting management affected yield, but not the relative performance of the varieties.

Table 10. Yield of Alfalfa Strains Grown in Mixed Swards with Smooth Bromegrass at Melfort, Saskatchewan. Values are means of four management systems.

	Yield					
	1981*	1982	1983	1984	1985	1986
	kg/ha					
Beaver		1083	1916	409	276	584
Rambler		1005	1963	679	561	1249
Peace		1246	2208	609	507	1104
Drylander		845	2136	624	607	1260
Rangelander		1027	1926	626	602	1123
SCMF3713		731	1868	1109	1012	1910

*1981 plots harvested but yields not recorded.

Source: S. Bittman

The results (Table 10) show that for long-term hay and pasture stands, alfalfa varieties should be evaluated in combination with the grass(es) with which they are to be grown in practice.

A COMPARISON OF GRASS SPECIES FOR HAY PRODUCTION ON TWO SOIL TYPES IN THE ASPEN PARKBELT

Twenty grass species were compared over a seven year period on a deep black soil (Melfort silty clay) and thirteen species over a six year period on a gray-wooded soil (Waitville loam). Plots were fertilized annually with 90 kg N and 22 kg P/ha. Plots were harvested in late June-early July and during the third week in September.

Several species had substantial loss of stand over the course of the experiment due to winterkill and other factors (orchard grass, meadow fescue, tall fescue, reed canary grass, tall wheatgrass, slender wheatgrass). Other species had consistently low yields (timothy, creeping red fescue, hard fescue, Kentucky bluegrass, meadow foxtail). Altai wild rye was particularly prone to invasion by weeds. The performance of the best species is summarized in Table 11).

Table 11. Average Yield of Grass Species Under Hay Management on Two Soil Types in the Aspen Parkbelt. (kg DM/ha)

Species	Black Soil (1980-1986)	Gray-wooded Soil (1981-1986)
Crested wheatgrass	7957	2684
Intermediate wheatgrass	7166	2192
Smooth bromegrass	7619	2457
Meadow bromegrass	6251	2581
Russian wildrye	6658	--
Green stipa (needle grass)	6069	2220

Source: S. Bittman

In the first year of seeding, Russian wildrye and green stipa yielded much less than the other species due to poor vigor. Intermediate and crested wheatgrass have the most vigorous seedlings followed by smooth and meadow bromegrasses. Species with poor seedling vigor require better control of weeds, should not be seeded with a companion crop and require up to two years to provide a usable stand.

A COMPARISON OF REED CANARY GRASS AND TIMOTHY

New, low-alkaloid varieties of reed canarygrass and the good seasonal production curve of this species has prompted increased interest in reed canarygrass for both hay and pasture. Because both reed canarygrass and timothy produce best under favorable moisture conditions, three low alkaloid varieties of reed canarygrass were compared to timothy when harvested at comparable stages of maturity and fed to 23 kg lambs for a six week period. The results are summarized in Table 12.

Table 12. Chemical Analyses and Feeding Value of Three Varieties of Reed Canarygrass and Timothy (three year average)

Species:	Reed Canarygrass			Timothy
Variety:	Frontier*	Rival	Venture	Champ
Heading to Early Anthesis				
Dry matter at harvest (%)	24	21	28	27
Crude protein (%)	17	19	16	13
Acid detergent fibre (%)	37	35	37	37
Dry matter intake (g/day)	659	710	746	662
Dry matter digestibility (%)	58	60	59	62
Digestibility of crude protein (%)	74	73	77	70
Regrowth (5-6 leaf stage)				
Dry matter at harvest (%)	20	20	22	24
Crude protein (%)	14	19	18	12
Acid detergent fibre (%)	42	37	38	41
Dry matter intake (g/day)	613	642	616	644
Dry matter digestibility (%)	54	61	55	59
Digestibility of crude protein (%)	73	76	73	64

*A high alkaloid variety.

Adapted from Dr. K. Wittenberg, University of Manitoba, Manitoba

Intake and digestibility of the reed canarygrass varieties were similar to those of Champ timothy when harvested at comparable stages of maturity and fed to lambs. Crude protein levels were higher for reed canarygrass varieties than for timothy. Palatability of reed canarygrass was equal to that of timothy when there was no choice. Rival was the variety of choice.

Under dry conditions gramine (an alkaloid) levels rose to levels that caused reduced animal performance (concentrations above 2 mg/kg of D.M. appear to adversely affect intake).

GROWING ALFALFA FOR THE DEHYDRATING INDUSTRY

In 1984, there were 23 alfalfa dehydrating plants in Western Canada with a capacity of approximately 400,000 tonnes. Currently, the total annual production for Western Canada is estimated at 600,000 tonnes, with five of the plants located in North East Saskatchewan. Export markets are the major source of product demand as approximately 75 percent of Canada's total processed alfalfa is exported. While Japan is the main customer, other markets have started to have some significance to the industry.

The domestic market has stabilized somewhat, but having a larger domestic market would add to the stability and flexibility of the processing industry as a whole.

In the Parkbelt area of Western Canada, alfalfa is grown on nonirrigated land. Yields of 3.5 to 5.5 tonnes of dry matter/ha are usual, depending on rainfall, age of stand, number of cuts, variety, management and other factors. Unfortunately, wide fluctuations in yield and quality occur between fields and from year to year, making management of fields and the dehy plant extremely difficult.

For those planning to produce alfalfa for sale to a dehydrating plant, the following suggestions are presented for consideration.

SEED

Always select pedigreed seed of the recommended varieties. Beaver and Algonquin appear to be the superior varieties as they provide the best balance between yield and quality. Algonquin may yield slightly better than Beaver and is of comparable quality. Many of the other varieties, including Anchor and Alouette, are high yielding but lower in quality. The creeping-rooted varieties are unsatisfactory because they tend to be high in fiber and regrowth is slow.

LAND PREPARATION

Use only fields free from perennial and hard-to-kill annual weeds to produce alfalfa for dehy. Excess trash or stubble may be removed by burning in the spring, provided the burning is done early enough to prevent damage to the alfalfa crowns. This is usually in late April when the ground in still wet and the stubble or trash dry enough to carry a fire.

Obtain a soil test to determine the amount and kind of nutrients that the alfalfa will require. Follow provincial recommendation guide for nutrient application times and rates. Nitrogen fertilizer is generally not required because alfalfa is capable of hosting nitrogen-fixing bacteria on its roots.

HARVEST

In northeastern Saskatchewan research has shown that if a stand is harvested three times per season for two consecutive years, it may not produce a satisfactory yield the following year. If possible, allow stands that have been harvested three times to recoup by letting them reach 20-50% bloom before being harvested the following year. Conversely, fields that were harvested only once (sun-cured) will likely provide the best stands for two or three cuts of dehy the next season.

Cutting height affects regrowth and persistence. Take the first cut as low as possible, especially in dense stands, because shading accelerates senescence. However, for the second and third cuts, it is suggested that cutting high enough to leave some green leaves on the stubble will enhance quality and persistence by leaving some photosynthetic area to support regrowth thereby lessening the drain on root reserves.

WEED CONTROL IN FORAGE CROPS

TOLERANCE OF SEEDLING FORAGE GRASSES TO HERBICIDES

'Fairway' crested wheatgrass, 'Magna' smooth bromegrass, 'Regar' meadow bromegrass, 'Prairie' altai wild ryegrass and 'Climax' timothy were seeded, along with separate rows of wild oats and green foxtail, into Melfort silty clay loam on May 28, 1986. Because of lack of soil moisture, crop establishment was slow and erratic until mid July when adequate rainfall was received. Fourteen herbicide treatments (including four numbered herbicides) were applied on July 16, 1986 across the grass strips in each of the 4 replicates. The herbicides were applied in 125 L/ha of water at 275 kPa with a tractor-mounted shielded sprayer. The forage grasses were in the 2-5 leaf stage at time of herbicide application.

At recommended rates MCPA + mecoprop + dicamba formulation was safe on all forage grasses at the 2-5 leaf stage. The mixture provided satisfactory control of lambs'-quarters and redroot pigweed. Sethoxydim completely killed timothy and severely injured crested wheatgrass, smooth brome and meadow brome. Altai wildrye was also affected slightly. Addition of bentazon improved the selectivity of sethoxydim on the forage grasses but significantly reduced its efficacy on wild oats. Bentazon applied alone was safe on all forage grasses and provided excellent control of the annual broadleaf weeds. Timothy was not as tolerant as the other forage grasses to chlorsulfuron. All forage grasses were tolerant to both rates of metsulfuron-methyl. The three sulfonylurea herbicides provided excellent control of the annual broadleaf weeds but were ineffective against the annual grass weeds (See Table 13).

With the exception of timothy, the tank-mixed formulation of dichlofop-methyl + bromoxynil was safe on all forage grasses. However, addition of bromoxynil drastically reduced the effectiveness of dichlofop-methyl against the annual grass weeds (See Table 13).

Table 13. Effectiveness of Herbicides for Weed Control in Grasses

Treatments	Rate kg a.i./ha	Crop Tolerance (Aug. 20, 1986)					Weed Control (Aug. 22, 1986)			
		CWG	TIM	AWG	MB	SB	GF	WO	LQ	RRP
MCPA/Mecop/Dicamba	.275/.062/.062	9	8	8	8	8	0.5	0	9	8
MCPA/Mecop/Dicamba	.412/.094/.094	8	8	7.5	8	8	2	0	9	9
Sethoxydim + Assist	.250 + 1%	3	0	6	4	3.5	9	9	0	0
Sethoyxdim + Assist + Bentazon	.250 + 1% + 1.08	5	1	8	7	8	8	4	9	9
Bentazon + Assist	1.08 + 5%	9	8	8	8	8	1	0	9	9
Chlorsulfuron	.01	9	7	8	8	7.5	2	0	9	9
Chlorsulfuron	.02	8.5	6	7	8	8	3	0.5	9	9
Metsul. methyl	.003	9	8	8	8.5	8.5	2.5	2	8	9
Metsul. methyl	.0045	9	8	8	8	8	1	1	8.5	9
Dichlofop-Methyl + Bromoxynil	.70 .30	8	5	8	8	7.5	3	1	9	9
Check	-	9	8.5	8	8	8	0	0	0	0
LSD (5%)		1.5	1.5	1.5	1	1	1.5	1.5	0.5	0.5

CWG = crested wheatgrass, TIM = timothy, AWG = Altai wild ryegrass, MB = meadow brome, SM = smooth brome, GF = green foxtail, WO = wild oats, LQ = lamb's-quarters, RRP = redroot pigweed.

- Crop tolerance ratings (0-9), where 9 = no effect, 0 = complete kill.
- Weed control ratings (0-9), where 0 = no control, 9 = complete control.

Source: N. Malik, Melfort Research Station

WEED CONTROL IN SEEDLING FORAGE LEGUMES

Beaver alfalfa, Altaswede red clover and Norgold sweetclover were planted in strips 3 m wide into a silty clay loam (O.M. = 11%) on May 27, 1986. Wild oats and green foxtail were sown in 1 m strips between the crops. Infestations of barnyard grass, redroot pigweed and stinkweed were present in the plot. EPTC and ethalfluralin 5G were applied pre-plant and incorporated to a depth of 7 cm with a rotovator on May 20. A second incorporation of ethalfluralin was done 4 days later. Sethoxydim was applied post-emergence when the grass weeds were in the 1- to 6-leaf stage. Establishment of the three legumes was successful, and by late August their growth was exceptionally vigorous (Table 14).

Table 14. Effectiveness of Herbicides for Weed Control in Seedling Legume Crops. (Scoring range 0 to 9).

Herbicide	Rate (kg a.i./ha)	Crop Vigor (Aug. 1/86) Alf	RC	SC	Weed Control (Aug. 1/86) WO	GF	BG	SW	RRP
EPTC	3.6	8.8	8.5	8.2	6.2	8.0	8.0	4.0	6.0
EPTC	4.4	8.2	8.0	8.2	8.0	8.5	9.0	3.5	7.5
EPTC	8.8	7.2*	5.6*	6.8*	8.8	9.0	9.0	5.2	8.5
Ethalfluralin 5G	1.1	9.0	8.8	9.0	7.6	6.4	8.3	2.0	7.8
Ethalfluralin 5G	2.2	8.5	8.5	8.5	8.5	9.0	9.0	5.2	9.0
Sethoxydim + Assist	0.25 + 1%	8.8	8.5	8.5	9.0	9.0	9.0	0.0	0.0
Sethoxydim + Assist	0.80 + 2%	8.6	9.0	9.0	9.0	9.0	9.0	0.0	0.0
Check	-	8.8	8.8	8.2	0.0	0.0	0.0	0.0	0.0
LSD (0.05)		0.9	1.0	0.9	1.8	2.3	1.7	3.1	2.6

Alf = alfalfa, RC = red clover, SC = sweet clover, WO = wild oats, GF = green foxtail, BG = barnyard grass, SW = stinkweed, RRP = redroot pigweed
*Values significantly different from check ($P < 0.05$)

Source: N. Malik - Melfort Research Station

Table 15. Effect of Several Herbicide Treatments on Forage Dry Matter Yield.

Herbicide	Rate (kg a.i./ha)	Forage Dry Matter Yield (kg/ha) Alfalfa	Weeds	Red clover	Weeds	Sweet clover	Weeds
EPTC	3.6	4218	637	2625	1206	5176	648
EPTC	4.4	3910	692	2653	449	4945	950
EPTC	8.8	4028	397	2062	480	4719	402
Ethalfluralin 5G	1.1	4842	288	2774	1255	5378	1117
Ethalfluralin 5G	2.2	4481	247	3054	145	6092	451
AC 263 499	0.037	3969	443	2878	187	6423	924
AC 263 499	0.075	3867	426	2827	308	5766	234
AC 263 499	0.150	3964	200	2774	472	6056	629
Hoe 33171	0.25	4374	634	2627	1422	4718	1396
Sethoxydim + Assist	0.25 + 1%	4096	573	2437	931	5156	1907
Sethoxydim + Assist	0.80 + 2%	4475	129	3096	796	5391	750
Check		4322	476	2778	925	4790	801
LSD (0.05)		898		939		1386	

Source: N. Malik - Melfort Research Station

The seedling legumes were tolerant to applications of EPTC up to 4.4 kg/ha. At the 8.8 kg/ha rate, emergence of alfalfa and red clover was delayed for a few days and some injury was observed on red clover and sweet clover. Control of the annual grass weeds was satisfactory at 4.4 kg/ha. The seedling legumes were tolerant to both rates of ethalfluralin tested and excellent control of the grass weeds and pigweed was obtained at 2.2 kg/ha. Sethoydim was safe on all three legumes even at the 0.8 kg/ha rate and excellent control of the grass weeds was observed at both rates tested.

