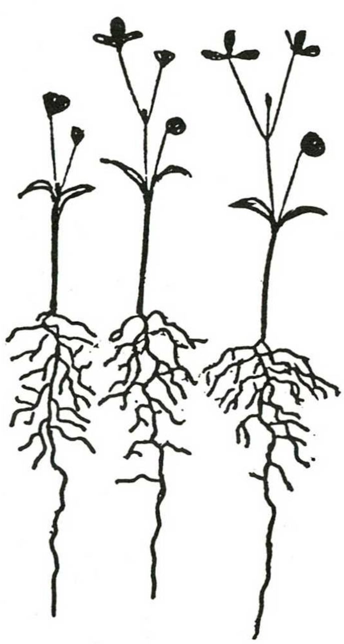
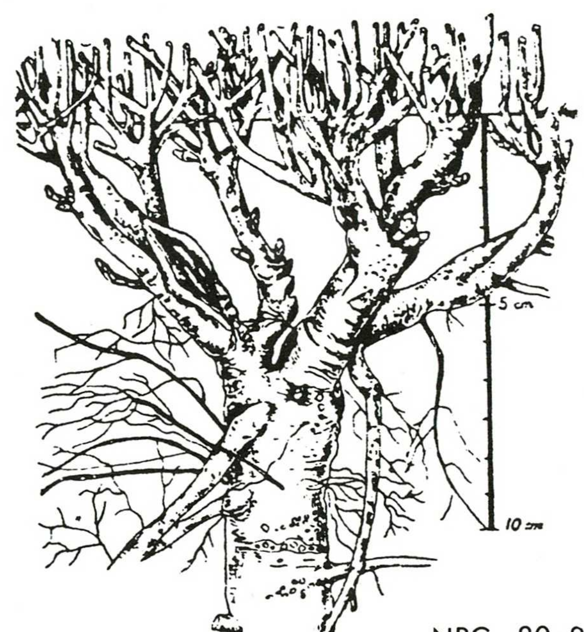
ALFALFA PRODUCTION

IN THE

PEACE RIVER REGION





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PREFACE

The first bulletin on "Alfalfa Production in the Peace River Region" was published in March, 1976. It was so well received that it was soon out of print. In the present revised edition much of the information has been updated with new research information. We have included a section by extension specialists to more clearly define some of the problems and concerns in specific areas of the Peace River Region. A section outlining the locations and titles of Agriculture Canada's alfalfa research plots in Northern Alberta and British Columbia has been included at the request of many producers.

J.S. McKenzie
Bulletin Coordinator
February, 1980

Acknowledgements

We acknowledge the B.C. Ministry of Agriculture for permission to include the Pest Control Notes supplement on "Verticillium Wilt of Alfalfa".

The Agriculture Canada Research Station at Beaverlodge, Alberta gratefully acknowledges Alberta Agriculture and the B.C. Ministry of Agriculture for their financial support during the course of some of the studies reported in this bulletin.

ALFALFA PRODUCTION IN THE PEACE RIVER REGION

Prepared by Representatives of
Agriculture Canada, Research Station, Beaverlodge
Alberta Agriculture and
British Columbia Ministry of Agriculture

C O N T E N T S

Agriculture Canada
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INTRODUCTION

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The entire agricultural land base in the Peace River region has developed within the Peace River drainage basin and within close proximity to the river itself. Because of the variety of major modifying factors in soil development we have considerable variation in soils in this region within very short distances.

In this brief 50-60 year span of agriculture from infancy to it's present state the experiences of producers themselves have to a certain extent sorted out the various soils capabilities and the adapted crops have become reasonably specific to soil suitability and capability. As a consequence alfalfa acreages which peeked in the 1940's had declined fairly steadily up to the early 1970's as the production difficulties became apparent.

With the introduction of the alfalfa dehydration industry to Alberta and the Peace, in a fairly major way, again alfalfa production came into some prominence and for a different use.

The nature of the dehydration industry places an onus for production in close proximity to the plant itself to maximize processing efficiency and on the producer to maximize yields if alfalfa production is to become a profitable alternative on his farm.

Neither of these two goals can be achieved unless some of the major limitations of soil and/or production practices are altered to include the use of the latest technologies respecting soils and alfalfa production.

It is the hope of all those that have had input into this publication that producers, extension people, and industry will find it serves them well in extending the present technology to them.

CONCERNS FOR ALFALFA PRODUCTION IN THE ALBERTA PEACE RIVER REGION

A) CONCERNS FROM FALHER

H. Goudreau, District Agriculturist
Alberta Agriculture, Falher

Over the years, alfalfa production in the M.D. of Smoky River #130 has had its ups and downs. With diminishing livestock numbers and increased use of other legumes such as clover, the importance of alfalfa declined till a few years ago when the pelletizing industry was introduced into the area. This industry being dependent strictly on alfalfa renewed the producers interest in this legume.

Along with this renewal emerged many problems associated with the industry, some of which to my knowledge and to the producers knowledge, have been identified. Yet, other problems appear to be involved but have not been fully exposed.

As studies are made, it appears that the success of alfalfa production involves and will continue to involve the solving and proper management of a series of problems rather than any individual one.

To be more specific there appears to be a series of questions related to stand establishment, soil related problems following establishment, and others on maintenance and longevity of a proper stand.

It is my feeling that individual producers will have to overcome more than one uncertainty (ie., acidity, weeds, insects, diseases, varieties, time of seeding and cutting, rates of seeding and fertilizing, drainage, etc.) before they will be satisfied with their yield. If alfalfa as a crop is to survive, it is imperative that overall management change rapidly to keep pace with the introduction of new information.

Alfalfa like many legumes grown in this region is needed in our crop rotations, but unless it is economically feasible to grow it, it will be replaced by legumes that are not necessarily cheaper to grow, or yielding higher monetary returns, but easier to manage and guaranteed to survive.

B) CONCERNS FROM EAGLESHAM

Dale Seward, District Agriculturist
Alberta Agriculture, Eaglesham

The major concern of the Wanham Alfalfa Dehydration Plant is weeds. Broadleaf and grassy weeds account for up to 20% of the vegetation in certain fields thus reducing quality of dehy products.

Soil characteristics may cause problems. Heavy clay soils that are improperly drained may become super saturated and put stress on alfalfa plants. We have an insignificant amount of acid soils.

Commercial seed quality has also been an area of concern. However, most producers are returning to the use of certified seed. Higher yields and better returns from the use of high quality seed offsets the higher initial cost.

Producers have some questions as to quality of seed innoculant for alfalfa.

An overall summary - There is no major problem that limits production of good quality alfalfa in I.D. #19.

C) CONCERNS FROM PEACE RIVER

J. Reid and F. de Mille, District Agriculturists
Alberta Agriculture, Peace River

Alfalfa is not a major crop in our district, due to limited livestock feed requirements, and dehydration opportunities. Many grain farmers grow other forages, especially, alsike and red clover which fit their crop rotations better, are cheaper to sow, and consistently produce seed for sale.

The alfalfa that we do see is generally poorly nodulated. This comes from poor innoculant being sold to area farmers and poor innoculation practices by the farmers. As we've learned more about innoculation, this situation has improved. Farmers must be aware of the most up-to-date information available about innoculant choice, care and handling to have successful alfalfa growth. There is also a lot of leaf disease causing the lower leaves to fall off and I would hope that the pathologists give us some in-sight into this problem.

There is considerable interest in this district for alfalfa seed production using leafcutter bees. With a potential as a minor industry in the area, the next 10 years will see this practice tested here commercially. Specialized information detailing seed production rather than forage production will be required. Grimm continues to be the most popular variety in the area.

D) CONCERNS FROM GRANDE PRAIRIE FOR GRAZING ALFALFA

Dave Thompson* District Agriculturist
Alberta Agriculture, Grande Prairie

The successful grazing program is hinged on good conditions for the pasture to produce, livestock requirements for food, and the farmer's ability to combine these conflicting requirements.

Grazing alfalfa has not been a popular alternative with many livestock producers. The combination of bloat risk, winterkill, and poor stands have limited the acceptance of alfalfa on many farms. These problems can be minimized with careful management. The main requirement for good grazing management has always been rotation. This applies to all pastures, not just alfalfa. One should try to keep the major limitations of each pasture in mind when organizing the grazing rotation. Alfalfa has specific requirements for good growth. They are:

1. Good stand establishment.
2. Not using regrowth from approximately August 15 until after the killing frost.
3. Avoiding grazing under soft soil conditions which can cause damage to the crowns.
4. Good soil fertility with regard to phosphorus and sulphur and possibly nitrogen after the early grazing season.

One seldom combines all of these just the way they should for any number of reasons: however, if rotations are planned with these in mind, we should be able to greatly surpass the yields we expected from continuously grazed, unfertilized stands.