The legumes were harvested on August 28, 1986 and weeds were hand-separated from the samples. Alfalfa and red clover forage dry matter yield differences were not significantly better than the check. In general, the total dry matter yield of broadleaf and grass weeds associated with alfalfa was less than those found in red clover and sweetclover samples.

WEED CONTROL IN FORAGE SEED CROPS

Alfalfa

Weeds are often a major problem in the production of alfalfa seed. Weed control is essential for successful establishment of alfalfa because the seedlings are not vigorous in the early stages of growth and offer little competition to aggressive weeds. In northeastern Saskatchewan, annual broadleaf weeds such as stinkweed, wild mustard, Shepherd's purse, cleavers, volunteer canola and annual grass weeds such as wild oats, green foxtail and volunteer cereals compete with alfalfa seedlings during the establishment year. In established stands, weeds also present a serious threat and may result in lower seed yields and lower grade due to weed seed contamination. Established stands are often invaded by dandelion, Canada thistle, perennial sow thistle, perennial grasses and the biennial narrow-leaved hawk's beard.

Weed competition

The effect of weed competition on alfalfa seed production has not been measured directly, but yield increases of 30 or more have been obtained at Melfort where terbacil (SINBAR) was used at the start of each growing season for three years. Applications of metribuzin (SENCOR) at the start of each season for four years controlled dandelion and increased seed yield by 68%. Results of the Agro-Man Project in Manitoba showed that applications of fluazifop (FUSILADE), sethoxydim (POAST) and haloxifop[2] (VERDICT) for suppression of quackgrass resulted in 75-109% increases in alfalfa seed yield in test sites where quackgrass density ranged from 546 to 1032 culms/m^2. Weeds can reduce alfalfa seed yields beyond their competitive effect if their floral parts offer better attraction to leafcutter bees than the alfalfa flowers or if the weeds smother the crop and the alfalfa flowers become less visible to the pollinators.

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[1] Common names of herbicides are followed by trade names in brackets.
[2] Research results referring to unregistered (on alfalfa) or experimental herbicides do not constitute recommendations.

Companion crops

Seedling alfalfa is most resistant to post-emergence applications of herbicides from the first to third trifoliate leaf stage. Seedlings should not be sprayed after reaching 10 cm (4") in height. Use relatively large volumes of water and low pressures for spray treatments. A good canopy formed by the companion crop (if used) and weeds will reduce the risk of injury.

Herbicides used in forages underseeded to companion crops must be safe on both crops. Use a registered herbicide to control annual grass weeds in companion crops. There are at least eight registered herbicides that can be used in seedling alfalfa (Table 16). There are few registered herbicides for control of broadleaf weeds in companion crops. For instance, if alfalfa is underseeded to canola, there is no registered herbicide for control of stinkweed, wild mustard, flixweed and shepherd's purse. EMBUTOX/COBUTOX/BUTYRIC 400 is registered for use in alfalfa but these products cannot be used on canola. At Melfort it has been found that TREFLAN and the trifluralin analog, ethalfluralin (EDGE), can be used at the recommended rate on seedling alfalfa or alfalfa underseeded to canola. TREFLAN was recently registered for stand establishment of alfalfa under the "Minor Use of Pesticides Program". Also if alfalfa is underseeded to flax, trifluralin (TREFLAN, RIVAL) can be used for control of annual grassy and broadleaf weeds. If alfalfa is underseeded to cereals, the farmer has a somewhat greater choice of broadleaf herbicides to choose from (See Table 17).

Table 16. Registered Herbicides for Alfalfa

	Seedling	Established
Annual Grass Weeds Only		
Avadex BW	X	
Avenge 200C	X	
Basfapon/Dowpon	X	
Hoe-Grass	X	
Mataven	X	
Annual + Perennial Grasses		
Kerb 50-W		X
Broadleaf + Grass Weeds		
Eptam 8E	X	
Princep		X
Sinbar		X
Treflan	X	
Velpar		X
Broadleaf Weed Only		
Embutox/Cobutox/Butyric 400	X	X

Table 17. Registered Herbicides For Seedling Alfalfa and Companion Crop

	Companion Crops			
	Wheat	Barley	Canola	Flax
For Annual Grass Weeds				
Avadex BW	X	X	X	X
Avenge 200C	X	X		
Basfapon/Dowpon				X
Hoe-Grass	X	X	X	X
Mataven	X			
Broadleaf + Grass Weeds				
Treflan	X	X	X	X
Broadleaf Weeds Only				
Embutox	X	X		

For details on range of weeds controlled by registered herbicides and rates of application, the reader is referred to the most recent publication of "Chemical Weed Control in Cereal, Oilseed, Pulse and Forage Crops", published annually by Saskatchewan Agriculture.

RESIDUAL HERBICIDES IN ESTABLISHED ALFALFA FOR SEED

Beaver alfalfa was sown in rows, 30 cm apart, into Melfort silty clay loam soil on May 22, 1985. Half of the plots were designated for fall applications, and the other half for spring applications. The fall applications were made on October 22, 1985 after the crop had been mowed down to 10 cm and a chilling frost had been experienced. The treatments were applied with a tractor-mounted shielded sprayer at a volume of 125 L/ha of water and a pressure of 275 kPa. The spring applications were made on April 25 when alfalfa was just beginning active growth. Crop tolerance and weed control ratings recorded on June 3, 1986 are compared in paired columns for the fall 1985 and spring 1986 applications (Table 18).

Table 18.

Herbicides	Rate kg a.i./ha	Crop Vigor (June 3/86) Fall	Spring	Weed Control (June 3, 86) Dandelion Fall	Spring	Stinkweed Fall	Spring
Hexazinone	0.5	8.3	8.4	2.3	7.1	8.7	8.5
Hexazinone	1.0	8.4	8.1	3.2	7.2	9.0	8.4
Chlorsulfuron	0.011	8.9	7.8	9.0	8.8	9.0	8.1
Chlorsulfuron	0.022	8.5	6.2*	9.0	9.0	6.8	9.0
Mets. methyl	0.01	6.8*	4.0*	9.0	9.0	9.0	9.0
Mets. methyl	0.02	3.0*	1.8*	9.0	9.0	9.0	9.0
Metribuzin	0.5	8.4	8.8	4.5	6.6	8.6	8.1
Metribuzin	1.0	8.2	8.2	4.3	7.4	9.0	9.0
Check	-	8.9	8.0	0.0	0.0	0.0	0.0
LSD (0.05)		0.9	1.1	2.0	1.2	1.9	0.7
Significance of season of applicaton		S		S		NS	

*Values significantly different from check (P < 0.05)
Crop tolerance ratings (0-9) where 0 = no effect, 9 = complete kill.
Weed control ratings (0-9) where 0 = no control, 9 = complete control.

In general, alfalfa was more tolerant to fall than to spring applications of the residual herbicides. The differences in crop vigor due to spring and fall applications of hexazinone (VELPAR), and metribuzin (SENCOR) were not significant. Alfalfa was tolerant to fall applications of chlorsulfuron (GLEAN), however, the crop was injured with the spring application at 0.022 kg/ha. Spring as well as fall applications of metsulfuron-methyl (ALLY) resulted in crop injury. The injurious effect of the spring applications was more severe and resulted in stunting, delayed maturity and delayed flowering. In general, the spring applications resulted in better control of dandelion. Both spring and fall applications of chlorsulfuron and metsulfuron-methyl were equally effective, completely controlling dandelion and were superior to most other herbicides. Control of dandelion was poor with the fall applications of hexazinone, DPX M6316 and metribuzin and fair with the spring applications. Satisfactory control of dandelion was achieved with the spring applications of AC 263 499. Fall as well as spring applications of the various herbicides were equally effective in controlling stinkweed. DPX M6316 was inferior to all other herbicides tested in controlling stinkweed.

EXPERIMENTAL AND UNREGISTERED HERBICIDES

A large number of herbicides have been tested on seedling and established legumes, in particular alfalfa, in western Canada. Some of these herbicides are already in use in other major crops but are not registered for use in forage legumes. Others are completely new herbicides that are still under research and development. Efficacy, selectivity, toxicology, environmental fate and environmental impact studies may still be in progress for these chemicals. One of the promising herbicides that has shown excellent selectivity in seedling alfalfa and established alfalfa, and a large number of other forage legumes is imazethapyr (PURSUIT). In Canada, the Expert Committee on Weeds (ECW) is responsible for compiling and documenting research data generated by federal and provincial research establishments, universities, producer groups and the agrichemical industry. Applications currently under review by Agriculture Canada include ethalfluralin (EDGE 50 DF) for stand establishment of alfalfa, bentazon (BASAGRAN) for seedling alfalfa and spot applications in established alfalfa, metribuzin (SENCOR 75 DF) and hexazinone (VELPAR) for dormant established alfalfa grown for forage or seed production. Producers should keep abreast of developments in registering herbicides for use in forage crops and use only those registered for the purpose desired.

Seedling clovers and sweetclover

Control of annual grass weeds is not a problem in clovers. For broadleaf weed control, however, there are no herbicides registered for sweetclover as indicated in Table 19.

Table 19. Registered Herbicides for Seedling Clovers

	Alsike Clover	Red Clover	Sweet Clover	White Clover
Annual Grass Weeds Only				
Avadex BW	X	X	X	X
Avenge 200C		X	X	
Hoe-Grass		X	X	
Mataven		X		
Broadleaf Weeds Only				
Embutox/Cobutox/Butyric 400	X	X		X
Tropotox Plus	X	X		X

Research at Melfort (silty clay loam, O.M.=11%) on soil-incorporated herbicides, triflualin (1.1-2.2 kg/ha)[3], ethalfluralin (1.1-2.2 kg/ha) and EPTC (3.6-4.4 kg/ha) from 1983 to 1987 demonstrated that seedling clovers were tolerant to these herbicides. Seedling red clover and sweetclover were also tolerant to imazethapyr (PURSUIT) at the rate of 0.075 kg/ha, adequate for control of stinkweed, shepherd's-purse, wild mustard, flixweed and pigweed. Research in Alberta has demonstrated that alsike clover and white clover are also tolerant to imazethapyr. Bentazon (BASAGRAN) tested at 1.08 kg/ha caused slight injury to red clover and severe injury to sweetclover, however, forage dry matter yields obtained the following year indicated that the legumes had recovered successfully. Diclofop/bromoxynil (HOE-GRASS II) tested at 1.08 kg/ha injured red clover and killed sweetclover. Forage dry matter yields obtained the following year indicated that red clover had recovered. Post-emergence applications of metribuzin (SENCOR) at 0.15 kg/ha severely injured seedling red clover and sweetclover, however, no adverse affect on forage yield was observed the following year. Since these tests were intended for forage production, we do not know the effects of herbicide injury, sustained by clovers in the seedling stage, on seed production in the following year. Research is still needed to determine residue levels if any, in the crop.

Seedling Birdsfoot trefoil

At Melfort it was demonstrated that seedling trefoil was tolerant to trifluralin (1.1 kg/ha), ethalfluralin (1.1-2.2 kg/ha), trifluralin + triallate (0.84+1.4), EPTC (3.3-6.7 kg/ha) and sethoxydim (POAST) tested at 0.35-0.80 kg/ha. Trefoil was injured at 2.2 kg/ha rate of trifluralin. Trefoil was severely injured by bentazon and propanil (STAMPEDE 360) tested at 1.0 kg/ha, and sustained moderate injury from 2,4-DB (1.08 kg/ha) treatment. Forage dry matter yield obtained the following year indicated that trefoil had successfully recovered from the initial injurious affects of the postemergence treatments. Research in Alberta has demonstrated that trefoil is also tolerant to imazethapyr.

FORAGE GRASSES GROWN FOR SEED

TOLERANCE OF SEEDLING GRASSES TO HERBICIDES

Grass seed producers have a choice of three herbicides (AVENGE 200C, HOE-GRASS, MATAVEN) for control of annual grass weeds and four herbicides (BUCTRIL-M, MCPA, PARDNER/TORCH DS, 2,4-D amine) for control of broadleaf weeds. For Kentucky bluegrass, AVENGE 200C is the only registered product. Research at Melfort during 1985-1987 has demonstrated that MCPA/mecoprop/dicamba (TARGET) and bentazon were safe on seedling crested wheatgrass, timothy, Altai wild ryegrass, meadow bromegrass and smooth bromegrass. All five species exhibited tolerance to chlorsulfuron (GLEAN) tested at 10 g/ha but timothy was slightly injured at 20 g/ha. All forage grasses exhibited tolerance to metsulfuron (ALLY) tested at 3 and 4.5 g/ha.

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[3] All rates are in kg of active ingredient per ha.

Only timothy was not tolerant to DPX M6316 (HARMONY) tested at 15 and 30 g/ha. Sethoxydim (POAST) tested at 0.25 kg/ha killed timothy and severely injured the other grasses. Forage dry matter yields obtained the following year indicated that crested wheatgrass, meadow bromegrass and smooth bromegrass had partially recovered. Fenoxaprop (EXCEL) tested at 0.18 kg/ha killed timothy and severely injured crested wheatgrass, but was safe on other forage grasses. Addition of 2,4-D amine improved the selectivity of fenoxaprop on crested wheat but not on timothy. Addition of 2,4-D amine did not decrease the efficacy of fenoxaprop against green foxtail and wild oats. With the exception of timothy, diclofop/bromoxynil (HOE-GRASS II) was safe on all forage grasses. However, addition of bromoxynil reduced the effectiveness of diclofop against the annual grass weeds.

EFFECTS OF GRAMINICIDES ON SEED PRODUCTION

The effects of difenzoquat (AVENGE 200C), diclofop (HOE-GRASS), flamprop (MATAVEN), propanil (STAMPEDE 360) and dichlobenil (CASORAN), applied at the recommended and twice the recommended rates each spring 1979-81 at Melfort, were studied on seed production of established bromegrass, crested wheatgrass and timothy (Waddington 1982). There were no grass weeds present at the experimental site. The grasses were swathed at the soft-dough stage, and threshed when mature. The 3-year average seed yield of bromegrass and crested wheat in the untreated plots were, respectively, 190 and 282 kg/ha. The 2-year average seed yield of timothy for the check plots was 159 kg/ha. Seed yields were very low in 1980 because a very dry spring reduced the number of seed heads.

Crested wheatgrass showed no visible signs of herbicide damage during the growing period in any year. Bromegrass treated with diclofop in 1979 lodged in a windstorm two days before swathing; the other treatments showed no lodging. No evidence of weakened straw appeared in later years. The higher rates of diclofop and flamprop reduced the number of timothy heads and also delayed their emergence and maturity in both years. The stand was thinned and dandelions invaded the plots. Propanil caused the same effect only in 1980.

Overall, seed yields either were not affected or were reduced by applications of herbicides. Flamprop at 1.0 kg/ha reduced seed yields of timothy in both years, and reduced bromegrass and crested wheatgrass yields in 1980, a year with a very dry spring. Diclofop and flamprop at both rates reduced timothy seed yield in 1981. This effect was probably in part a cumulative one resulting from stand thinning in 1980 and damage to the surviving plants in 1981. Difenzoquat had the least effect over the course of the experiment.

EFFECTS OF BROADLEAF HERBICIDES ON ESTABLISHED GRASSES

The effects of 2,4-d, tested at 0.5 and 1.0 kg/ha in the autumn, before stem elongation in spring and at shot blade stage, were determined on seed production of established bromegrass (Carlton) at Beaverlodge Research Station (Darwent 1985). The mean seed yield for the untreated plots for the period 1983-1985 was 438 kg/ha. At the 0.5 kg/ha rate of 2,4-D, seed yields were not affected by any of the treatments but at the 1.0 kg/ha rate (applied at the shot blade stage), the mean seed yield was 348 kg/ha, significantly less than that of the untreated plots.

Dicamba (BANVEL) was tested at 0.15, 0.30 and 0.60 kg/ha in the autumn, and in the spring before stem elongation and at the shot blade stage of bromegrass. At the 0.15 kg/ha rate, seed yields were reduced only when the herbicide was applied at the shot blade stage. At the 0.30 and 0.60 kg/ha rates, the herbicide was safe only when applied in the autumn.

In another test near Dawson Creek, B.C., the effects of clopyralid (LONTREL) alone and with 2,4-D, mecoprop (MECOTURF), chlorsulfuron (GLEAN), mecoprop + clopyralid and 2,4-D/picloram (TORDON 202C) were investigated on seed yield of established Climax timothy (Darwent 1984). Timothy exhibited tolerance to clopyralid (0.2 kg/ha) and 2,4-D/picloram (0.45 kg/ha). Chlorsulfuron at 0.02 kg/ha or more and mecoprop (1.0 kg/ha) treatments caused serious seed yield reductions. Slight yield reductions were observed with 2,4-D and clopyralid + 2,4-D even though no crop injury was observed.

THE ROLE OF FERTILIZERS IN FORAGE PRODUCTION

Critics of modern agriculture technology point to the increasing use of fertilizer, herbicides and other pesticides as a cause, rather than a necessary result of poor farming practices. Many farmers, because of economic necessity and the effect of some agricultural policies, have been encouraged to produce annual crops on poor or problem soils that should have been used for the production of perennial forages. Because of excessive tillage, the use of too much summerfallow, the clearing of bush, trees and even shelterbelts, breaking of land on steep slopes, the draining of sloughs and "pot holes", and the failure to include soil improving crops such as perennial grasses and legumes in the crop rotation, considerable damage to the soil by wind and water erosion and the development of salinity has occurred in all areas of Western Canada including the Aspen Parkbelt.

In order to sustain levels of production required both for economical survival of the farmer and to feed a growing world population, it is imperative that the nutrient and organic matter lost from the soil as a result of marketing crops off the farm be replaced. Table 20 shows the estimated amounts of soil nutrients removed from the soil by various crops at the yields shown.

Several management practices can be employed to reduce these losses, and thus reduce the amount of inorganic fertilized required for optimum crop production.

These are summarized as follows.

1. Proper inoculation of legume crops (alfalfa, sweet clover, faba beans, etc.) will permit symbiotic rhizobia to fix a large proportion of the plants' nitrogen requirement from the atmosphere (70-100%).

2. Feeding farm grown crops to livestock on the farm and returning the manure to the soil will markedly reduce the loss of soil nutrients. (Table 21). If manure is managed to minimize seepage and volatilization (NH_3) losses, purchases of commercial fertilizers could be reduced by an estimated 65-70%.

3. Including perennial forage crops, (particularly legumes) in the crop rotation will reduce or eliminate soil erosion and thus avoid loss of fertile soil and the nutrients contained in it. Plowing down legumes as green manure crops will add appreciable organic matter and nitrogen to the soil (Table 22).

4. Returning crop wastes to the soil will increase organic matter content of soils. This will have many beneficial effects including the enhancement of microbial activity.

5. Adopting better soil management practices to reduce or eliminate the susceptibility of soil to erosion (minimum tillage, control of weeds by herbicides, contour tilling, and seeding, and not producing annual crops on steep hillsides, etc.).

6. Many additional management practices: establishing shelterbelts, snow trapping techniques, etc., will protect the land from erosion and reduce the need to replace lost soil nutrients with chemical fertilizers.

The technology is available to protect the soil from deterioration <u>and</u> produce high yields of good quality food for mankind, either directly in the form of cereals, oilseeds and pulse crops, or indirectly by converting forage crops, damaged or unmarketable crops to high quality food by feeding to ruminant livestock.

Table 20. Estimated Nutrients Contained in Various Crops* (kg/ha)

Crop	Yield	Nitrogen	Phosphorus	Potassium	Sulfur
Alfalfa (16% CP)	4500	115	11.0	89	11
Sweetclover (13% CP)	5000	104	10.0	65	20
Bromegrass (12% CP)	4500	86	14.4	90	13
Wheat (16% CP)	3000	77	11	11	5
Barley (12% CP)	4000	77	13	16	6
Canola (21% CP)	2200	74	15	18	13
Flax (21% CP)	1600	54	8.5	12.6	3.7

*Seed only, in the case of cereal and oilseed crops. Return of crop residues to the soil is assumed.

Note: Alfalfa and sweetclover, if properly inoculated with the appropriate rhizobia, can obtain from 80-90% of their nitrogen requirements from the atmosphere under favorable soil and growing conditions.

Table 21. Estimated Plant Nutrient Losses When Crops are Sold Off the Farm vs Marketed Through Steers*

	Nitrogen (N)	Phosphorous (P_2O_5)
Grain sold off the farm		
1090 kg (40 bu) wheat (16% CP)	61	22
1527 kg (70 bu) barley (12% CP)	65	31
Hay produced for sale		
1818 kg (2 tons) alfalfa (16% CP)	102*	22
Crops marketed through farm-finished steers (Manure returned to soil)		
(a) Grain		
1090 kg wheat = 145 kg beef	9	5.9
1527 kg barley = 191 kg beef	11.5	7.7
(b) Alfalfa		
1818 kg = 182 kg beef	10.9	7.3

*Assuming no N_2 fixed from air and not including ammonia lost is rumen gases or volatilization of manure. (If properly inoculated 90-100% of N could be fixed.)

Table 22. Yield of Dry Matter and Nitrogen from Sweetclover, Alfalfa and Redclover on a Degraded Black Loom at White Fox, Saskatchewan in the Second Year After Establishment

Growth Stage (Date)	Crop	Dry Matter (kg/ha)			Nitrogen (kg/ha)		
		Tops	Roots	Total	Tops	Roots	Total
Early Bud	Alfalfa	2280	930	3210	66	16	82
(June 15)	Redclover	1830	720	2550	49	13	62
	Sweetclover	2280	620	2900	66	10	76
Full Bloom	Alfalfa	3700	1560	5260	71	30	101
(July 15)	Redclover	3390	1020	4410	62	19	81
	Sweetclover	4830	910	5740	83	11	94

Source: K.E. Bowren

NUTRITION OF PERENNIAL FORAGES

ALFALFA

Most research on the nutrition of perennial legumes has been done with alfalfa, but the principles also apply to crops such as clover, trefoil, and sainfoin.

Alfalfa is an ideal cultivated crop for maintaining and improving the quality and productivity of soils, while producing high quality feed, particularly for ruminant livestock. Today, Canada grows 4-5 million hectares of alfalfa in pure and mixed stands (grass-alfalfa).

Alfalfa seed should be inoculated with Rhizobium meliloti bacteria immediately prior to seeding. The bacteria infect the root hairs of the plant and form nodules, enlarged plant cells filled with bacteria, in which the bacteria convert atmospheric nitrogen into nitrogen forms that the plant can use. Other legumes, require their own specific strain of Rhizobium. Under ideal conditions, an established stand of alfalfa will be provided with all of its nitrogen through symbiotic nitrogen fixation. The alfalfa roots should be checked periodically for the presence of nodules. Large nodules that are bright pink when cut open are a good indication that nitrogen fixation is occurring.

Alfalfa commences growth early in the spring and grows throughout the summer into the late fall. An understanding of climatic as well as soil factors must be considered when recommending fertilization of alfalfa swards. Alfalfa can be grown on all soils except those that are poorly drained or too coarse textured to retain moisture. However, coarse textured soils associated with a high water table can be as productive as fine textured soils if fertility is adequate. Alfalfa tolerates moderate salinity. Because soil acidity interferes with nitrogen fixation by Rhizobium bacteria, it is very difficult to establish alfalfa on highly acidic soils. Consequently, soils with a pH of 6.5 or lower should be limed to a pH of 7.0. Most prairie soils have a pH of 7.0 or higher and are suitable for alfalfa production.

NUMBER OF HARVESTS ANNUALLY

Three harvests of alfalfa can be taken annually without any adverse effects on stand density and longevity, provided that the crop is supplied with an adequate supply of nutrients and moisture. Under normal moisture conditions in the Aspen Parkbelt a two cut system is normal, unless harvesting for "dehy". Under a three harvest system, yields can be in excess of ten tons per hectare of forage with protein content in excess of 18%. For optimum yield and protein, harvesting should occur at 'full bud' and not later than the 5% bloom stage of growth (Fig 2.). Delaying harvest beyond this time will result in minimum increase in forage yield but a significant reduction in protein. Between the 2nd and 3rd harvest, it is recommended that there be at least a six-week period of growth so that the crop can prepare for over-wintering by accumulating and storing carbohydrates in its roots. If a third harvest is taken it should be in October after the first killing frost.

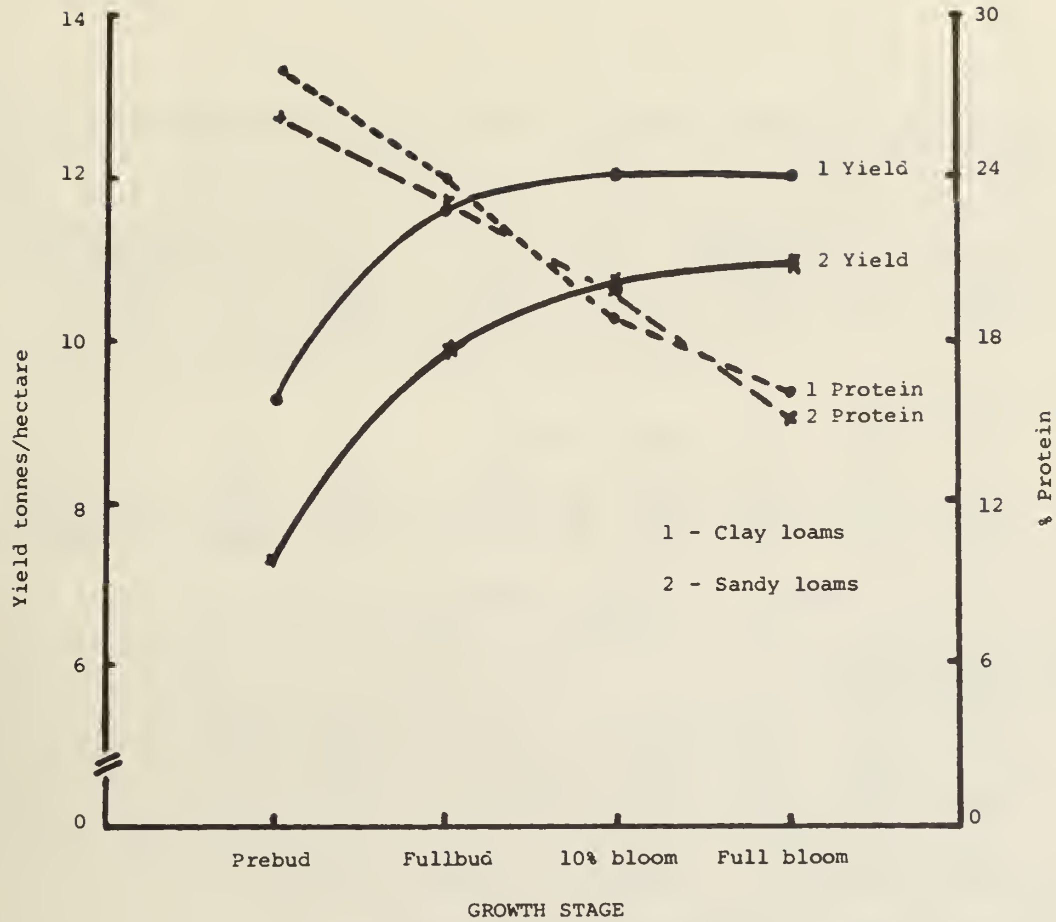
NUTRIENT REMOVAL

Table 23 shows that under a three-cut management system at Brandon, a high-yielding crop of alfalfa uses a tremendous amount of the four major plant nutrients. In comparison, a 2690 kg/ha crop of wheat uses approximately 1/4 as much nitrogen, 1/2 as much phosphorus and sulfur and 1/6 as much potassium as a 12 t/ha crop of alfalfa. This large removal of nutrients makes it essential to annually monitor the soil fertility and forage nutrient composition by soil and plant analysis.

RESPONSE TO FERTILIZER

Alfalfa is very responsive to applications of fertilizer. Forage yield increases of 39, 27, and 38% for the 1st, 2nd and 3rd cuts respectively, have been obtained on clay loam soils. On sandy loam soils, with adequate fertility, increases in the order of 300% for the 1st and 2nd cuts are possible. Without fertilizer there was no 3rd cut (Table 23). Protein content increased on the clay loam soils by 25 to 38% and by greater than 120% on the sandy loam soils with the addition of fertilizer (Table 23).

Despite the fact that alfalfa responds to fertilizers only 15 to 25% of



Source: L. Bailey - Brandon Research Station

Fig. 2. Yield of herbage and protein content of alfalfa grown on clay and sandy loam soils at different growth stages (fertilized treatments).

the total alfalfa cropped area in Canadian prairies receives fertilizer.