Establishing a good stand is a delicate undertaking. The recommended seeding rate would be about 2 pounds of alfalfa with from 4 - 8 pounds of a suitable grass (brome, timothy, creeping red fescue, etc.). This may be seeded alone or with a cover crop, often a cereal such as oats or barley. The key is to choose a crop which will be harvested as early as possible to permit the forages to establish during the late summer. Given good moisture and an early harvested nurse crop, the growth is usually good.

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The least harmful periods for grazing alfalfa are mid-summer and late fall. The rotation should include other grasses and legumes to allow the producer sufficient flexibility to avoid spring and late summer grazing of alfalfa. Another consideration for the Peace region is trying to avoid grazing when the soil is very soft. Trampling of the alfalfa crown leads to injury related diseases and a gradual thinning of the stand.

Fertilizing of alfalfa is a controversial subject. The response of stands to nitrogen, phosphorus and sulphur has been positive when these nutrients are lacking. As a rule, we should probably consider two broadcast applications of a nitrogen-phosphorus fertilizer such as 39-11-0 in early spring and again after the mid-summer grazing. Sulphur should be added as determined by soil test.

Bloat is always a threat to cattle and sheep. The accepted practice is to try to maintain one-half the stand in legumes and the balance in grasses. If the alfalfa dominates, one should increase the growth of the grass. Very often, we find that the grasses dominate and the alfalfa is crowded out. We can reduce this with judicious grazing of the alfalfa stand during the sensitive fall period. There is no way of entirely ruling out bloat, but the incidence of bloat on 50-50 grass legume pasture is low.

A good deal remains to be done in developing bloat-free alfalfas, in working out good cultural practices and in the area of grazing management. This will take time and further research.

ALFALFA PRODUCTION IN THE B.C. PEACE RIVER REGION

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Alfalfa has been produced in the B.C. Peace River Region for many years. It is grown primarily for hay and pasture use, and more recently, for processing into alfalfa pellets. Seed production has not been a popular practice.

Farmers recognize alfalfa for its high nutritive value and ability to improve the fertility status of soil. It is used as a hay crop, either grown alone or with grasses. However, its use for pasture is less popular due to the danger of bloat. In view of the excellent soil-building properties of alfalfa, many grain and oilseed producers include it in their cropping programs.

Alfalfa seed production has not been a popular cropping practice. Leaf-cutter beekeeping can be very expensive and time-consuming, and in view of the problem of winter-kill in crop stands, many growers are of the opinion that seed production is too risky.

Alfalfa growers continue to face numerous production problems. The most serious problem is winter-kill, a phenomenon influenced by many factors. Crop losses have been extensive even in well-managed stands. However, on-going research work has helped many growers to better understand and overcome this major problem.

Although it is not a serious problem, stand establishment is often difficult. Inadequate seedbed preparation, competition from weeds and low soil fertility status are contributing factors. However, improved management practices have resulted in the establishment of some very high yielding stands.

Another problem of more serious consequence over the long-term is the fact that a considerable acreage of B.C. Peace River soils are relatively acidic (pH 5.0 - pH 6.0), resulting in reduced crop performance and yield. This problem will be overcome as acid-tolerant varieties of alfalfa are developed and the practice of liming acid soils becomes economical.

Of major concern to alfalfa growers is a disease known as "Verticillium wilt." A survey completed in 1979 by John Yorston, Plant Pathologist, B.C. Ministry of Agriculture, revealed that this serious disease has established itself as far north as Quesnel, B.C. Diseased plants were not found in the Peace River Region. However, the disease is spread through infected seed lots; consequently it may be only a matter of time before the disease infects local alfalfa stands.

Full cooperation is required from growers, seed suppliers and Federal and Provincial Agriculture agencies to ensure that this disease does not become established in this area.

The potential for alfalfa production is excellent in the Peace River Region. Continued research work coupled with sound crop management practices will result in increased production and use of this important legume crop, and will help ensure a supply of high quality product to support the local dehydration industry.

SOILS AND NUTRIENT REQUIREMENTS FOR THE PRODUCTION OF ALFALFA IN THE PEACE RIVER REGION

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Research Station, Beaverlodge, Alta.

Soils:

Peace River region soils are extremely variable in kind of deposition (parent material), texture, color, profile development (soil structure), pH (soil reaction) and many other characteristics. The large relatively flat low lying areas are former laking basins usually clay loam to clay textured. These lacustrine (lake laid) or alluvial (flood plain) soils are generally high in organic matter Dark Gray or Black (Chernozemic) and slightly to moderately calcareous. Some of these lacustrine areas are very low in organic matter, classified as Gray Wooded or Luvisolic soils. Severely restricted drainage from depressional areas can result in accumulations of sedge or moss peat, organic soils.

From the lacustrine flats the land rises to the higher generally coarser textured glacial till soils on ridges or hills. These may also vary from Chernozemic types to the low organic Luvisolic soils. These soils are generally more deeply leached, may be slightly calcareous to acidic in reaction, and have varying amounts of stones.

Most of the Peace River region is underlain by saline sandstone bedrock. This is usually thinly covered with glacial till materials but may in some areas like the Kleskun Hills, or around Valleyview be at or very near the surface. This results in very tough, poorly structured high sodium soils. These may have a very high pH if the surface salt concentration is high but may also be acidic in the cultivated topsoil layer.

There are also extensive areas of wind and water deposited (aeolian and alluvial) soils sandy to silt loam textured. These sandy dune or barcane soils and the humpy silt textured soils are found adjacent to the major river channels, notably on the Wapiti, Smoky, and Peace River. These soils are usually fairly high in lime ($CaCO_3$) and may in some cases have free lime at the surface.

There are many other variations like the gravelly very coarse textured beaches of former laking basins and water deposited sands and silts on slopes over clay textured soils. There are localized salt accumulation or saline seep areas associated with outcroppings of saline sandstone bedrock. In contrast there are also strongly acidic soils formed on deeply leached, coarse textured low calcium glacial till or on acidic shale materials.

Adaptability for Alfalfa:

Alfalfa is very widely grown in the Peace River region of Alberta and British Columbia. Specific conditions or soil types are, however, required for best growth.

The following statements regarding adaptation of alfalfa are from the bulletin 'Alfalfa in Canada' (Heinrichs, 1969).

1. Alfalfa is particularly well adapted to soils that have a high lime content or soils that are nearly neutral.

2. Alfalfa requires well-drained soils and does not tolerate a water-logged surface for more than two weeks.

3. Alfalfa does very well on soils with a high water table, into which the roots penetrate and obtain water during periods of drought. A water table 10 to 15 feet below the surface can be readily reached by its roots.

4. In regions where moisture is deficient, alfalfa responds well to irrigation and produces yields of four tons or more of dry matter per acre.

Research in the Peace River region and elsewhere has adequately demonstrated that alfalfa grows best at a pH of 6.1 and higher (Hoyt et al 1967 and 1974). It is estimated that 31% of the cultivated soils in the region are below pH 6.1 and require lime for best growth of alfalfa. On acidic soils, liming, good fertility, and specific inoculants will stimulate nodule bacteria to fix adequate amounts of N and thus increase or enhance alfalfa growth.

Soil pH Profiles: Figure 1 shows the changes in pH of the various depth layers of some soil types. From left to right the topsoil 6 inch plow layer is progressively more acid. In all profiles one or more subsoil layer is more strongly acid than the topsoil. This is usually above the lime or lime and salt accumulation layer. All but the very strongly acid soils have this visual lime accumulation layer in the top three feet and seldom deeper than four feet. The more calcareous as well as the fine textured clay soils usually have this high pH layer at shallower depths.

All but one profile in Table 1, the Notikewin Dark Gray and Black solonetz, are Gray Wooded (Luvisol) soils. About 49% of the soils in the Peace River region are Gray Wooded compared to 9% Dark Gray and Black. The Dark Gray and Black soils have higher organic matter content in the surface layers, have less leaching, and generally are not as strongly acid in the subsoil as the Gray Wooded counterparts. Surface horizons however, may be similar in soil reaction but the high organic matter may "buffer" the deleterious effect of low pH and/or high soluble aluminum.

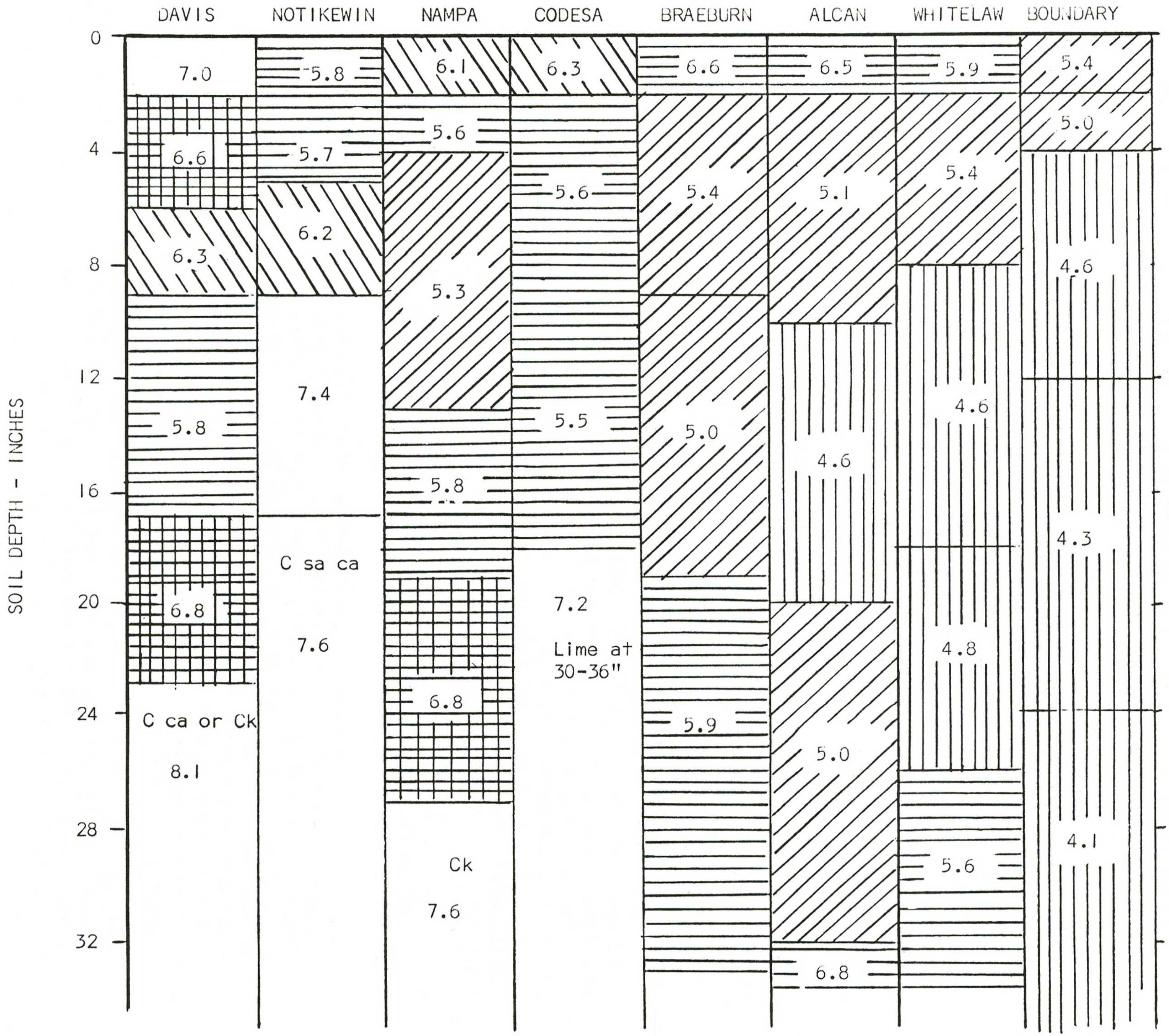

Fig. 1. Soil pH profile - some representative types.

The Davis series on the left, a moderately calcareous silt loam is considered a very good alfalfa soil. It is near neutral to slightly basic in reaction, and medium textured with good moisture and root penetration. In some regions this soil may have a high water table. Points 1 to 3 under adaptation are thus met for the production of alfalfa. Similarly well adapted for alfalfa would be the Kathleen, Judah, Tangent, Culp and Leith Gray Wooded and Dark Gray Wooded soils on moderately to strongly calcareous silty clays, silt loam and sandy loam soils. Some of these do not have any part of the profile lower than pH 6.0 and may have the calcareous layer (pH 7.0) at or very near the surface. However, these soils are found on gently rolling topography and may be in association with clay soils in depressions which can cause "drowning out" of alfalfa.

The Notikewin Dark Gray - Black solonetz representative of the Valleyview, Debolt, Kavanagh and Kleskun soil types has a strongly to moderately acid top soil and a saline subsoil at depths of 2 to 10 inches below the surface. Here the high pH, usually $>$ 7.0 may be due to high Na rather than Ca and these soils are droughty, the subsoil obstructs root and moisture penetration and the topsoil generally is too acid for good alfalfa growth. Droughtiness and restriction of alfalfa root penetration on solonetz soils was shown by lime and fertilizer tests on the Kleskun soil series at Heart Valley (1970-75). Without fertilizer the average yield was less than 3/4 ton alfalfa hay per acre per cut. With fertilizer the yield was increased to nearly one ton/ac and with lime and fertilizer the yield was over one ton/ac/cut (lime at 2 1/2 tons per ac $CaOH_2$ applied June 30, 1969). In every year there was a pronounced "border" effect in all treatments as a result of a cultivated (bare fallow) strip around the test plot area. This amounted to double the growth in some cases indicating the high requirement for moisture, and/or the extra N that may have been released by the cultivation of the border.

The Nampa clay loam to clay soil is representative of a large area of lacustrine and lacustro-till soils. Occurring on nearly level to gently sloping topography these soils usually have fair surface drainage but the subsoil at times restricts moisture and possibly also root penetration. The surface layers may be only slightly acid but the subsoil layers are strongly acid usually to a depth of 18 to 30 inches before the lime layer is reached. This pH profile is fairly characteristic of a large group of soils, such as the Donnelly and Cadotte series as well as the Dark Gray and Black soil types found on the same lacustrine and lacustro-till parent materials.

The Codesa group (sandy materials overlying fine clay materials) is well suited from the standpoint of surface texture and drainage but also has low pH layers in the top 12 to 14" of soil. (The Black and Dark Gray counterparts Peoria and Belloy may not be as strongly acid as the Codesa series.)

Soils developed on glacial till parent materials are usually more strongly acidic in the subsoil although the top soil may be only slightly acid. In the Braeburn series depth to the lime accumulation layer is usually greater than in the Nampa soil and may be at 4 ft or more in the Alcan or the Dixonville till.

The Whitelaw loam and clay loam - another acid soil is representative of stoney, gravelly till soils (glacio-fluvial materials). Besides being stoney, and quite likely droughty (excessively drained), these soils are usually very strongly acid to 4 or more feet.

The Boundary complex, on residual and modified residual medium textured acid shales and weathered sandstone is also very strongly acid throughout the profile. Alfalfa, however, responds to the application of lime incorporated into the top 6 inches.

Because alfalfa does not tolerate a waterlogged surface for more than two weeks, a medium to coarse textured soil or adequate surface drainage is required. Thus, the coarser textured soils, loamy sands to silty clay loams, when moderately to strongly calcareous, are well adapted. The Culp, Heart, Sundance, Groundbirch, Beryl, Codesa, Alluvium, Toad, Lynx, Davis and Kathleen soils meet these requirements. Similarly the Dark Gray and Black soil types on these same aeolian and alluvial parent materials are also well suited for alfalfa. These coarse to medium textured soils accupy between 18 and 20% of the arable acreage in the Peace River region (Upper and Lower Peace River region and the B.C. Block). Some of these coarse textured soils are on gently rolling topography and the clay sub-soil in the depressions restricts moisture penetration or the soil may be frozen at time of spring snow melt. If flooded for over two weeks, alfalfa will be killed out.

Under favourable conditions the tap root of alfalfa will penetrate the soil to a depth of 8 to 10 m or more (Griffith 1974). Thus, alfalfa has the ability to probe deeply into the lower soil horizons for moisture and nutrients, being able to do this more effectively in the friable medium to coarse textured soils. In addition, alfalfa requires enormous quantities of moisture. It is estimated (Griffiths 1974) that it takes approximately 800 g of water to produce 1 g of dry matter. This amounts to about 24 inches of water over an acre to produce 4 tons of alfalfa. In the Peace River region the average annual rainfall is around 18 inches. About 6 inches of water is received as snow, most of which runs off in the spring melt. Thus, at the above rate of production and water consumption there would be a net deficite of between 10-14 inches. In the Peace River region production is generally not as high, moisture use efficiency may be greater, and subsoil reserves may be used. However, lack of moisture is a limitation to the production of alfalfa, particularly on the fine textured soils of sloping land where moisture infiltration is restricted and run-off is accentuated. Under high fertility the amount of water used per ton of dry matter is greatly reduced. A four year irrigation-fertility study in Arizona showed a reduction of from 16.1 cm water/metric ton of alfalfa produced to 10.2 cm of water/metric ton of alfalfa adequately fertilized with phosphorus. This amounts to about 15 inches per 4 tons of alfalfa when adequately fertilized - making the moisture supply of the Peace River region seem much less deficient. Irrigation where feasible from the standpoint of soil types and available water could greatly increase alfalfa yields.