FERTILIZING AT ESTABLISHMENT

Because it has a small seed, alfalfa needs a readily available supply of phosphorus and other plant nutrients right after emergence. By the time a young plant reaches 25% of its total dry weight, it may have accumulated as much as 75% of its total phosphorus. High rates of fertilizer placed with the seed will damage the seedlings. When potassium and sulfur are recommended, they should be broadcast and worked into the soil or drilled to a depth of 7.5 to 10 cm prior to seeding. The best response to phosphorus fertilizer is obtained when it is placed 2.5 cm directly below the seed. Good response is also obtained when the phosphorus is placed 2.5 cm below and 2.5 cm to the side of the seed. Placing the phosphorus greater than 2.5 cm to the side of the seed, or broadcasting and incorporating it into the soil, reduces its effectiveness. If machinery for specific placement of phosphorus fertilizer is not available, the fertilizer may be broadcast and incorporated 7.5 to 10 cm into the soil.

Table 23. Annual Nutrient Removal by Alfalfa Forage Harvested at the Full Bud Stage (kg/ha)

Cut	Fertilized* Yield t/ha	Fertilized* Element N	P	K	S	Protein (%)	Unfertilized Yield t/ha	Unfertilized Element N	P	K	S	Protein (%)
A. Clay Loam Soils												
1st	5.0	185	13	175	12	23	3.6	108	7	86	8	19
2nd	3.3	116	8	100	8	22	2.6	83	5	52	6	16
3rd	3.6	122	8	90	8	21	2.6	55	5	42	6	16
Total	11.9	423	30	365	28		8.8	256	17	180	20	
[Fertilizer (kg/ha) 0 - 60 P_2O_5 - 30 K_2O - 30 S]												
B. Sandy Loam Soils												
1st	4.0	152	10	104	10	24	1.0	18	2	11	2	11
2nd	3.2	112	7	74	8	22	0.8	13	1	6	2	10
3rd	3.4	119	8	68	8	22	0.0	--	--	--	--	--
Total	10.6	383	25	246	26		1.8	31	3	17	4	
[Fertilizer (kg/ha) 0 - 60 P_2O_5 - 120 K_2O - 30 S]												

C. Fertilized Wheat (Include straw and grain)

Grain Yield	N	P	K	S	
2690 kg/ha	95	14	60	12	(kg/ha removed)

Source: L. Bailey - Brandon Research Station

FERTILIZING ESTABLISHED STANDS

Increased use of fertilizer, use of improved varieties, herbicides, insecticides, improved management and, in some areas, irrigation have resulted in increased yield of alfalfa forage. This increased production of high quality forage has resulted in increased removal of mineral nutrients from the soil. Most experiments on alfalfa fertilization have been conducted at yield levels that are low by present-day standards, making the results of questionable value and possibly misleading when making current fertilizer recommendations.

Nitrogen

Nitrogen is required for protein synthesis. Properly inoculated alfalfa will fix large quantities of atmospheric nitrogen and under optimum conditions needs no additional fertilizer nitrogen. Application of nitrogen at the time of seeding may encourage weeds and adversely affect stand establishment. Where a response to nitrogen on established stands has occurred, it may indicate a low efficiency of nitrogen fixation. On acid soils, where nodulation and nitrogen fixation may be poor, alfalfa responds well to nitrogen application. The nitrogen content of alfalfa forage harvested at the full bud to 5% bloom stage is generally in excess of 3%. If little or no nitrogen fixation was occurring, the cost of applying nitrogen requirements as fertilizer could be prohibitive.

Phosphorus

Phosphorus plays a key role in many life processes such as photosynthesis, carbohydrate and protein synthesis, and transfer of heredity.

A 14 year study shows that 75% of prairie soils tested were moderatley or severely deficient in available phosphorus. Determining the phosphate requirement of alfalfa is difficult due to the complexity of soil and environmental factors governing the availability of soil phosphorus to plants, the low recovery of phosphorus from fertilizer (35% to 50%), and the low concentration of phosphorus in the forage (0.2 to 0.4%). This low concentration of phosphorus is indicative of the relatively small amount of phosphorous removed from the soil by a crop of alfalfa forage. It is sometimes found that alfalfa does not respond to phosphorus fertilizers. Table 24, however, shows that alfalfa will respond in both yield and protein content, to applications of phosphate fertilizer at rates in excess of 60 kg P_2O_5 per ha, probably on a P deficient soil. In Manitoba, fall broadcast application of phosphorus fertilizer on established stands of alfalfa was economical.

Potassium

It is generally believed that the majority of prairie soils contain sufficient plant available potassium for alfalfa production. However, recent studies have shown that soils with low potential for supplying potassium and low exchangeable potassium, required an annual application of 100 kg of K/ha to produce maximum yields (Table 25) and to optimize protein content (Table 26). There was also a significant response to potassium application on soils that tested in the medium and high ranges of exchangeable potassium. At maximum yield, taken at full bud, concentration of potassium in the forage was in excess of 2.0% and represented a large removal of soil and fertilizer potassium. Annual application of potassium maintained and increased yield of alfalfa over an eight-year period by improving winter hardiness (Table 24). Without potassium, the number of plants in the stand rapidly decreased due to winter kill.

Broadcast application of potassium on established alfalfa is effective and efficient, with essentially all topdressed potassium recovered by the crop. The element may be applied at anytime during the growing season with good efficiency. This is particularly so when it is applied immediately after a harvest or when irrigated.

Table 24. Effect of Phosphorous Fertilizer on the Yield, Phosphorous Content and Protein Composition of Alfalfa at the Full Bud Stage.

Rate of P_2O_5 (kg/ha)	Yield forage (t/ha)	Phosphorous (%)	Protein (%)
0	5.0	0.08	11.3
23	6.1	0.15	12.5
45	10.2	0.20	13.8
67	12.5	0.22	20.0
112	11.2	0.25	18.8

Table 25. Total Alfalfa Forage Harvested Over a 5-yr Period from Five Soils Fertilized with K.

Soils	Annual rate of K (kg/ha)				
	0	50	75	100	200
	Tonnes/ha				
Souris (50)+	9.1	20.8	26.8	34.8	41.4
Miniota (1250)	17.3	27.1	32.0	35.1	46.3
Waitville (310)	23.7	32.0	34.8	38.2	49.0
Carroll (695)	57.6	57.4	57.5	58.0	57.9
Newdale (972)	44.8	51.7	52.8	52.6	52.7

+Numbers in parentheses represent initial exchangeable K (kg/ha).

Table 26. Effect of Potassium Fertilizer on the Yield, Potassium Content and Protein Content of Alfalfa, Grown on Low-Medium K Soils*

Rate of K_2O (kg/ha)	Yield (t/ha)	Potassium (%)	Protein (%)
0	3.3	0.8	9.4
56	6.4	1.2	12.5
84	8.3	1.8	17.5
112	10.6	2.5	20.0
224	10.0	3.2	21.2

*Initial potassium levels in the soil ranged from 30 kg/ha (27 lb/acre) to 360 kg/ha (321 lb/acre).
- 5 Station years on three Manitoba soils.
- The plots also received an annual application of 67 kg/ha (60 lb/acre) P_2O_5 and 34 kg/ha (30 lb/acre) of sulfur.

Table 27. The Effect of Potassium Fertilizer in Protecting Alfalfa from Winterkill on a Sandy Loam Soil

Year	With Potassium*		Without Potassium	
	Stand Density**	Yield*** (t/ha)	Stand Density**	Yield*** (t/ha)
1970 (seeded)	-	-	-	-
1971	98	2.6	102	2.2
1972	102	3.2	90	2.5
1973	97	4.5	82	2.5
1974	98	4.2	51	1.4
1975	102	4.6	35	0.9
1976	100	4.4	15	0.5
1977	95	4.0	15	0.5

*Received an annual application of 112 kg/ha K_2O.
**Number of plants in 3 one meter row lengths taken in May and expressed as a percentage of the same count taken in the previous September.
***First cut only.
- Initial soil test: 260 kg/ha exchangeable potassium (0-15 cm).

Sulfur

Plant protein contains about 1.0% sulfur and 17.0% nitrogen. There is a close relationship between the nitrogen and sulfur nutrition of alfalfa. For optimum forage yield, the ratio of total nitrogen to total sulfur in the plant is 14:1. For maximum yield of forage, the concentration of sulfur in the herbage at full bud should be in excess of 0.20%. Thus, the annual broadcast application of sulfur not only increases herbage yield, but also increases herbage protein (Table 28).

Micronutrients

Micronutrients play an important physiological and metabolic role in the nutrition of forage crops. Apparent response to boron, copper and manganese has been reported in Saskatchewan and Manitoba, but research has not verified this. It is important however, to continue to monitor forages and to investigate claims of micronutrient problems. These elements, although required by plants in very small quantities, may cause severe economic losses to producers when they are either deficient or present in excessive amounts.

Table 28. Effect of Sulfur Fertilizer on the Yield, Sulfur Content and Protein Content of Alfalfa

Rate of S (kg/ha)	Yield (t/ha)	Sulfur (%)	Protein (%)
0	3.6	0.10	8.8
17	6.2	0.16	11.3
34	9.6	0.21	18.8
51	12.0	0.23	20.6
67	11.7	0.23	21.3

- 5 station years on a gray-wooded soil.
- Initial sulfur content of the soil was 15 kg/ha.
- The plots also received an annual application of 67 kg/ha P_2O_5 and 34 kg/ha K_2O.

GRASSES

Nitrogen is the major nutrient required for the production of quality grass for both hay and pasture. Unfortunately only about 7% of the fertilizer used in Manitoba is used for forage production. Perhaps the most important argument for increasing the use of nitrogen on grasses is its yield and protein-increasing effects, which enable more livestock to be kept per unit of land. While nitrogen is usually the most effective plant nutrient in increasing yield and protein content of grasses, other plant nutrients may become limiting as yields are increased by the use of N fertilizer. Stand life, regrowth, efficiency of protein production and high forage mineral content are obtained only when the crop receives adequate amounts of the essential plant nutrients. Soil testing will indicate the possibility that various soil nutrients are limiting production.

Nutrition

Grasses for hay or pasture, are generally established on summerfallow or partial fallow, but may also be seeded into clean stubble. The fertilizer requirements of the grass at seeding are determined by soil analysis as for cereals. However, grass seeds are not as tolerant of high rates of nitrogen fertilizer placed with the seeds as are cereals. Rates of phosphorus up to 30 kg P_2O_5/ha can be safely placed with the seeds, but it is recommended that all other fertilizers be broadcast and worked into the soil 5 to 10 cm deep immediately prior to seeding.

Nitrogen

The available nitrogen under an established grass sward is generally very low, often zero. Response to nitrogen depends on the time and rate of application, the source of nitrogen and on the age and species composition of the sward.

All nitrogen should be broadcast on established grass swards prior to commencement of regrowth. The closer the application is to the commencement of regrowth, the more effective is the applied nitrogen in increasing yield. Consequently, spring-applied nitrogen is more effective in increasing herbage yield than fall applied nitrogen (Table 29). Also, a split-rate application of nitrogen (applying equal increments of nitrogen in the spring and immediately after each harvest except the final) is comparable to a single spring application where moisture supply is adequate. The split-rate technique has the added advantage of equalizing the production of herbage with a relatively higher protein content throughout the growing season when compared to the single spring application and is particularly useful for pasture production where rotational grazing is practiced.

Annual applications of nitrogen are required for high yields of quality herbage. Yield of forage and the protein content of grasses will increase with increased rates of annually applied nitrogen fertilizers (Fig. 3). There is usually a negligible residual effect on forage yield and protein content in the year after fertilizer nitrogen application unless there has been a poor growing season the previous year or higher than required rates of nitrogen were applied. It has been found that the response of old grass stands was greater than that of new stands when fertilized for the first time with nitrogen. With continued annual application, however, similar responses were obtained on all stands. In general, the amount of nitrogen annually required for optimum production of high quality forage is in the range of 60 to 200 kg N/ha. The exact amount required is dependent on the plant available nitrogen in the soil, and the required yield and protein content of the herbage produced (influenced to a large degree by moisture conditions).

Under eastern prairie conditions, urea (46-0-0) and ammonium nitrate (34-0-0) are more efficient sources of nitrogen for quantity and quality of grass production than is solution-nitrogen (28-0-0) (Table 29). For early season hay-type grasses, ammonium nitrate is the most effective source of nitrogen in increasing yield. For late season hay-type grasses, urea and ammonium nitrate are equally effective in increasing yield. Urea, however, is the best source of nitrogen for increasing yield of pasture-type grasses and for increasing the protein content of all grasses. The yield advantage obtained with urea on hay and pasture type grasses is due to the good regrowth and excellent second cut yields obtained when this compound is used.

Phosphorus

Most soils are deficient in phosphorus for optimum crop production. Consequently, it is essential that adequate levels of phosphorus be applied to optimize yield of quality forage. The yield increases obtained when phosphorus is applied are not generally as great as those obtained for similar units of applied nitrogen, however, phosphorus prolongs stand life, particularly when the stand is subjected to intensive grazing. The element

Table 29. Effect of Type of N Fertilizer and Time of Application on the Yield (kg/ha) and Protein Content (%) of Bromegrass and Russian Wild Rye for Each of Three Cuts

	Source of Nitrogen							
	Check		NH_4NO_3		Urea		Soluble N	
	Yield	CP	Yield	CP	Yield	CP	Yield	CP
Bromegrass								
Time of application (120 kg N/ha)								
April								
Cuts - June	2530	9	4150	18	3540	19	3300	18
- August	400	6	1150	13	1050	14	850	8
- October	600	7	1650	16	2000	17	1070	8
Total	3530		6950		6590		5220	
October								
Cuts - June	2530	9	4130	18	3500	19	3000	18
- August	450	6	1100	13	1000	14	600	8
- October	600	7	1490	16	1800	17	1100	8
Total	3580		6720		6300		4700	
Split Application*								
Cuts - June	2500	9	3500	19	3000	19	2700	18
- August	450	6	1530	16	1340	17	1200	9
- October	600	7	1900	18	2250	18	1400	11
Total	3550		6930		6590		5300	
Russian Wild Rye								
Time of application (120 kg N/ha)								
April								
Cuts - June	650	7	2330	15	2010	16	1830	13
- August	400	6	1100	12	1830	14	900	8
- October	650	7	1200	13	1900	16	1000	9
Total	1710		4630		5740		3730	
October								
Cuts - June	650	7	2400	15	1790	16	1500	12
- August	400	6	1100	13	1520	14	650	7
- October	600	7	1300	13	1730	16	1100	9
Total	1650		4800		5040		3250	
Split Application*								
Cuts - June	650	7	2200	15	1930	16	1600	12
- August	400	6	1050	12	1850	14	900	8
- October	600	7	1350	14	1850	16	1120	9
Total	1650		4600		5630		3620	

*120 kg split in equal applications at beginning of season and following each cut (except final cut).