Alfalfa Dehydration Plants

Grimshaw Area: Extremely variable - ranging from highly calcareous to very strongly acid soils. A band 6-12 miles wide of calcareous (high pH) sandy loam to silty clay loam soils (mostly Davis, Tangent, Kathleen and Judah) parallels the Peace and Smoky rivers. (The good alfalfa soil area on the east side of the river is at the present time not readily accessible to the pelleting plant.) Adjacent to the calcareous soils is a narrow band (1-6 miles wide) of somewhat saline tough lacustrine clays, Doig, Cadotte, Grimshaw, Falher, Nampa series and the very tough Solonetzic clays, the Notikewin and Kleskun soil types. The glaciofluvial somewhat gravelly, non-calcareous, loam and clay loam soils, Whitelaw and Berwyn series, are generally fairly acid in the subsoil and comprise a large percentage of the area adjacent to the lacustrine soils. Next to the glacio-fluvial soils are the lacustro-till clay loam to clay, Albright and Hazelmere series. These have a pH profile similar to the Nampa series. The northwest corner of this area is predominantly Alcan, Braeburn and Dixonville series, clay loam and clay till soils. All three may be extremely acid ($pH < 4.5$) in some subsoil layers. The Alcan and Dixonville soil types are usually strongly acidic throughout a four-foot profile. Associated with these till soils are the very strongly to extremely acid Boundary and Josephine soils, formed on grayish coloured weathered shale materials. Reference - Soil Survey of the Grimshaw and Notikewin area Report No. 25 Alberta Soil Survey 1968.

Falher Area: Located in the middle of lacustrine clay loam and clay soils, Falher-Rycroft series, Dark Gray and Black and Falher-Nampa series Dark Gray and Gray Wooded or Luvisolic soils. These soils may be medium to strongly acid in the plough layer and strongly to very strongly acid to a depth of 16 to 20 inches. Lime and salts are usually found at or above this depth. Alfalfa does quite well on these soils once started and the roots get down to the calcareous subsoil. The area is relatively flat and depressional and there may be some problems with seedbed preparation and soil crusting, particularly on the Gray Wooded and Dark Gray soils.

The Judah, Davis and Culp soils to the west, silty clay to sandy loam textures, are best suited for alfalfa. The depressions in the Judah-Nampa soil area probably present some "drowning" out hazards. This might be overcome by a partial levelling or covering of the clay with a layer of silty loam soil. In some areas surface drainage could be considered.

To the north and southeast there are two upland areas, mostly Braeburn till with lacustro-till, Esher and Donnelly soils separating the Falher laking basin from the McLennan laking basin. (Ref: Soil Survey of the Rycroft-Watino Sheet Report No. 15, 1950. Alberta Soil Survey.)

Wanham Area: There is a narrow strip of lacustrine clay soils, Falher-Rycroft series along Highway 49. These are not the best alfalfa soils, but under good management and application of lime where needed, can be quite productive. Silty to sandy, Judah, Davis and Culp soils are predominant in the area to the north and east. Gently rolling to rolling topography with Wanham-Nampa series, Depression podsol and Gray Wooded solod may present some problems. The Birch Hills, Braeburn-Donnelly soils may be somewhat excessively drained and acidic. The Codesa-Donnelly, Belloy-Esher and Landry-Peoria soils on the lower slopes of the Birch Hills are suitable for alfalfa if corrected for low pH. (Ref: Soil Survey Rycroft-Watino Sheets. Report No. 15, 1950. Alberta Soil Survey).

Dawson Creek Area: Surrounding Dawson Creek and to the north the soils are mostly Black and Dark Gray clay loam to clay solods, Rycroft-Falher lacustrine, and Landry-Esher lacustro-till, associated with the Mytron and Murdale till soils. A large portion of the area to the south is comprised of Fellers soil - Bisequa Gray Wooded sandy loam and loams, mostly on steeply sloping and hilly topography at elevations above 3000 feet. This soil is usually strongly to very strongly acid to a depth of over 50 inches. (In this regard similar to the Whitelaw and Boundary soils - pH 5.6 surface soil to 4.2 in the subsoil.) The Codesa, Donnelly and Alcan soils in the area northwest of Dawson Creek could be considered fair alfalfa soils when managed and limed where necessary. The Donnelly soil can be strongly to very strongly acid to a depth of 30 in., while the Alcan may be strongly acid to a depth of six feet. The Sukunka, Devereau, Arras and associated Rolla and Coleman soils on uniform silty lacustrine, moderately and strongly calcareous deposits are found along the Kiskatinaw River. From the standpoint of pH these are good alfalfa soils. The Rolla series, Black Solod as well as the Gray Wooded and Dark Gray types, Sukunka, Devereau and Arras on steep slopes may be excessively drained while the Coleman series, Low Humic Elluviated Gleysol may at time be excessively wet. These soils have a tough subsoil which may be saline. (Ref: Soil Survey of the Peace River area in British Columbia Report No. 8 of the British Columbia Soil Survey, 1965.)

FERTILIZING ALFALFA

Nutrient Content

Alfalfa has a high nutrient content and therefore a high fertility requirement. In "Plant Nutrients Used by Crops" compiled by the Western Canada Fertilizer Association the macronutrient content of 4 tons/ac (9 tonne/ha) of dried alfalfa forage is 240 lb N, 40 lb P_2O_5, 190 lb K_2O and 20 lb sulfur. In the root system there could be another 2 or more tons/ac of dry matter containing upwards of 120 lb N, 20 lb P_2O_5, 95 lb K_2O and 10 lb S. In addition various amounts of the semimacronutrients calcium, magnesium and iron, and the micronutrients boron, copper, zinc, molybdenum, manganese and chlorine would also be contained in the plant material.

Nutrient concentration in legumes is associated with stage of growth. Younger plant tissues generally have a higher concentration of nutrients than older tissue (Griffith 1974). Reid, Post & Jung (1970) found that P, K,Ca, Mg and micronutrient content of red clover and alfalfa declines with maturity.

Chemical composition of alfalfa herbage at four stages of maturity of the spring growth (Smith, 1969).

	Growth Stage			
Constituent	Pre-bud	Mid-bud	1/10 bloom	Full bloom
Ca%	1.48	1.47	1.41	1.28
P %	0.40	0.34	0.28	0.24
K %	2.16	1.61	1.42	1.10
Crude Protein %	26.5	23.3	17.9	15.8
Carotene ppm	228	224	208	105

Total nutrient requirements for a season are increased by (a) harvesting higher annual dry matter yields, and (b) harvesting more than 1 cut of younger plant material which contains a greater concentration of mineral elements. Because alfalfa has an extensive root system surface soil deficiencies may not affect growth. Deficiencies, however, can be corrected with the application of fertilizer containing the deficient nutrients.

Nitrogen (N)

Nitrogen deficient alfalfa will have pale green leaves turning to yellow and stunted growth. Severely deficient plants will lose their leaves, those on the lower part of the plant (the older leaves) dropping first. Fertilizer N is usually not required by established alfalfa. Although the requirement is high, alfalfa generally derives its N from the nitrogen - fixing bacteria associated with its roots. In soils low in available N, fertilizer N may be beneficial for stand establishment. Up to 40 lb NO_3 - N/ac in the topsoil is not considered excessive for establishment of alfalfa. Better initial growth and no adverse effect on nodulation can be expected with this moderate amount of N.

Preliminary testing has shown that the application of N on established stands can result in increased vigour and growth. Time of application of additional N and amounts required will be researched in current fertilizer tests with alfalfa.

Phosphorus (P)

Symptons of P deficiency are not well defined and may be difficult to detect. Stunted plants, retarded rate of growth, spindly plants delayed flowering and a purplish tinge to the edges of leaves are some indicators of this deficiency. The response to P is often most marked during establishment or early growth when the root system is limited. This was shown in two tests with alfalfa on sandy soils in the Fort Vermilion area. In recent tests with established alfalfa on six different soil types in the Peace River region P fertilizer has not significantly increased the yield of forage. Because P fertilizer does not move readily in soil, sufficient P for several years' harvest could be applied and incorporated prior to the seeding of alfalfa. Soil test values which would indicate low P availability for alfalfa and rates required to give economical increases in yield have not yet been worked out. Soils with test values below 20 lb P/acre six inch (15 cm) should show responses or at least improved stand establishment with the addition of phosphorus.

Potassium (K)

Potassium deficiency symptoms are fairly distinctive and appear first in the older leaves. Small white spots develop around the upper margins of the lower leaves and the areas around the spots turn yellowish green to yellow and finally die and turn brown. In severe deficiencies the marginal yellowing may be more pronounced than the spotting. (Coldwell 1943).

Potassium is generally not considered deficient in Peace River region soils. Because of a high requirement for K continued production of high yields of alfalfa, however, could cause deficiencies to develop. Soils most likely to become deficient are those with low organic matter and coarse texture. As with P, soil test values for K indicating deficiencies and rates required to give economical increases in yield are not well known. Soils with less than 200 lb/ac of exchangeable K could be considered low in potassium. Additions of K as potassium chloride 0-0-60 or potassium sulphate 0-0-54 could aid in establishment and longevity if not in increased yields of alfalfa stands. Current tests have not shown increased yields of alfalfa forage from the addition of K.

Sulphur (S)

In S-deficient alfalfa the younger leaves, including the veins turn pale green to yellow with older leaves turning yellow in later stages. The symptoms are similar to a nitrogen deficiency except when N is limiting the older leaves tend to be affected first. Poor nodule development, and a low rate of N fixation are also associated with S deficiency.

Sulphur may be deficient in some Peace River region soils - particularly deeply leached, coarse texture, low organic (Luvisolic) soils. With alfalfa, severe deficiencies have been shown on Braeburn, Demmitt, Sloan, and Hazelmere soil series. With other crops S deficiencies have been shown on other low organic coarse textured, (high lime) soils. Sulphur deficiency may be expected under heavy cropping to alfalfa even where S reserves of the soil are considered adequate for other crops. On soils testing low in S the addition of S increases yield and protein, decreases mortality of young alfalfa and increases winter hardiness. In field tests (1965 - 73) the average increase of alfalfa dry matter was 0.7 tons/ac ranging from 0.2 tons to 2.4 tons/ac. In these tests, phosphorus and potassium alone did not increase yields of alfalfa but P & K or NPK with S gave the highest yield. About 20 lb S per acre are required and this could be applied as a soluble sulphate in sulphur bearing fertilizers or incorporated in the less soluble form of nearly pure S granules. Since pure S has to chemically react before it becomes available to plants it may be feasible to supply several years' requirements in one application.

Boron (B)

In boron deficient alfalfa the leaves near a growing point are yellowed, sometimes reddened. Lateral terminals may also be affected but all the lower leaves remain a healthy green color. (Coldwell 1943).

Usually this gives the crop a yellowed appearance known as "Alfalfa Yellows". Because this symptom is most pronounced during a dry season the yellowing caused by boron deficiency is often attributed to dry weather. In severe deficiencies the plants are stunted by a shortening of the terminal internodes, buds may be deformed or appear as white or light brown dead tissue, and flowers fail to form. Boron is relatively immobile in the plant and the youngest growth generally shows deficiency symptoms first. Low soil pH or high pH (excess lime) both reduce boron availability. A boron deficiency was demonstrated in the greenhouse by Nyborg and Hoyt (1970) but has not been shown in the field in the Peace River region. Boron deficiencies are most likely on coarse textured sandy soils and in fields that have grown alfalfa for a period of years. Applications of 30 to 45 lb of boron per acre or 28 lb boric acid per acre will correct the deficiency.

Calcium and Magnesium (Ca & Mg)

Calcium and magnesium are least available to crops in low pH soils but have not been shown deficient in the Peace River region. Calcium may play a part in cell-wall formation. A deficiency may result in a collapse of the petioles of older leaves and emerging young leaves are small, undeveloped and unfolded and the petioles do not lengthen. Small white dots turning to gray over the entire surface of older leaves with a greyish green color are other symptoms.

Magnesium moves readily within the plant and therefore would show up in older leaves. In severe cases there is an almost complete yellowing of all leaves and a marked reduction in growth.

On acid soils the occasional addition of dolomitic limestone would normally take care of any calcium and mangnesium problems. Sufficient levels in alfalfa prior to bloom (top 7.5 cm of the plant is 1.76 to 3.00% for Ca and 0.31 to 1.00% for Mg. There could be around 200 lb of calcium and 50 lb magnesium in 4 tons of alfalfa dry matter.

Zinc (Zn)

Zinc deficiency is rare - since alfalfa is reported to absorb Zn from soils considered markedly deficient for other crops. There have been no known deficiencies of Zn in Peace River region soils. Zinc is least available in highly calcareous (high pH) soils.

Molybdenum (Mo)

Molybdenum is needed both in the process of N fixation by nodule bacteria and in N assimilation or protein formulation. A deficiency results in symptoms similar to that of N deficiency. When Mo is deficient the N metabolism is altered and legumes are in effect N starved. Amounts in the order of 1 oz of molybdenum oxide per acre are adequate to correct molybdenum deficiency in legumes.

Copper (Cu)

Copper deficient alfalfa plants look very much like those under drought conditions, severely limited growth, folded up and/or withered leaves and excessive shedding. Most commonly deficient on raw peat or muck soils and on highly weathered sandy soils. May also be deficient in high lime or calcareous soils. Deficiency levels may exist in alfalfa if content falls below 10 ppm at 1/10 bloom. To correct a deficiency, apply 10-17 lb/ac of copper sulfate. The rate should be doubled for organic soils.

Iron (Fe)

Chlorosis yellowing due to iron deficiency is not frequently observed in legumes, but may appear on plants growing on calcareous, high pH, soils. Closely related to manganese chlorosis, and iron to manganese ratio is very important (Somers & Shive 1942).

Manganese (Mn)

Would not normally be considered deficient. Deficiencies in some crops appear as a yellowing of the tips or between veins, spreading over entire leaf, but leaving veins prominently green. Like iron, manganese is least available in coarse textured, calcareous (high pH) soils. Manganese sulphate at 50 lb/ac or spraying with a 2% solution of manganese sulphate will correct this deficiency in legumes.

Chlorine (Cl)

Although essential for the life cycle of plants, required only in minute amounts and not considered a problem.

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CROP ROTATIONS: THE ROLE OF LEGUMES

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Inclusion of a legume in cropping rotations has long been recognized as a recommended practice to improve crop productivity. The beneficial effect of legumes is usually associated with the ability of the legume to fix atmospheric nitrogen. Also, it is often suggested that deep-rooted legumes such as sweet clover and alfalfa improve subsoil aeration, moisture infiltration and root penetration by subsequent crops. Research efforts at the Beaverlodge Research Station have been directed towards understanding the effects of legumes on the soil and subsequent crops, with the goal of making the legume a more effective component in the cropping systems.

Do legumes in rotation increase the yield of cereal crops?

Over the years, several field tests have been conducted in the Peace River region to measure the effect of legumes on the production of subsequent cereal crops. The results of these tests are summarized in Table 1. The early work (1934-44 and 1949-54) indicated that replacement of summerfallow with a sweet clover crop provided a slight advantage for wheat production. In tests since 1954, when the yield of barley or wheat following a legume was compared to yield following the respective cereal crop, or fallow following the cereal crop, there was often a substantial yield increase following the legumes. For example, the 7-year total yield increase following several legumes ranged from 2400 to 4100 kg/ha (45 to 76 bu/acre) on a Gray Luvisol soil. The tests also showed that legumes do not always have a positive effect on subsequent grain crops. In two tests there was an overall negative effect from the previous legumes.

Although it is clear that legumes grown in rotation affect the yield of subsequent cereal crops, the cause and the amount of the beneficial effect and why the benefit fails to occur in some soils are not completely understood.

Do deep-rooted legumes improve subsoil permeability?

It has often been suggested that good crops of cereals follow sweet clover and alfalfa because the penetrating tap-roots improve aeration, increase moisture-holding capacity and allow access to nutrients which have been leached into the subsoil. These suggestions are partially supported by experimental data but require further experimental confirmation.

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Table 1. The effect of legumes in rotation on the yield of cereal crops.

Soil	Test date	Test * years	Test crop	Total** yield of test crop - 100 kg/ha (bu/acre): previous crop in rotation — Fallow	Test crop	Alfalfa	Birdsfoot trefoil	Alsike clover	Red clover	Sweet-clover	Brome-alfalfa
Gray luvisol	1934-44	2	wheat	26(38)	-	-	-	-	-	29(43)	-
Black Solod	1949-54	2	wheat	32(48)	27(40)	-	-	-	-	31(47)	-
Gray Luvisol	1955-66	4	wheat	38(57)	-	67(99)	-	-	-	-	58(86)
Gray Luvisol	1967-75	7	barley	-	119(221)	152(282)	150(279)	160(297)	159(296)	143(266)	-
Gray Luvisol	1967-75	3	barley	-	74(138)	66(122)	-	69(129)	61(113)	56(108)	-
Gray Luvisol	1967-75	3	barley	-	51(96)	72(135)	-	70(130)	73(136)	61(113)	-
Black Solod	1967-75	5	barley	-	147(273)	172(321)	179(333)	167(310)	164(305)	164(305)	-
Black Solod	1967-75	3	barley	-	91(162)	68(127)	69(129)	68(126)	70(129)	64(120)	-
Gray Luvisol	1968-76	3	barley	-	57(106)	-	-	-	-	-	71(133)

* Number of years of test crop following legume, test crop and/or fallow.

** Total yield for the number of test-years shown in 3rd column.

The results of a field experiment begun in 1960 at McLennan on an Orthic Grey Luvisol (Nampa) are of interest. Wheat was grown continuously from 1962-1976 after alfalfa, alfalfa-brome mixture or fallow of a fallow-wheat rotation. Over the 16 years, wheat following alfalfa has yielded 70% more than following fallow-wheat and 54% more following alfalfa-brome. The effect of the preceding alfalfa on wheat yield was still evident in the sixteenth year. Such a prolonged effect is undoubtedly due to factors in addition to N_2 fixation, indirectly suggesting that the three factors mentioned above are of importance.

The experimental evidence for the effect of deep-rooted legumes on improvement of subsoil is indirect, but field observations and demonstration rotations indicate that lasting benefits can be obtained by growing a deep-rooted legume such as sweet clover soon after new land is broken. Experiments currently being conducted by the Beaverlodge Research Station will hopefully provide some direct evidence on the effect of legumes on sub-soil permeability.