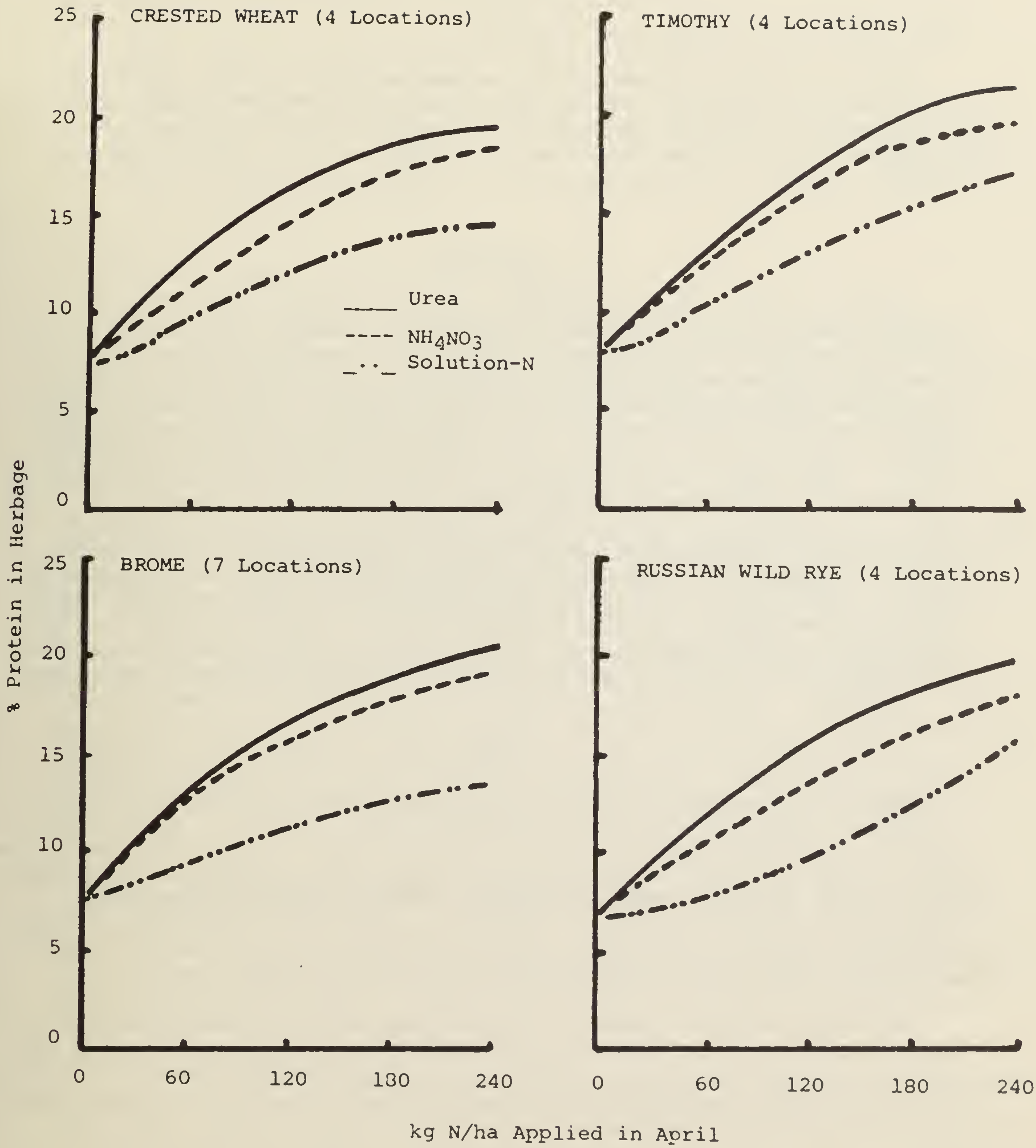


Fig. 3. The effect of rates of spring applied Urea, NH_4NO_3 and Solution-N on the crude protein content of Crested Wheat, Timothy, Brome and Russian Wild Rye. (Bailey, L.D., Brandon Research Station).

also increases the efficiency of plants in utilizing other nutrients and water, and thus promotes rapid regrowth.

Unlike nitrogen, phosphorus can be applied in the spring and/or fall with equal effectiveness. In the Aspen Parkbelt of Western Canada, 30 to 50 kg P_2O_5/ha is considered adequate for annual production of hay and pasture. The objective is to produce herbage containing at least 0.2% phosphorus or greater.

Potassium

Coarse textured and well-drained soils are generally deficient in potassium for optimum production of high quality forages. The quantity of potassium required by various grasses differs. However, for grasses recommended in the Aspen Parkland, a level of 2.0 to 2.5% potassium in the forage should be the goal of any fertilizer program. When forage is grown without potassium fertilizer, on soils low or deficient in potassium, stand life and forage quality decrease, particularly when grazing is practiced; further, the element has been shown to increase carbohydrate accumulation in the roots thus enhancing winter hardiness and early spring regrowth.

An annual (spring and/or fall) broadcast application of 60 to 200 kg K_2O/ha is adequate for production of grass forage on soils low in potassium. Although application of potassium fertilizer may not result in large yield increases, the benefit obtained from crop quality, winter hardiness (stand longevity), disease resistance and water use efficiency generally more than compensates for the cost of the fertilizer, according to studies at Brandon.

Sulfur

Recent studies have shown that this element is limiting crop production on several coarse-textured and well-drained soils. Sulfur is used by the plants for the manufacture of certain essential amino acids in proteins. The level of soil available sulfur should be higher than is required for optimum plant growth, since the increased uptake of sulfur by the plants is beneficial to ruminant animals. The use of sulfur fertilizer may not result in dramatic yield increases, but rather in increased protein and increased efficiency in the use of nitrogen and other plant nutrients.

The objective of a sulfur fertilizer program is to produce forage with a sulfur concentration of 0.20 to 0.25%. The element can be broadcast in the spring and/or fall with equal effectiveness. In general 20 to 35 kg SO_4-S/ha applied annually is adequate to maintain production on most soils that may be low of deficient in the element.

Micronutrients

The need for micronutrients is best diagnosed by leaf or tissue analysis. Deficiencies are corrected by either foliar sprays or soil incorporation of the deficient element(s). Micronutrients may be applied to forages not only to correct deficiencies but also to increase the levels of the nutrient(s) in the forage to meet the requirement of livestock feed, although this may be more costly than supplementing the ration with appropriate mineral supplement.

NUTRITION OF FORAGE LEGUME-GRASS MIXTURES

Fertilizer recommendations for legume-grass mixtures must take into account the relative proportions of legume and grass in the stand. In general, if the stand has less than 25% grass in the stand it is recommended to follow the fertilizer practices outlined for pure legume stands. Similarly, if the stand has less that 25% legume then it is recommended to treat the stand as a grass stand.

A general rule for fertilizing mixed stands is (1) determine the percentage of grass in the stand, (2) determine the quantity of nitrogen that would be added if the stand was 100% grass, (3) multiply the percentage of grass in the stand by the nitrogen required for a 100% grass stand, this is the nitrogen that is required for the mixture.

For other elements, proportional cuts in rates are not suggested. Grasses and legumes are effective and efficient feeders of broadcast fertilizers applied either is late fall or early spring. A general recommendation for grass-legume mixtures is 40 N, 40 P_2O_5, 30 K_2O per hectare applied in late fall or early spring. It must be remembered that the previous discussion for pure stands of grasses and legumes with respect to secondary and micronutrient requirements apply equally to mixed stands.

DETERMINING OPTIMUM LEVEL OF NITROGEN (N) FERTILIZER FOR SEVERAL GRASSES

Researchers in Alberta and Saskatchewan have shown that economic optimum N fertilizer rates are considerably higher than rates used by producers. Some estimates show that the rate of fertilizer N used on grasslands in Western Canada is as low as 13 kg N/ha.

At the Brandon Research Station*, the economics of applying N fertilizer to smooth bromegrass (SBG), intermediate wheat grass (IWG), crested wheatgrass (CWG) and Russian wild rye (RWR) grown for hay on two soil types, a clay loam and a sandy loam was determined, taking into account the age of the stand, N fertilization and precipitation data.

Total available N included soil nitrate N plus applied fertilizer N.

The economic optimum application rate was obtained at the point where the last dollar spent of N fertilizer returned one dollar in additional value of the standing hay crop.

The total available N required to maximize dry matter yields under average spring precipitation conditions for a three year old stand are shown in Table 30. These data indicate that both precipitation and soil type had considerable effect on both maximum yields and on the quantity of fertilizer N needed to produce them. Clay-loam soils were potentially more productive than sandy-loam soils and required larger amounts of N fertilizer to maximize dry matter yields. Both dry matter yield and N rate for maximum yield on both soil types were strongly dependent on spring precipitation.

The economic optimum level of fertilizer N will always be less than that needed to produce maximum yields. Fig. 4 shows how the price ratio of fertilizer N/standing hay affects the economic optimum nitrogen level for four grass species, on two soil types, under average April, May and June precipitation (168 mm). The inset precipitation adjustment table on each graph in Fig. 5, indicates how much more or less N to apply under moist (mean + 54 mm) or dry (mean - 54 mm) conditions. An example is smooth bromegrass on sandy-loam soil (Fig. 4). In this graph the precipitation adjustment is represented graphically. If the fertilizer N/standing hay price ratio was approximately 10:1 (eg. N, $460/tonne, hay, $46/tonne) then the economic optimum N would be approximately 130 kg/ha on sandy-loam soil under average precipitation conditions. The graph shows that economic optimum available N on sandy-loam soil would vary from 62-196 kg N/ha, depending on precipitation. A producer can then subtract the quantity of N indicated by soil test results to determine application rates. This information will help producers to maximize profits. On other types of soils the figures would differ, although the principles would be similar.

The value of standing hay, in contrast to baled hay must be used to determine the price ratio. This is because harvesting costs per tonne vary with yield since cutting is performed on a per hectare basis, while baling and hauling are on a per bale basis. These costs must be subtracted from the price of baled hay to determine the value of standing hay. Alberta studies indicated that the total costs for handling hay (cutting, baling and hauling) ranged from $15-$21/tonne. It is expected that these costs would be similar in Manitoba.

The results of this analysis indicate that producers should increase their use of N fertilizer if they wish to maximize profits. The economic optimum quantity of N fertilizer to apply depends on both soil type and spring precipitation.

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*W.P. McCaughy, E.G. Smith and A.T.H. Gross

Table 30. Effect of Total Spring Precipitation and Soil Type on Forage Productivity and Nitrogen Application Rates Necessary to Produce Maximum Yields

Species	N rate for maximum yield (kg ha^{-1})	Maximum yield (kg ha^{-1})
Sandy-loam		
SBG	207 $\pm$ 66*	4.3 $\pm$ 2.1*
CWG	280 $\pm$ 90	3.8 $\pm$ 1.7
IWG	265 $\pm$ 85	3.8 $\pm$ 1.6
RWR	228 $\pm$ 83	2.1 $\pm$ 1.4
Clay-loam		
SBG	362 $\pm$ 116	9.2 $\pm$ 3.0
CWG	520 $\pm$ 166	9.3 $\pm$ 2.9
IWG	350 $\pm$ 112	9.0 $\pm$ 2.1
RWR	312 $\pm$ 76	7.5 $\pm$ 2.0

Source: Brandon Research Station

*Note: In an average spring these precipitation adjustment values would be ignored, in a moist spring they would be added to the mean values, and in a dry spring they would be subtracted.

Producers should be aware that forage crops remove nutrients other than nitrogen from the soil. In commonly grown grass hays, the ratio of N:Phosphorus varies from about 6 to 10 parts of N to 1 of P. As hay production is increased because of application of N other nutrients, phosphorus, potassium and sulfur, and numerous trace minerals, are also being removed from the soil and may in time be reduced to a level when they limit production. Their levels should be periodically checked by soil analysis and, if found to be low, corrected by use of fertilizer containing the limiting nutrients.

At the Pathlow pasture project on a gray wooded soil in N.E. Saskatchewan, responses to P and S fertilization have been excellent and economically advantageous (see companion publication "Pasture Production and Utilization in the Aspen Parklands of Western Canada".)

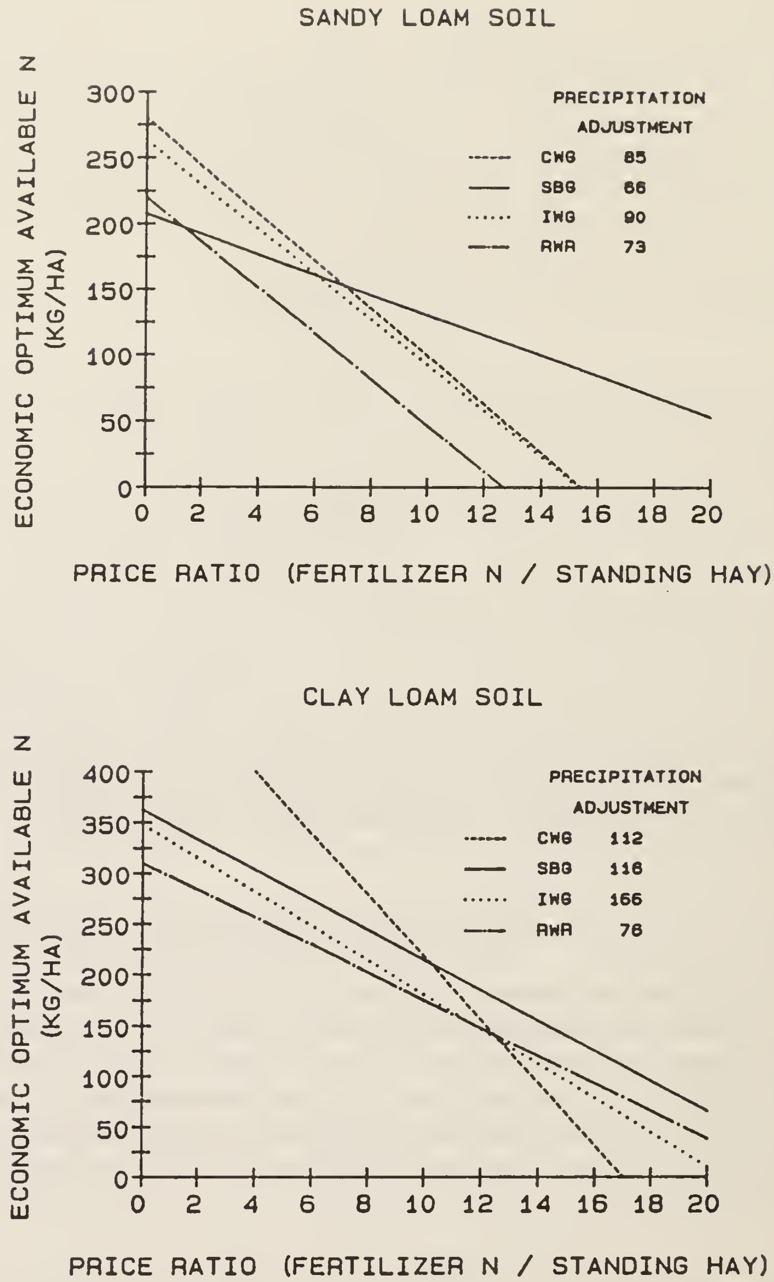

Fig. 4. Economic optimum available N vs price ratio (fertilizer N / standing hay) for smooth bromegrass (SBG), intermediate wheatgrass (IWG), crested wheatgrass (CWG) and Russian wildryegrass (RWR) on two soil types.