How much nitrogen do legumes add to the soil?

Estimates of the amount of nitrogen fixed annually by several legumes grown on three Peace River region soils vary from 0 to 442 kg N/ha (0 to 394 lb N/acre) in 3 years (establishment year plus 2 years) (Table 2). These data reflect variations due to soil type and legume species, with soil type being an important factor. The nitrogen-fixation potential of legumes is greater on Gray Luvisol soils than on Black solod soils. High nitrogen fixation is related to high legume herbage yields. Year to year variation in nitrogen fixation by alsike clover and red clover grown on two soils (Table 3) indicate that climatic factors exert considerable influence on nitrogen fixation.

The amount of nitrogen added to the soil will be equal to the amount fixed if the crop is not harvested for forage and the whole plant is incorporated into the soil (i.e. green-manuring). When the herbage was removed, the amount of nitrogen added to the soil by five legumes after two years of growth was considerably less than the total amount of nitrogen fixed (Table 4, cf Table 2). For the Rycroft soil (Black solod) there was a substantial depletion of soil N by all legumes. A vigorous healthy stand may fix several kilograms of nitrogen per hectare and add significantly to the soil N particularly if the legume crop is green-manured. However, it is possible that a poor stand, which is ineffective in fixing nitrogen will deplete the nitrogen content of the soil.

Legume species differ in the rate at which nitrogen is fixed. For example, by the end of July alsike clover fixed 85% of its total annual potential and red clover fixed only 73% of its total annual potential (Fig. 1). That is, if both clovers had a total annual fixation potential of 150 kg N/ha (134 lb N/acre), by the end of July, alsike cover would fix 128 kg N/ha (114 lb N/acre) and red clover would fix 110 kg N/ha (98 lb N/acre). When a legume crop

Table 2. Total yields and estimates of nitrogen fixation by 5 legumes grown on 3 soils for 2 years after establishment. Nitrogen fixation estimates determine by measuring the nitrogen in the herbage and in barley crops following the legumes.

	Yield - 100 kg/ha (tons/acre)			Nitrogen fixation - kg N/ha (lb N/acre)		
	Gray Luvisol (Beryl)	Black Solod (Landry)	Black Solod (Rycroft)	Gray Luvisol (Beryl)	Black Solod (Landry)	Black Solod (Rycroft)
Alfalfa	14.8(6.6)	10.8(4.8)	8.3(3.7)	442(394)	171(153)	10(9)
Sweet clover	9.3(4.2)	10.8(4.8)	7.7(3.5)	214(191)	125(112)	0
Alsike clover	10.5(4.7)	10.8(4.8)	4.7(2.1)	303(271)	152(135)	0
Red clover	11.8(5.3)	12.5(5.6)	4.1(1.8)	334(298)	250(224)	0
Birdsfoot trefoil	8.1(3.6)	9.7(4.4)	6.8(3.0)	190(170)	145(129)	0

Table 3. Annual nitrogen fixation by alsike clover and red clover grown on 2 soil types. Nitrogen fixation measured by the acetylene reduction technique.

Year		Annual nitrogen fixation - kg N/ha (lb N/acre)			
		Alsike Clover		Red Clover	
Planted	Measure	Gray Luvisol (Hazelmere)	Black Solod (Landry)	Gray Luvisol (Hazelmere)	Black Solod (Landry)
72	73	83(74)	31(28)	58(52)	14(12)
72	74	100(89)	42(37)	52(46)	23(20)
73	74	137(122)	49(44)	77(68)	25(22)
73	75	21(19)	7(6)	16(14)	5(4)
74	75	62(55)	16(14)	45(40)	12(11)
74	76	83(74)	50(44)	41(36)	38(25)

Table 4. Estimates of nitrogen added to 3 soils by 5 legumes grown for 2 years after establishment. Esimates determined by measuring nitrogen uptake by barley. Legume stand were cut for hay.

	N added to soil - Kg N/ha (lb N/acre)		
	Gray Luvisol (Beryl)	Black Solod (Landry)	Black Solod (Rycroft)
Alfalfa	106(94)	82(73)	-98(-82)
Sweet clover	51(45)	76(68)	-117(-105)
Alsike clover	79(70)	73(65)	-102(-91)
Red clover	69(62)	62(55)	-108(-96)
Birdsfoot trefoil	60(54)	102(91)	-114(-102)

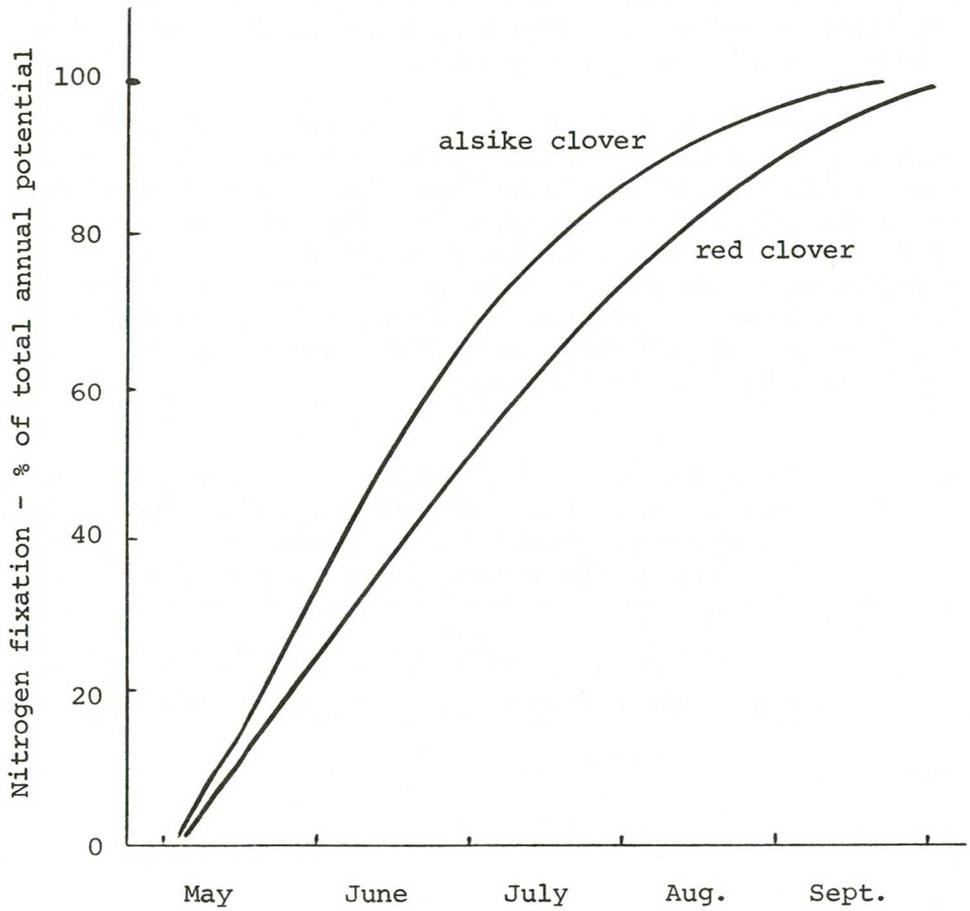

Fig 1. Seasonal nitrogen accumulation from nitrogen fixation by alsike clover and red clover.

is green-manured, it is often desirable to provide a partial summerfallow to obtain a complete kill of the legume and to prepare a good seedbed for the following crop. Alsike clover has the potential to add more nitrogen to the soil than red clover if the legume is plowed down at mid season.

The use of legumes offers an alternative for nitrogen fertilizers which are steadily increasing in price. Table 5 shows that replacement of the summerfallow year in a fallow-rapeseed-barley-barley rotation with a green-manure legume crop adding 125 kg N/ha (111 lb N/acre) to the soil can reduce the total fertilizer N requirement from 218 kg N/ha (195 lb N/acre) to 112 kg N/ha (100 lb N/acre), a reduction of nearly 50%. Even when this is balanced against the increase costs for legume seed, the savings in input costs will be considerable.

Table 5. Comparison of fertilizer N requirements for a fallow-rapeseed-barley-barley rotation and a legume-rapeseed-barley-barley rotation. Calcultations based on nitrogen fixation by the legume crop of 125 kg N/ha (111 lb N/acre).

	Fertilizer N required - kg N/ha (lb N/acre)	
	Fallow-Rape-Barley-Barley	Legume-Rape-Barley-Barley
Rape	50 (45)	18 (16)
Barley	84 (75)	39 (35)
Barley	84 (75)	55 (49)
Total	218 (195)	112 (100)

Summary

1. Inclusion of a legume in cropping rotations is generally beneficial, particularly if the legume stand is healthy, vigorous and actively fixing nitrogen. Yields of cereals can be increased substantially by growing them in rotation with legumes. However, there can also be a negative effect, resulting in decreased yields of cereal crops following legume stands which do not fix nitrogen.

2. It is generally accepted that deep-rooted legumes such as sweet clover and alfalfa improve sub-soil permeability. Research results indirectly support this view.

3. Forage legumes that are commonly grown in the Peace River region have the capacity to fix up to 220 kg N/ha (197 lb N/acre) annually. The ability to obtain fixation rates approaching the upper end of the range mainly depends on obtaining a healthy vigorous stand. Nitrogen fixation is generally lower on soils with high organic matter content (Black) than soils with low organic matter content (Grey Luvisols). Nitrogen fixation varies with legume species, soil type, and yearly climatic factors (precipitation, temperature, etc.)

4. The amount of nitrogen added to the soil depends on the amount of nitrogen fixed by the legume under a given set of environmental conditions. Also, the amount of nitrogen added can be greatly increased if the legume crop is green-manured. The time of plow-down of green manure crop can influence the amount of nitrogen added to the soil. Approximately 80% of the annual potential nitrogen fixation has occurred by late July to early August.

5. Replacement of a summerfallow year with a green-manure legume crop can save approximately 112 kg/ha (100 lb/acre) of fertilizer nitrogen in a four year rotation.

SOIL ACIDITY - LIMING FOR PRODUCTION OF ALFALFA

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INTRODUCTION

Alfalfa is very sensitive to acid soil conditions. In the Peace River Region, about one-third of the cultivated soil is sufficiently acid to reduce the yield of alfalfa. In some areas of the Peace Region over half of the land is affected for the production of alfalfa. Therefore, fields used for growing alfalfa must be selected carefully or alternatively acid soil areas should be limed before alfalfa is seeded. The economic losses resulting from poor productivity and poor stand establishment when alfalfa is seeded on acid soils and the cost of liming soils are quite high. Therefore it is very important to soil test to identify field suitability for growing alfalfa or to clearly identify acid soil areas.

IDENTIFYING SOIL ACIDITY

Soil pH

Acid soil conditions can only be positively identified by soil tests. The scale used to measure soil reaction is pH. The reaction is alkaline when the pH is above 7.0, neutral at 7.0, and acid below 7.0. Soils between pH 6.5 and 7.5 are considered to be neutral. Liming experiments in the Peace River Region have shown that yield of alfalfa is reduced when soil pH is less than 6.1. However, due to the variability of soil pH fields where the average pH is 6.1 to 6.4 may have areas where the pH is less than 6.0. Therefore ideally, fields seeded to alfalfa should have an average pH of 6.5 or higher.

SYMBIOTIC NITROGEN FIXATION

As discussed in Section H, the nodule bacteria (rhizobium meliloti) responsible for symbiotic nitrogen fixation by alfalfa are very sensitive to soil acidity. Soil acidity results in reduced nitrogen fixation and therefore lower yields and protein content on alfalfa. As indicated on page H-5, alfalfa yields on moderately acid soils (pH 5.5 to 6.0) can be increased substantially by inoculating with high numbers of effective rhizobia. However on more strongly acid soils and in the long term, the application of lime will be required to raise the soil pH and thus create a more favourable environment for survival and growth of rhizobium bacteria.

Other Factors

Poor growth of alfalfa in fields or parts of fields where legumes such as red clover and alsike grow well suggests an acid soil condition. However other factors such as poor subsoil drainage may cause poor alfalfa growth relative to other legumes. Therefore, the only definite method of identifying acid soil conditions is the measurement of soil pH. For cereal crops, acidity can be further identified by determining soil aluminum and manganese levels.

RESPONSE OF ALFALFA TO LIME

Yield

Numerous field experiments have been conducted where yields of alfalfa have been determined on limed and unlimed soils over a pH range from 6.0 to 4.5. In each case sufficient lime was added to raise the pH to 6.5. Average response to lime at various pH levels is shown in Figure 1. Response of alfalfa to lime in the Peace River Region has generally been somewhat higher than that shown in Figure 1. On stony acid soil (pH 5.0) alfalfa yields are reduced by 80% or more and on soil of pH 5.5, alfalfa yields are reduced by 50% or more. These results were obtained on small plots where good stands were established and adequate levels of phosphorus, potassium, and sulphur were added. In each case, 2 cuts of alfalfa were taken. In many cases the alfalfa stand on the unlimed area became very thin and had to be re-established after 2 or 3 years.

Very few trials have been established to determine the response to lime under field scale conditions. One year's results have been obtained from two locations; one near Falher and one near Arras west of Dawson Creek, B.C. At the Falher site, lime increased the yield of alfalfa by 0.5 tons per acre (1.12 T/ha). The average pH in this field is 6.0 but ranges from about 5.5 to 6.5. This illustrates that fields with an average pH of 6.0 may contain significant areas where the yield of alfalfa would be reduced by acidity. Lime increased the yield of alfalfa by an average of 1.0 tons per acre (2.24 T/ha) at the Arras location. The average pH was about 5.7. The rate of lime applied in these two field trials was in the range of 1 to 1½ tons per acre.

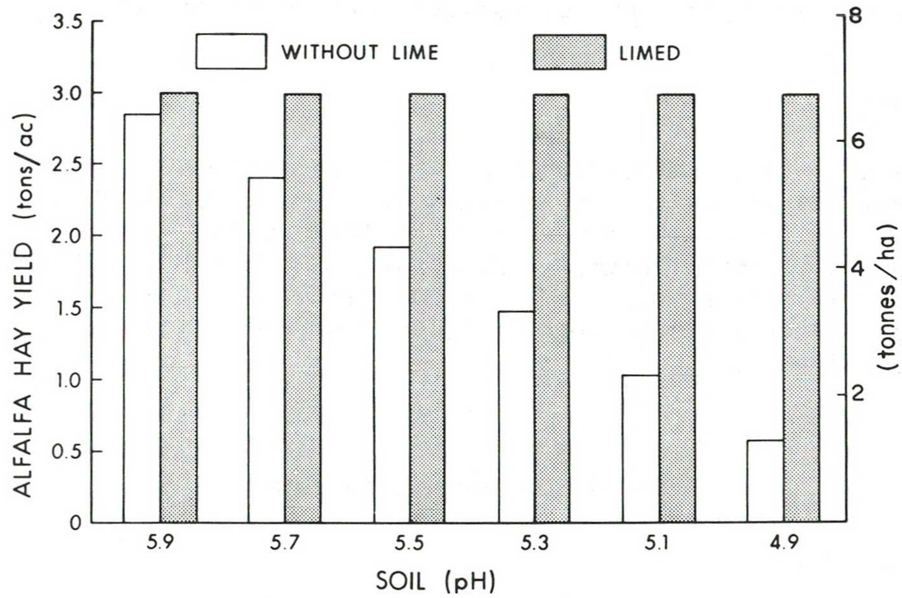

Figure 1. Response of alfalfa to lime at various pH levels.

Protein

Protein is an important quality factor in alfalfa production, particularly for the dehydration industry. Reduced nitrogen fixation resulting from soil acidity reduces both the yield and protein content of alfalfa. On a moderately acid soil (pH 5.8) near Edmonton, lime increased the yield of alfalfa by 0.25 tons per acre and the protein content by 2% (from 16 to 18%).

Application of Nitrogen Fertilizers

The occurrence of poor nodulation and low rates of nitrogen fixation has prompted increased interest in the application of nitrogen fertilizer to legume crops such as alfalfa. Application of nitrogen fertilizer to alfalfa grown on acid soils has improved yields but these applications did not result in satisfactory economic returns. For example on soils of pH 5.5, application of 200 pounds per acre of nitrogen ($40.00 per acre) was required to produce yields equivalent to those on limed soils. Fertilizing legume crops with nitrogen tends to reduce symbiotic nitrogen fixation by an amount similar to the rate of fertilizer applied.

LIME - SOURCES, APPLICATION, AND RATES

Sources

There are essentially two sources of liming material: limestone and marl. These materials are composed primarily of calcium carbonate ($CaCO_3$). Calcium carbonate as limestone or marl can be burned to form calcium oxide (CaO) sometimes called hot lime. When water is added to calcium oxide it forms calcium hydroxide [$Ca(OH)_2$] which is hydrated or builders lime. All of these materials can be used to neutralize the acidity of acid soils. Limestone and marl are used most commonly because of cost and ease of handling. Processing limestone and marl to calcium oxide or hydroxide adds additional cost. Also, calcium oxide and hydroxide are caustic and corrosive when wet and therefore require dry storage.

Limestone and marl (calcium carbonate) react very slowly to neutralize soil acidity unless they are in a fine particulate form. The general specifications for agricultural lime are that at least 50% of the material should pass a 60 mesh seive.

Interest in marl as a liming material results from the fact that developed sources of limestone are located in Southern Alberta (Steel Bros. at Exshaw and Summitt Lime Works near Coleman). Transportation costs from these sources to various locations in the Peace River Region amounts to \$35.00 to \$50.00 per ton. Unfortunately there are very few marl deposits in the Peace River Region of sufficient size, purity, and accessibility to be of commercial value. A deposit on the Pimm Brothers farm near Grimshaw is the largest and most accessible marl deposit known in the Peace River Region.