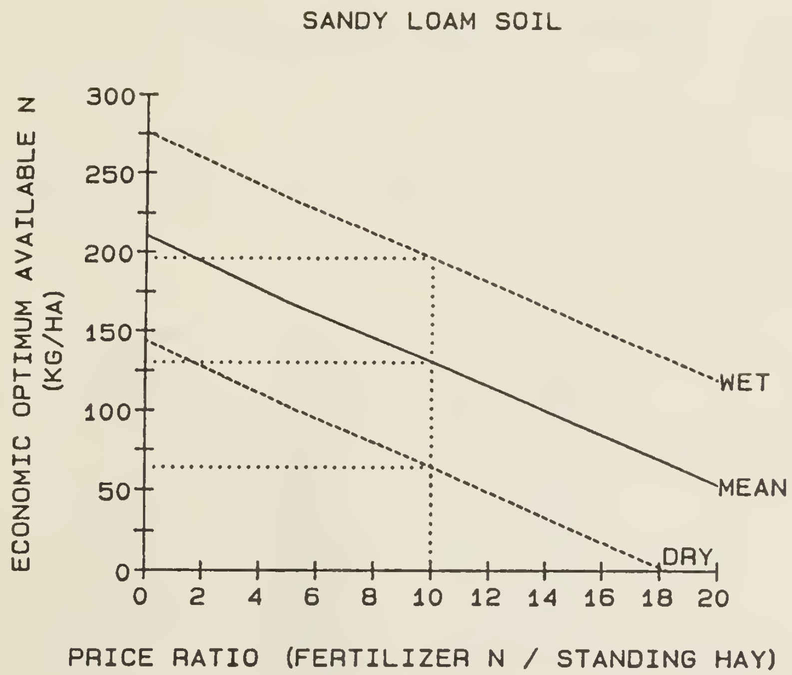

Fig. 5. Example showing the variabilty in economic optimum available N due to precipitation conditions for smooth bromegrass on sandy loam soil.

EFFECT OF DATE OF FIRST CUT AND OF SPRING VS FALL APPLIED NITROGEN FERTILIZER ON HAY PRODUCTION

For optimum hay production in the short growing season of the Aspen Parkland, timing of the first cut for hay production is of vital concern. The relative merits of spring vs fall application of nitrogen fertilizer is also of considerable interest.

In 1985, an experiment was set up to investigate the effects of autumn versus spring fertilizer application and timing of first cut on hay production in northeastern Saskatchewan on Magna smooth bromegrass, Parkway crested wheatgrass and Chief intermediate wheatgrass.

Magna smooth bromegrass (SB), Parkway crested wheatgrass (CWG) and Chief intermediate wheatgrass (IWG) were seeded on June 13. Nitrogen fertilizer (100 kg 34-0-0 kg) was applied either in October or spring (late April/early May) of each year. The first cuts were taken on June 12, June 23, July 3, July 16 or July 30, while the second cut was taken in late September for all treatments in each year. The yields shown in Table 31 are the average total annual production of the first and second cuts combined for each treatment for 1987 and 1989. The crude protein values shown in Table 32 are for the 1989 growing season only.

Table 31. Averaged Total Annual Production (kg/ha) of First and Second Cut Combined Yields for 1987 to 1989

Time of fertilization	Date of first cut	Magna SB (kg/ha)	Parkway CWG (kg/ha)	Chief IWG (kg/ha)	Treatment mean (kg/ha)
Fall	June 12	5018	4787	4871	4892
	June 23	4886	4928	5102	4972
	July 3	4622	4900	5452	4991
	July 16	4395	4357	4751	4501
	July 30	4250	4632	5127	4670
	Average	4634	4721	5061	4805
Spring	June 12	4256	4241	4408	4302
	June 23	4747	4852	4979	4859
	July 3	5049	4381	4729	4720
	July 16	4434	4108	5004	4515
	July 30	3961	3982	4709	4218
	Average	4489	4313	4766	4523

Source: P.R. Horton, Melfort Research Station

Table 32. Crude Protein (%) for 1989

Time of fertilization	Date of first cut	Magna SB Cut 1 (%)	Magna SB Cut 2 (%)	Parkway CWG Cut 1 (%)	Parkway CWG Cut 2 (%)	Chief IWG Cut 1 (%)	Chief IWG Cut 2 (%)
Fall	June 12	17.01	16.50	14.84	16.41	17.24	13.64
	June 23	14.18	16.88	14.14	17.46	14.67	15.41
	July 3	12.91	19.77	12.22	21.31	13.22	20.48
	July 16	11.22	20.89	10.69	21.52	11.74	20.79
	July 30	8.78	21.03	9.73	22.21	8.83	21.58
Spring	June 12	17.52	17.15	15.42	18.22	17.48	15.69
	June 23	14.28	18.16	14.61	18.54	14.48	16.51
	July 3	12.74	18.54	12.08	21.18	12.58	20.21
	July 16	11.55	21.71	10.58	22.91	11.36	22.13
	July 30	9.24	21.39	8.84	22.09	8.74	22.13

Source: P.R. Horton, Melfort Research Station

EFFECT OF FERTILIZER ON THE PRODUCTION OF ALFALFA HAY ON THREE SOIL TYPES IN NORTHEASTERN SASKATCHEWAN

Various fertilizer treatments containing from 0 to 67 kg N/ha, 0 or 20 kg P/ha and 0, 22 or 46 kg S/ha were applied to Rambler alfalfa grown on three different soil types, a Waitville loam, Melfort silty clay and Whitefox fine sandy loam for 5 to 7 years. The initial fertility of the soil is summarized in Table 33.

Table 33. Soil Analyses of Three Sites, Prior to Seeding Alfalfa (mg/kg)

Soil Type	Depth	Nitrate N	Soluble P	Sulfate S	pH
Waitville loam	0.0-0.3	10.4	6.7	3.9	7.4
	0.3-0.6	5.6	3.1	5.3	8.0
Melfort silty clay	0.0-0.3	25.6	28.4	11.5	6.7
	0.3-0.6	3.2	4.0	11.5	7.4
Whitefox fine sandy loam	0.0-0.3	5.7	16.5	4.9	6.7
	0.3-0.6	12.3	9.8	3.4	7.0

The effect of fertilizer treatments on the yield of alfalfa three years after establishment on the different soil types is summarized in Table 34.

Table 34. Effect of N, P and S Fertilizers (kg/ha) on Yield of Alfalfa Hay (tonnes/ha)* Three Years After Establishment

Soil Type	Nitrogen Fertilizer	Phosphorus Fertilizer	Sulfur Fertilizer 0	22	26	45
Waitville loam	0	0	5.18	--	--	--
	10	0	6.33	--	--	--
	22	0	--	--	8.14	--
	10	10	6.33	--	--	--
	10	20	5.03	7.52	--	6.22
	45	20	6.90	7.73	--	9.48
	67	20	5.53	8.77	--	6.73
Melfort silty clay loam	0	0	7.80	--	--	--
	10	0	7.58	--	--	--
	22	0	--	--	--	--
	10	10	7.88	--	7.99	--
	10	20	7.51	7.19	--	8.10
	45	20	8.33	7.34	--	9.09
	67	20	7.56	7.72	--	8.21
Whitefox fine sandy loam	0	0	4.34	--	--	--
	10	0	4.26	--	--	--
	22	0	--	--	4.89	--
	10	10	4.85	--	--	--
	10	20	5.35	4.69	--	4.70
	45	20	5.47	3.69	--	4.77
	67	20	5.32	5.91	--	5.91

*Total for 2 cuts

Source: W.F. Nuttall

If we value alfalfa hay at $70 per tonne, nitrogen at 55¢/kg, P at $1.15/kg and S at 32¢/kg, the value of the additional hay produced by applying fertilizer, less fertilizer cost per hectare, can be determined. The results on the treatments shown in Table 34 are summarized in Table 35.

Table 35. Returns Over Fertilizer Costs of Applying Various Fertilizer Treatments (kg/ha) to Alfalfa Grown on Three Soil Types ($/ha)

Soil Type	Nitrogen Fertilizer	Phosphorus Fertilizer	Sulfur Fertilizer 0	22	26	45
Waitville loam	0	0	0	--	--	--
	10	0	75.00	--	--	--
	22	0	--	--	186.78	--
	10	10	63.50	--	--	--
	10	20	-39.00	128.26	--	29.90
	45	20	72.65	123.71	--	238.85
	67	20	-38.35	184.41	--	34.25
Melfort silty clay loam	0	0	0	--	--	--
	10	0	-20.90	--	--	--
	22	0	--	--	-7.12	--
	10	10	-11.40	--	--	--
	10	20	-40.80	-78.24	--	-21.90
	45	20	-10.65	-86.99	--	28.15
	67	20	-76.65	-72.49	--	-45.55
Whitefox fine sandy loam	0	0	0	--	--	--
	10	0	-11.10	--	--	--
	22	0	--	--	18.08	--
	10	10	18.70	--	--	--
	10	20	42.20	-11.04	--	-17.70
	45	20	31.35	-100.29	--	-32.05
	67	20	8.75	43.01	--	35.65

COMMENTS

1. In this project, the alfalfa was not inoculated. It should have been, because soil cannot be counted upon to provide the required rhizobia.

2. Economic response of alfalfa to fertilizer was quite variable in this test and difficult to interpret. On the Waitville soil there was an excellent response to sulfur in the presence of nitrogen and phosphorus. On the Melfort soil, response of alfalfa to fertilizer was, with one exception, uneconomic. On the Whitefox soil there was a good response to nitrogen and phosphorus combined, and a good economic response to S when used in combination with high level of N (+P) or the intermediate level of N, without P.

3. It would appear that the ratios of these three fertilizer elements may be important and that imbalance will adversely affect yields.

USE OF BARNYARD MANURE

One tonne of manure contains about 5 kg nitrogen, 2 kg phosphorus, 5 kg potassium, some sulfur and trace minerals, and a good supply of organic matter. All these values vary according to the kind of animal, the kind of feed fed, the kind and amount of bedding used and the method of handling the manure. When spread on the land these ingredients become available for crop production. Not only is the supply of plant nutrients increased, but the added organic matter has a beneficial effect on the physical properties of the soil and helps prevent or reduce erosion on sandy or other erodible soils.

Research conducted by Bowren (Melfort Research Station) found that the greatest response has been obtained when manure was applied to problem soils, such as Gray Luvisol, which tend to bake and form a hard crust because they lack organic matter. On such a soil at Snowden, Saskatchewan, manure applied once every 3 years at 17 tonnes/ha increased the yield of wheat on summerfallow from 1755 to 2902 kg/ha, annually, over an 11-year period. It also increased the yield of the second crop (oats) from 1656 to 2340 kg/ha. At Star City, a similar rotation (on a lighter-textured Gray Luvisol soil, higher in organic matter) showed a 405 and 216 kg/ha annual increase of wheat and oats, respectively, over an 8-year period. The manure was even more effective when used in conjunction with alfalfa as a green manure crop.

On a degraded Black soil at Parkside, manure at 34 tonnes/ha applied every 5 years over a 37-year period, increased the average yield of wheat in the first and second crops by about 470 kg/ha and increased the yield of each of two hay crops in the same rotation by about 1.1 tonnes of dry matter/ha. The manure also improved the chemical and physical properties of the soil, particularly the phosphorus content, water-stable aggregate, organic matter content and water-holding capacity.

Removing manure from the feedlot and spreading it directly onto the land is the most economical and practical disposal method; however, this may create a weed problem, so piling the manure to allow further rotting may be desirable. Because of its fibrous nature, fresh manure greatly improves the physical structure of heavy-textured soils. Rotted manure, on the other hand, tends to make sandy soils more compact and this often improves their moisture-holding capacity. Manure should be worked into the soil as soon as possible after it is spread, and preferably at the time that forage stands are broken or during the summerfallow year of the rotation. If it is applied before the sod is broken, it can be hauled by manure spreaders even in fairly wet weather. A timely breaking operation allows excellent incorporation and thus reduces nutrient loss by runoff or volatilization.

Spreading manure directly onto forage land has some obvious disadvantages: for example, harrowing may be required to break up and spread large lumps, which tend to foul or smother the herbage; and water runoff, particularly in the spring, may carry considerable nutrients away and pollute waterways. If it must be done, spread the manure on the forage stand in the late fall or early spring, or on areas that have been grazed down and from which the cattle have been temporarily removed. Set the spreader to deliver a relatively low rate of manure and the beaters to pulverize it as much as possible, so that rain will wash the material off the plants and into the soil before the next grazing. Similarly, when applying manure to hayland, spread it immediately after removal of the hay crop so that rain will work the manure into the soil before the aftermath is grazed or a second hay crop removed.

Applying manure on summerfallow is also a good practice provided it is immediately incorporated into the soil to prevent contamination of runoff water. Spreading it in early spring or even late summer provides sufficient time to eradicate weed growth before a crop is seeded. Manure applied at this time increases the organic matter content of the soil and assists in controlling erosion on the summerfallow. Manure spread in the summerfallow year has longer to decompose than that applied during the sod fallow year and it can contain a higher percentage of undecomposed straw and raw material.

In a tilled summerfallow system, manure can be spread and incorporated into the soil quickly to avoid loss of nutrients. In a zero-till system, applied manure would have to be carried into the soil by precipitation, which of course could lead to nutrient losses, and pollution of waterways.

Spreading manure on frozen soil is not recommended because it may pollute water sources during the spring thaw and, also, nutrients may be lost through volatilization and runoff.

COMMON DISEASES OF FORAGE CROPS

Diseases are caused by fungi, bacteria, mycoplasmas, viruses, viroids, nematodes, mineral deficiencies, toxicities, and chemical injuries. The fungi are the most common cause of plant diseases. They grow as microscopic tubes or hyphae, and produce spores, or single celled, microscopic "seeds". The spores are distributed by wind, water, insects, etc., and infect healthy plants, usually during wet weather, cause disease and produce more spores to infect more plants.

Good management of forage crops usually reduces disease, and always increases yield. Avoiding a harvest in the fall before dormancy will allow a build-up of root reserves which will help to reduce winter injury, whether caused by low temperatures, snow mold or other diseases. Removal of infected hay reduces the number of spores produced by the disease causing fungi and thereby reduces disease losses.

In the Parkland, diseases usually cause less that 12% loss, but some can cause complete losses when weather conditions favor the disease and inoculum is available, for example Winter Crown Rot, Cottony Snow Mold, Brown Root Rot and Northern Anthracnose.

Disease (Crop)	Symptoms	Control
Winter Crown Rot (Forage legumes) Cottony Snow Mold (Cereals, forage grasses)	Damage appears in the spring as dead patches. In older stands single plants are killed. Sometimes a cottony growth can be found just as the plants are uncovered by melting snow. This disease is difficult to differentiate from winter killing, but usually is not associated with areas with poor snow cover.	Do not harvest during the critical period (Aug. 15 - Sept. 25), to allow the crop to enter the winter with good root reserves.
Yellow Leaf Blotch (Alfalfa)	Yellow blotches between the veins on the leaves appear early in the season and later become orange to brown. This disease causes the leaves to drop and lowers the quality of hay.	Cut early to avoid leaf loss and reduce reinfection. Anik and Rambler are resistant.
Black Stem (Alfalfa and Clovers)	Dark brown to black areas appear on the stems and can completely cover the lower stem. The same fungus also causes angular brown-black leaf spots.	Remove all crop material cleanly to reduce reinfection.
Verticillium Wilt (Alfalfa)	Infected plants wilt, the leaves turn yellow and die to a light tan color, but stems remain green even after leaves are dead. This disease is only serious in irrigated areas.	Rotate to cereal or grass crops, and control all broad leaved weeds. Resistant varieties are being bred.
Common Leaf Spot (Alfalfa)	Dark brown circular lesions appear on the leaves, later small brown fungal bodies appear in the lesions.	Harvest cleanly to remove inoculum.
Bacterial Wilt (Alfalfa)	Scattered plants in a stand show stunted growth with a yellow-green color. A cut through the taproot shows a yellowish brown discolored ring.	Usually serious only in irrigated areas. Newer varieties are resistant.
Brown Root Rot (Forage legumes)	Dead or weakened plants in the spring show brown lesions on the roots. Gray, later black, spheres of the fungus form on, or are imbedded in the dead areas of the roots. This disease appears erratically and can	Varieties developed in the Parkland show resistance, ie. Yukon sweetclover and Peace alfalfa.

	be absent from previously severely diseased fields the following year.	
Downy Mildew (Alfalfa)	The upper surface of leaves becomes yellowish, and on the lower surface a gray downy growth appears. The shoots become distorted and leaves curl down.	Algonquin, Angus, Anik and Thor are resistant varieties.
Powdery Mildew (Red and Alsike Clovers)	A white powdery growth spreads over the upper surface of the leaves.	At present, there are no reliable control measures.
Northern Anthracnose (Red Clover)	Elongate, dark marginal lesions form on the stems and petioles. The leaves above the lesions die and during wet weather masses of spores are produced on the infected areas.	Norlac is a resistant variety.
Root Rot-Spot Blotch (Most grasses, cereals)	Roots show a brownish discoloration and later die. Brown, usually elongate spots on leaves and stems, sometimes with a yellow ring around the lesions.	Rotation with broad leaved crops reduces disease levels.
Ergot (Most grasses and cereals)	Seeds are replaces by fungus bodies two to five times larger than the seed, which can be seen sticking out of the head. They are brown with a purplish tint outside and white inside. Before seed formation, honeydew is formed on infected heads.	Ergot bodies are toxic and must not be allowed in food or feed. Mowing the plants before heading prevents their formation.
Silver top, Whitehead (Many grasses)	Dead dried heads on healthy green shoots appear variably in stands of grasses. The heads are easily pulled out of the sheath, and show a shrunken discolored base of the stem.	Damage is only to seed yield. Spring burning is sometimes effective.
Brown Leaf Spot (Bromegrass)	Brown spots, usually oval with a yellow halo, appear on the leaves. When heavily infected, the leaves die.	Harvest cleanly, fertilize to recommended levels.
Selenophoma Leaf Spot (Bromegrass)	Brown margined, irregular spots with gray centers speckled with black tiny fungal bodies.	Harvest cleanly to remove crop residue from field.

Purple Eyespot (Timothy)	Small, oval, purple spots with light centers appear on the leaves.	North American varieties are more resistant than are foreign varieties. Maintain good fertility.

Source: W.B. Berkenkamp, Melfort Research Station

FORAGES IN CROP ROTATIONS

Perennial forage crops, both grasses and legumes, improve soil quality and help to protect the soil from erosion when included in crop rotations in the Aspen Parkland of Western Canada. Research and producer experience have demonstrated the value of such crops when they are included in the crop rotation on a regular basis. A cropping system must be flexible to take advantage of soil moisture, market prospects and other conditions, but on many soils, perennial forages should be grown for up to 50% of the time for best long-term land use. On the fertile silty clay loam at Melfort, contained 0.55% N in the 0-15 cm layer in 1963. Subsequent research has shown that with wheat prices greater than $163 per tonne, a six year rotation containing two years of a grass-legume hay, provided high economic returns, with or without the use of fertilizer. This rotation permitted a nutrient buildup and had other benefits consistent with a sustainable agriculture. On degraded soils the rotation was even more beneficial.

A COMPARISON OF GRAIN AND GRAIN-FORAGE ROTATIONS

Research comparing a commonly used straight grain rotation with a grain-forage rotation on five different soil types has been on-going in northeastern Saskatchewan for about 30 years to evaluate their long term effects on crop production and soil characteristics.

Results show that on degraded soils there is an advantage for longer term grain-forage rotations with reduced summerfallowing compared to straight grain rotation (Tables 36 and 37). At all stations the yield of TDN (total digestible nutrients) per hectare was higher in a six year grain-forage rotation than in a 3-year straight grain rotation. Grain yields were higher in the grain-forage rotation on the degraded soils at Somme and White Fox. In addition, the nitrate content of the soil (Table 38) on both fallow and stubble is considerably higher on fields in the grain-forage rotation at Melfort and Somme. The protein content of wheat in the grain-forage rotation is higher (0.4% on fallow and 0.6% on stubble, and 0.5% on fallow and 0.7% on stubble) on average at Melfort and Somme , respectively, than for that from the straight grain rotation.

Table 36. Crop Rotation Studies in Northeastern Saskatchewan (Yield, kg/ha)

Station & soil type	Number of Years	2-Year Wheat - fallow rotation	3-Year Rotation		6-Year grain forage rotation*		Wheat after sod breaking	Average hay yield
			Wheat wheat fallow	Wheat wheat stubble	Wheat on fallow	Wheat on stubble		
Archerwill Waitville (L)	20	1962	2127	1420	2091	1581	1679	2978
Somme Tisdale (C)	26	-	2690	1800	3024	2564	2029	3839
Henribourg Glenbush (FSL)	14	2181	2159	1407	1945	1408	1617	3348
Melfort Melfort (SCL)	27	2794	2773	2470	2848	2296	2424	3425
White Fox Whitefox (FVL)	28	-	1421	916	2349	1688	1817	2494

*2 years of forage

Source: K.E. Bowren

Table 37. Annual Production TDN* kg/ha from Total Area of Land in Rotations

Station:	Melfort	Archerwill	Henribourg	Somme	White Fox
Soil Type:	Melfort SCL	Waitville L	Shellbrook LL	Tisdale C	Whitefox FVL
	Years Mean				
Rotation**	27	20	15	26	28
- fallow, wheat	1243	873	971	-	-
- fallow, wheat, wheat	1555	1003	1053	1736	693
- fallow, wheat, hay, hay, wheat, wheat	1750	1397	1223	1968	1326

*TDN of wheat, 89%; of hay, 55% (dry matter basis).

Source: K.E. Bowren

RETURNS

The economic value of including forages in cropping systems varies from farm to farm and from year to year, depending on the use that can be made of the forage crop and the relative market value of forage and grain. The relative value of hay to wheat (per unit of weight) required to provide equal returns per hectare from the 6-year grain-forage rotation and the 3-year straight grain rotation at each of the test sites is as follows:

Station	Ratio
Archerwill	0.31:1
Henribourg	0.032:1
Melfort	0.43:1
Somme	0.17:1
White Fox	0.00:1

This means that, if hay was worth at least 43% as much as wheat on an equal weight basis, the 6-year rotation "paid off" at Melfort. At White Fox, the forage crop did not have to be worth anything in order to justify its inclusion in the rotation!

SOIL IMPROVEMENT

Rotations which included forages improved the chemical and physical properties of the soils. This improvement is generally more pronounced on the degraded and Gray Luvisol soils than on Black soils, which have a higher organic matter content.

Table 38. Fall Nitrate Nitrogen in the 0-60 cm Soil Layer (kg/ha)

Rotation	Melfort (Msic) (8 year average) Fallow	Stubble	Somme (Tic) (11 year average) Fallow	Stubble
3-year straight grain	86	37	61	19
6-year grain/forage	114	58	83	29

Source: K.E. Bowren

Legume crops are particularly useful in improving not only nitrogen, but organic matter content and tilth of soils. A year's growth of sweetclover contains about 60 kg/ha of nitrogen. When sweetclover was added to a 3-year grain rotation and worked down as a green manure crop at the bud stage, during the summerfallow year, total grain production and net return per ha were increased by 20%. In other studies, the amounts of dry matter and nitrogen in legume crops were measured at various stages of growth. The results are summarized in Table 39.

Table 39. Yield of Dry Matter and Nitrogen (kg/ha)

Stage of growth	Dry matter Alfalfa	Dry matter Red clover	Dry matter Sweet-clover	Nitrogen Alfalfa	Nitrogen Red clover	Nitrogen Sweet-clover
Seedling	1631	1524	1878	38	32	45
Early bud	2434	1783	2725	69	48	81
Full bloom	4828	3897	5360	94	75	89
Mature seed	5248	4906	5478	99	92	64

Source: K.E. Bowren

If the alfalfa, red clover and sweetclover had been used as green manure at the early bud to full bloom stages of growth, they would have returned 69-94, 48-75 and 81-89 kg of N per ha, respectively. Legumes also add a large amount of dry matter to the soil which increases organic matter content, promotes microbial activity, increases moisture holding capacity, and improves tilth. If hay or seed is removed from the legumes after the bud stage and only the roots and stubble worked into the soil, alfalfa and red clover add proportionately more dry matter and nitrogen than does sweetclover.

Experienced farmers agree that both sweetclover and alfalfa make good green manure crops. Although herbicides can be used safely to control many broadleaved weeds in seedling stands of alfalfa, they are not recommended in sweetclover. While alfalfa stubble supplies more nitrogen and organic matter than does sweetclover, it is usually more difficult to kill in a plow-down operation.

In addition to providing a good source of feed for ruminant livestock, grass crops help to prevent erosion by building up soil organic matter content. In a 3-year period, bromegrass, crested wheatgrass, intermediate wheatgrass or Russian wild rye contribute about 6 tonnes of root fibre per ha in the top 25 cm of soil.

BREAKING GRASS SOD FOR CEREAL AND OILSEED CROP PRODUCTION

Research on working up bromegrass and intermediate wheatgrass sods, revealed that methods of breaking tested, produced about the same clod structure. Moldboard plowing produced the highest crop yields and retained the least amount of root fiber in the surface soil on both grass sods (Tables 40 and 41).

Table 41. Wheat Yields (kg/ha)

Method of breaking and length of fallow	1st Crop After Breaking			Total of 1st Two Crops After Breaking		
	Brome-grass	Intermediate wheatgrass	Average	Brome-grass	Intermediate wheatgrass	Average
Full Fallow						
Plow	2318	2385	2351	3825	3881	3853
Discer	2228	2070	2149	3735	3420	3578
Cultivate and spike	3194	2126	2160	3791	3566	3679
Rotary cultivator	2138	2036	2087	3701	3488	3594
Partial Fallow						
Plow	1969	1969	1969	3431	3296	3364
Cultivate and spike	1980	1688	1834	3319	3139	3229
Rotary cultivator	1890	1676	1783	3263	3083	3173
Average full fallow	2216	2160	2188	3769	3589	3679
Average partial fallow	1946	1778	1862	3341	3173	3257

Source: K.E. Bowren

Table 40. Condition of Surface Soil (0-3 cm) After Breaking Grass

Method of breaking & length of fallow	Amount of Root Fiber (kg/ha)			Dry Aggregates, % Under 0.84 mm			Water-stable Aggregates, % Over 210 microns		
	Brome-grass	Intermediate wheatgrass	Average	Brome-grass-	Intermediate wheatgrass	Average	Brome-grass	Intermediate wheatgrass	Average
Full Fallow									
Plow	295	941	618	46	45	46	26	27	27
Discer	707	1092	900	45	45	45	30	30	30
Cultivate and spike	912	1425	1169	45	46	46	23	31	27
Rotary cultivator	567	998	783	47	48	48	28	32	30
Partial Fallow									
Plow	597	989	793	53	53	53	27	30	29
Cultivate and spike	1629	1285	1457	50	55	53	33	37	35
Rotary cultivator	1079	1427	1253	51	52	52	31	33	32
Average full fallow	551	1114	867	46	46	46	27	30	29
Average partial fallow	979	1233	1168	51	53	53	30	33	32

Source: K.E. Bowren

Full fallow treatments were broken on August 15 and summerfallowed until seeding 22 months later. Partial fallow treatments were broken on July 10, after the hay was harvested, and fallowed until the next spring, then seeded. The partial fallow treatments produced, on the average, 422 kg/ha less grain in the first two crops after breaking.

In the above table, note that root fiber and water-stable aggregates in the surface soil were greater at the end of the partial fallow than the full fallow. The partial fallow produced more grain (about 1.5 tonnes) than the full fallow. However, since two crops were grown on the partial fallow (total average 3257 kg/ha) in the same period as one on the year long fallow (average 2188 kg/ha). At the end of both periods, the area which had been in bromegrass had less root material in the surface soil than that in intermediate wheatgrass. This difference was greater after full fallow than partial fallow, indicating that the bromegrass sod decomposed faster.

With grasses like crested wheatgrass and Russian wild ryegrass, which have a bunchgrass root system, more time and tillage are required to break down the sod and prepare a seedbed than with bromegrass or intermediate wheatgrass in a partial fallow system.

Flax and oats are good crops to grow on a bromegrass-alfalfa sod fallow. Table 42 shows the yields (10 year average) of various crops tested at Melfort.

Table 42. Crop Yields on Sod (kg/ha)

	Check	Fertilized*	Average
Flax	1051	1078	1064
Wheat	1574	1771	1673
Oats	2468	2655	2562
Barley	2052	2390	2221
Argentine-type canola	965	1169	1068
Polish-type canola	892	1064	979

*Fertilizer supplied 34 kg nitrogen and 34 kg P_2O_5/ha.

Source: K.E. Bowren

Note that fertilizer substantially increased yields of all crops except falx. Soil tests should be used to determine nutrient requirements as these vary, depending on the management and fertility program and the amount of legume in the sward. If soil test information is not available, the fertilizer required for stubble crops on the same farm should be used as a basis for determining what should be added to sod fallow.

Tables 43 and 44 give 3 year average data for soil analysis of sod fallows and of annual crop yields following grass sods. The annual crops were fertilized at two levels of nitrogen.

Table 43. Soil Analysis of Sod Fallow

	Russian wild ryegrass	Crested wheatgrass	Bromegrass
Ease of breaking and preparing a seedbed	difficult	medium	fairly easy
Soil test data, fall after breaking			
- NO_3 (0-60 cm), kg/ha	151	83	117
- P (0-15 cm), kg/ha	18	17	21
Soil moisture total (0-122 cm), cm			
- at breaking time* (July)	28.2	31.0	31.8
- fall after breaking* (late October)	40.4	42.2	42.9
- spring at seeding time	37.3	40.1	43.7
Surface soil particles less than 0.84 mm, %			
- fall after breaking*	50	47	43
- spring at seeding time*	48	51	49

*2 year average only.

Source: K.E. Bowren

Table 44. Crop Yields on Sod Fallow with Two Levels of Nitrogen, Both in Combination with 34 kg P_2O_5/ha (kg/ha)

Crop	N level* (kg/ha)	Russian wild ryegrass	Crested wheatgrass	Bromegrass
Wheat	8	2696	2414	2751
	45	2734	2834	2864
Oats	8	3362	3446	3961
	45	3600	3599	4105
Barley	8	2844	3000	3005
	45	2851	2940	3111
Flax	8	1379	1566	1665
	45	1573	1553	1698
Target rape	8	1935	2229	2095
	45	1974	2328	2213
Echo rape	8	1622	1650	1520
	45	1526	1631	1572

*Fertilizer: 11-48-0 at 71 kg with the seed alone (8 and 34), plus 113 kg of 33.5-0-0 (45-34).

Source: K.E. Bowren

Because all the sod had a fairly high nitrate nitrogen content to begin with, the additional nitrogen in the (45-34) fertilizer treatment did not consistently affect the yield and often resulted in a reduction in the bushel weight of the grain. The high nitrogen content of the grass sod was due partly to the use of a nitrogen fertilizer (about 68 kg N/ha) for several years before breaking.

A well-worked, firm seedbed into which seeds can be placed at a shallow, uniform depth is very important, especially when seeding canola, flax or barley and may be difficult to obtain from sod fallowed for only 6 months. Also, weed control with herbicides may be more difficult in canola, than in cereal crops.

ANNUAL CROPS FOR FORAGE

Annual crops provide a major source of fodder for livestock production, whether in the form of pasture, silage, hay (greenfeed), soilage (zero grazing) or straw. When annual crops are damaged by hail, frost, drought or during a feed shortage, most can be salvaged as forage and in some cases can be more valuable as fodder than grain, for example Canola.

Perennial crops do not require cultivation and seeding operations each year. In the Parkland of Western Canada, on the black and gray wooded soils, growing conditions are quite different from those in the Southern Prairies and Eastern Canada. A short cool season with insufficient heat units for corn, is typical of this area, and only adapted species and varieties should be grown.

SILAGE CROPS

Oats is usually the most productive silage crop in the Parkland, with yields averaging 8100 kg/ha dry matter, but average protein content of 8.0%, is lower than some of the other cereal crops. The highest yielding variety is Foothill followed by Laurent, Frazer, Grizzly and Harmon in descending order. The more recently released varieties have not been tested for their forage yield.

Barley is the most commonly used silage crop in the Parkland, probably due to producer familiarity, availability of seed and the choice of a grain or silage crop. It is a satisfactory yielder, 6200 kg/ha dry matter, and contains the highest protein (9.3%) of the cereal crops. Johnston is the highest yielding variety, followed by Empress and Klages.

Wheat is as productive as barley, 6200 kg/ha, with a lower protein content at 8.9%. Glenlea and Pitic are good yielding varieties in the Parkland.

Spring rye is a low yielding crop, 5900 kg/ha, with a low protein content (7.5%), and should not be used for silage production. Its only advantage is that even under extreme drought it grows tall enough to harvest.

Triticale, a cross between wheat and rye, is a better silage producer than either wheat or rye (6600 kg/ha @ 8.4% protein). Triwell and Carman are high yielding varieties. Newer varieties have not been sufficiently tested.

Sunflowers are extremely variable in yield and this feature cannot yet be related to any climatic factor. The average yield is 7200 kg/ha, with 10% protein, but some years they yield less than half that of oats. Special equipment is required to harvest sunflowers due to their height and large stem diameter, so they are are rarely used as a silage crop.

Corn is not particularly productive is the Parkland, (5500 kg/ha at 10% protein), due to a cool season and low heat units.

Faba beans produce more protein per ha than do peas due to their high protein content (17.8% protein). Faba bean yields slightly better than peas on black soils (5000 kg/ha) and about the same on solonetzic and gray wooded soils. Faba beans make highly palatable, nutritious silage. Another advantage of faba beans is their upright growth habit. Outlook, Aladin and Herz Freya are good silage varieties.

Peas yield about the same as faba beans (5100 kg/ha) but have a slightly lower protein content (16.6%). The smaller seed size of peas results in lower seed costs. Tara, Century and Lenca are the better silage varieties.

Other crops, such as proso and foxtail millet, sorghum and sorghum-sudangrass hybrids, soybeans and jerusalem artichoke are not adapted as silage crops in the Aspen Parkland.

MANAGEMENT

When operationally more convenient, cereals for silage production can be seeded somewhat later than for grain production because cereals harvested for silage (except corn) are at a less mature stage than when harvested for grain. Early crops such as barley produce best when seeded in the last week of May. Seeding rates somewhat higher than those recommended for grain production should be used since thin stands affect yields more adversely with silage than with grain.

Growing legumes (peas, sweetclover, etc.) in combination with cereals such as oats and barley, will not increase overall yields over the average of the two crops separately but will increase the protein content (and perhaps palatability) compared to the straight cereal silage.

Delaying harvest time can reduce both quality and yield. During the growing season, yield increases until the soft dough stage, then the energy used to fill the seed is greater than that being produced by the plant, and yield declines. The percentage protein decreases through the growing season because the amount of stem increases in proportion to leaves. However, yield of protein per ha increases until the soft dough stage. Protein content can be increased by harvesting earlier but yield of forage is lower.

PASTURE

Oats is commonly used as pasture since it produces more regrowth than other spring cereals, which produce a large amount of growth in the spring and very little later. Spring seeded winter crops such as winter wheat, fall rye, winter triticale and Italian ryegrass are slow to start but heavy producers during mid and late summer. When planted in the spring, these winter crops do not produce heads and continue to grow until late in the fall, responding like perennial pastures to rotational grazing. A considerable amount of pasture can be produced by seeding a mixture of spring and winter crops, harvesting an early silage crop, then grazing the regrowth until late fall.

Forage rape, and kales are highly productive if not grazed until late fall. Animals should only be allowed access to small portions of the field to avoid waste. These crops cannot be efficiently harvested as silage due to their late maturity and high moisture content. The kale variety, Maris Kestrel, is recommended for use in Canada.

HAY

Most annual crops harvested as whole plant material for livestock feed, are used either for pasture or silage. Some can be put up as hay if required. Oats is the most common cereal put up as hay. Peas, faba beans, oilseeds, sunflowers and Jerusalem artichokes, are not amenable to putting up as hay due to the physical nature of the plant and/or the difficulty in drying the crop in the swath.

Most of the foregoing material is derived from Alberta and Saskatchewan sources. Table 45 summarizes typical yields of annual crops grown in Manitoba and Table 46 provides a summary of various management practices involved in the production of annual crops in Manitoba.

Table 45. Typical Yields and Composition of Several Annual Crops Grown in Manitoba for Fodder*

Crop	Dry Matter (kg/ha)	Total Digestible Nutrients (%)	Crude Protein (%)
Barley	5000-6000	58-63	10
Corn	5800-7300	62	12
Fababeans	2480	50-63	15-18
Fall rye	1500	62	22
Foxtail millet	4030	57	9
Italian ryegrass	4600-4900	54-59	11-13
Jerusalem artichoke	6170	--	--
Oats	5600-9800	52-58	10-11
Peas	5600	56	19
Proso millet	3100-5600	55-58	11-12
Rapeseed	1300-4200	59	15
Siberian millet	6000	56	11
Sorghum	4890	59	11
Sorghum/Sudangrass	3200-5300	52-57	11
Spring rye	5900-6100	52-54	9-10
Sunflowers	1200-2960	57	12
Triticole	5630	45-57	10-13
Western ryegrass	3930	57	17
Wheat	2600-6200	53-63	11-12

*Yields and composition are, of course, subject to wide variations in growing conditions, stage when harvested, and harvesting and storage methods.

Table 46. Summary of Agronomic Practices Involved in the Production of Annual Crops in Manitoba

Crops	Optimum Seeding Date	Seeding Deadline Dates	Seeding Rate kg/ha	Seeding Depth cm	Days to Emergence	Days to Maturity	Stage to Harvest or Glaze
Oats	May 1 to June 20	Early Fall June 20	90 - 115	4 - 7	10	100 - 103	Graze at mild to early dough stage 20-30 cm
Barley	May 1 to May 31	June 20	90 - 120	4 - 5	8	84 - 90	Early dough
Wheat	May 1 to May 31	June 20	100 - 135	3 - 8	10	99 - 105	Mid dough
Triticale	April 15 to May 15	June 1	110 - 150	5	10	104 - 108	Early dough
Spring Rye	May 1 to May 31	June 20	45 - 95	2.5 - 5	12	80	Early dough
Fall Rye	Aug. 25 to Sept. 15	Sept. 15	45 - 95	2.5 - 5	10	88 - 104	Graze 15 cm silage early dough
Corn	May 1 to May 25	June 10	55000-70000 plants/ha	2.5 - 5	5 - 10	100 - 115	65-70% H_2O WP
Peas	May 1 to May 25	June 10	130 - 200	5 - 8	8	89 - 93	
Foxtail Millet	May 25 to July 10	July 15	20 - 25	1 - 2.5	10	60 - 90	Heading
Proso Millet	May 15 to July 10	July 15	25 - 35	1 - 2.5	10	85 - 90	
Sorghum	May 15 to June 1	June 5	6 - 8	2.5 - 3.5	10		Mid dough
Sorghum Sudan Hybrids	May 25 to June 16	July 5	20 - 30	1 - 2.5	10		Graze 60 - 75 cm
Fababeans	April 25 to May 15	May 25	135 - 180	5 - 10	10	102 - 112	10-20% pods black WP 35-45% moisture
Sunflowers	May 1 to June 5	June 10	40000-50000 plants/ha	8 - 10	12	110 - 120	
Ryegrass (Italian)	April 10 to June 1	June 5	20	less 2	6 - 10	40 - 60	Early flowering
Ryegrass (Westerwold)	April 10 to June 1	June 5	20	less 2	6 - 10	40 - 60	
Argentine Rape	May 5 to May 30	June 10	5 - 8	1.5 - 4	5 - 8	90 - 100	
Polish Rape	May 5 to June 15	June 25	5 - 7	1.5 - 4	5 - 8	75 - 85	
Pasture Rape	May 15 to June 10	June 15	6	1.5 - 3.5	7		
Fodder Beets	May 1 to June 5	June 10	6-7 monogerm 2-15 multigerm	2 - 4	7		Oct. - Nov.
Red Clover	May 1 to June 10	June 15	7	1 - 2.5	7		
Sweet Clover	May 1 to June 10	June 15	11	1 - 2.5	7		E. bloom or bud stage

Yields of selected perennial and annual crops at Brandon are summarized in Table 47.

Table 47. Performance of Forage Crops at Brandon

	Yield kg/ha Long Term	Years
Alfalfa	5092	27
Bromegrass		
- check	3600	26
- fertilized	5954	11
- seed	210	13
Corn		
- grain	3324	26
- silage	7320	30
Fescue		
- hay	1870	8
- seed	24	2
Hay		
- grass + legumes	4028	28
Oats	9766	5
Pasture		
- clipping	3801	27
- grazing*	189	19
Rapeseed	1276	25
Russian wild ryegrass		
- check	3417	12
- fertilized	3930	5
Sunflowers	1160	17
Sweetclover		
- hay	4433	18
- seed	191	10
Timothy	1616	4
Trefoil (Birdsfoot)	3736	3
Wheatgrass - Crested		
- check	3678	15
- fertilized	5555	5
Wheatgrass - Intermediate		
- check	4511	21
- fertilized	6261	5
- seed	419	2
Wheatgrass - slender	3470	9
- tall	4491	4

*Animal Unit Days per Hectare

Source: A.T.H. Gross, Brandon Research Station

KOCHIA

Kochia is a fast growing annual that is well adapted to dry, saline soils and prefers hot weather. It is tap rooted, but will produce shallow roots under moist conditions. At Melfort it has produced yields of 2.6 and 7.2 tonnnes of dry matter per hectare for early and late cuts, respectively. If cut before becoming too tall or stems becoming too coarse (usually at a height of 1 meter in the Aspen Parkbelt) it can contain 12% crude protein and 60-61% digestible dry matter. However, it has a high mineral content, making it unsuitable when fed at over 50% of the ration for ruminants. It has been suggested that kochia might be grown along with another saline-tolerant crop to produce a more acceptable feed. However, if the "other" crop produces well, there is no point is growing the kochia. Alternating loads of kochia with another crop (sweetclover or barley), when making silage would likely provide a more acceptable feed for ruminants.

Because of its reputation as a weed, it is suggested that seed be obtained from the southern U.S. (Texas or New Mexico). This strain will not set seed under conditions in the Aspen Parkland. It should be sown (broadcast) at the rate of 4-8 kg/ha (heavier rates encourage finer-stemmed, more palatable feed) in October, and lightly harrowed in.

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