Application and Rates

Ground limestone and marl are generally applied with spinner spreaders similar to those used for fertilizers. However spreaders designed only for fertilizers will not work satisfactorily. Farmers interested in applying limestone or marl should enquire at local fertilizer outlets. Some may have suitable application equipment and these enquiries will encourage the development of distribution and application facilities. A single application of lime is estimated to last 10 to 20 years. Therefore it is unlikely that many farmers will want to own application equipment for liming.

Rates of application of lime are generally in the range of ½ to 3 tons per acre. The rate of application required should be determined by a "lime requirement" test. The Agricultural Soil and Feed Testing Laboratory will provide these analysis on request. For alfalfa and other legumes it is important that lime be applied at least ½ of a growing season (i.e. July) prior to seeding. This will allow sufficient time for the lime to react and raise the soil pH. If the pH does not rise sufficiently before alfalfa is seeded, the rhizobium bacteria on the inoculated seed may die before nodulation occurs.

ALFALFA VARIETIES AND COMPANION CROPS

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In the Peace River region, 3 different types or species of alfalfa varieties are grown. Medicago sativa is the purple flowered type. It is characterized by being tall and erect growing, has high seed and forage yield, good seedling emergence and very quick recovery after cutting. The seed pods are tightly coiled and the seeds have a fairly permeable seed coat. They have a tap root system which will penetrate the soil to a considerable depth, depending on soil structure and water availability. They are not winter hardy in general. However, there is a hardier subdivision of common alfalfa known as the Flemish type, which although not too winter hardy, does survive our milder winters reasonably well and is excellent for dehydration purposes. An example of a Canadian Flemish variety is Angus which has recently been licensed. Foreign varieties licensed in Canada are Alfa, Thor, Anchor, and Saranac. Rapid recovery after cutting and tap roots are indicators of the M. sativa germ plasm.

Medicago falcata is a yellow-flowered species. It is characterized by finer leaves and stems, slow seedling emergence, impermeable or hard seeds and lower seed yields. Forage yields are good in the first cut but as recovery is slow, second cuts are seldom taken unless moisture conditions are favorable. The roots are fibrous while some strains may have branch roots and others creeping roots. The growth habit is often low to the ground. The seed pods are straight or slightly crescent-shaped and are very prone to shattering. The main advantage of this species is its persistence and excellent winter hardiness. Anik is a more erect variety that has recently been licensed and may be useful primarily in the northern regions of the Peace. Slow recovery after cutting, fibrous roots and excellent winter hardiness are characteristics of the M. falcata germ plasm.

As Medicago falcata and Medicago sativa species intercross very readily, nature and plant breeders have combined them in various proportions into the third type, Medicago media which comprises the majority of varieties recommended forthis area. The variegation in flower color which ranges from purple to yellow is an obvious indication of the M. media germ plasm.

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*Present address: Agriculture Canada
Experimental Farm
Prince George, B.C.

A brief description of the major varieties licensed in Canada is outlined. Most of them are adequately described in the Agriculture Canada publication no. 1377 "Alfalfa in Canada."

Canadian Varieties

Beaver - A good yielding variety, good winter hardiness and medium recovery after cutting.

Algonquin - Higher yielding than Beaver, but not as winter hardy, developed from Rhizoma.

Angus - A high yielding Flemish variety, not as winter hardy as Beaver.

Grimm - A good yielding variety, good winter hardiness and medium recovery after cutting. Susceptible to bacterial wilt. Certified seed not available.

Rambler - Good forage yields, good winter hardiness, slow recovery after cutting and is creeping rooted in areas of low moisture.

Roamer - Similar to Rambler.

Kane - Similar to Roamer.

Drylander - Good hardiness, slow recovery after cutting and yellow flowered.

Peace - A new variety developed at the Beaverlodge Research Station, similar to Grimm but higher yield and superior winter hardiness.

Foreign Varieties

Saranac - A Flemish variety high yielding and good recovery after cutting. Reduced winter hardiness.

Anchor - A Flemish variety high yielding and good recovery after cutting. Slightly more hardy than Saranac.

Chimo - Similar to Saranac

Thor - Similar to Saranac.

Vernal - Similar to Beaver in yield, less winter hardy.

Performance of Varieties

At Beaverlodge we conduct Uniform Alfalfa Variety trials for forage and seed which include many of the varieties listed above. The results of tests established in 1968, 1969 and 1970 and seeded at 8 lb/acre without a companion crop show small differences in yield between varieties, but a wide variation due to climatic conditions (Table I). Under the same climatic conditions in 1971 new stands gave the highest yields and yields were reduced in older stands. Because of the dry summers of 1970 and 1973 only one cut was taken and this is reflected in the disappointing poor yields of less than 1 ton per acre.

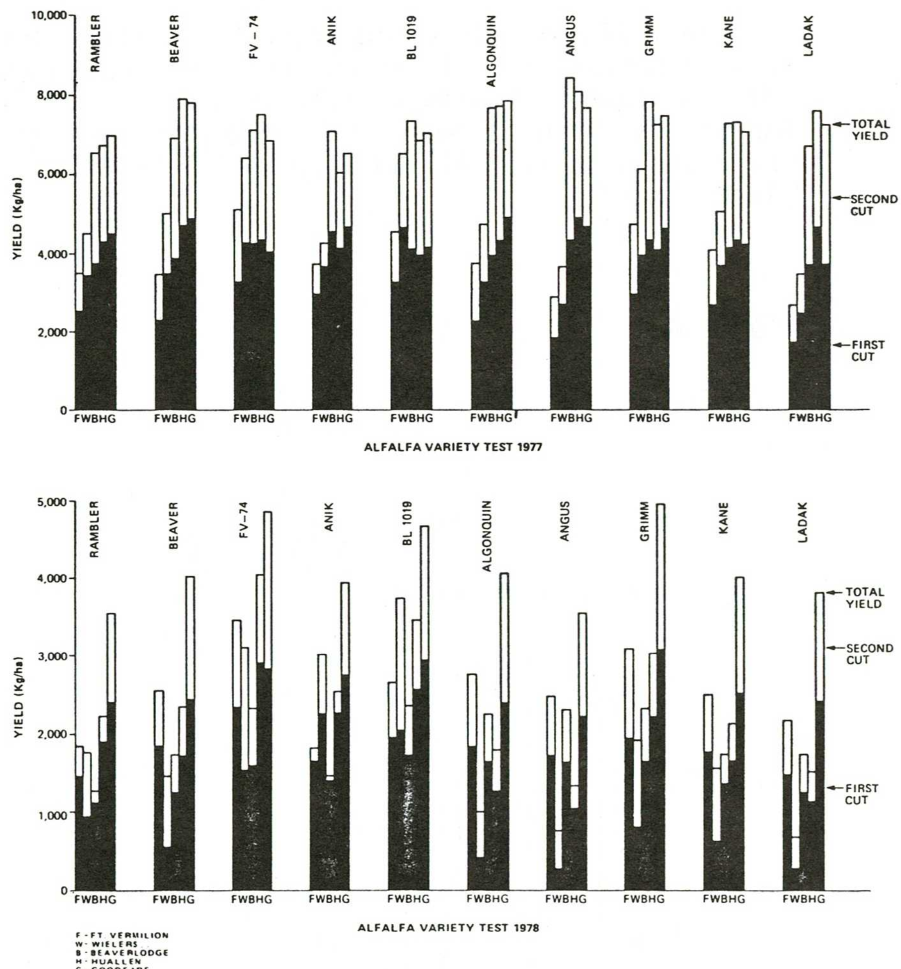
Table I

HAY YIELDS (TONS/ACRE) AT BEAVERLODGE

Variety	Year of Seeding 1968 3 yr. average (69-70-71)	1969 4 yr. average (70-71-72-73)	1970 3 yr. average (71-72-73)	% of Beaver
Beaver	1.57	1.63	1.84	100
Grimm	1.48			
Ladak	1.52	1.67	1.84	99
Rambler	1.75	1.71	1.87	105
Roamer	1.55	1.63	1.76	97
Vernal	1.38	1.72	1.89	99
Saranac		1.67	1.85	101
Titan			1.77	96
Range of yields	0.94 - 2.15	0.97 - 2.97	0.80 - 3.33	
Year	1970 1971	1973 1971	1973 1971	

Other alfalfa variety trials have recently been established at 5 locations through out the Peace River region. These locations include the Beaverlodge Research Station, Goodfare, HuAllen, the Fort Vermilion Experimental Farm and at a location (Cooperator, H. Wieler) near Fort Vermilion. Figure I outlines the 1977 and 1978 yields of 10 varieties established in 1975 and 1976. At the 5 locations, yield differences within any one variety are much greater between locations than are the differences in yield between the 10 varieties at any one location. These differences are due primarily to soil type and precipitation during the growing season.

Figure I

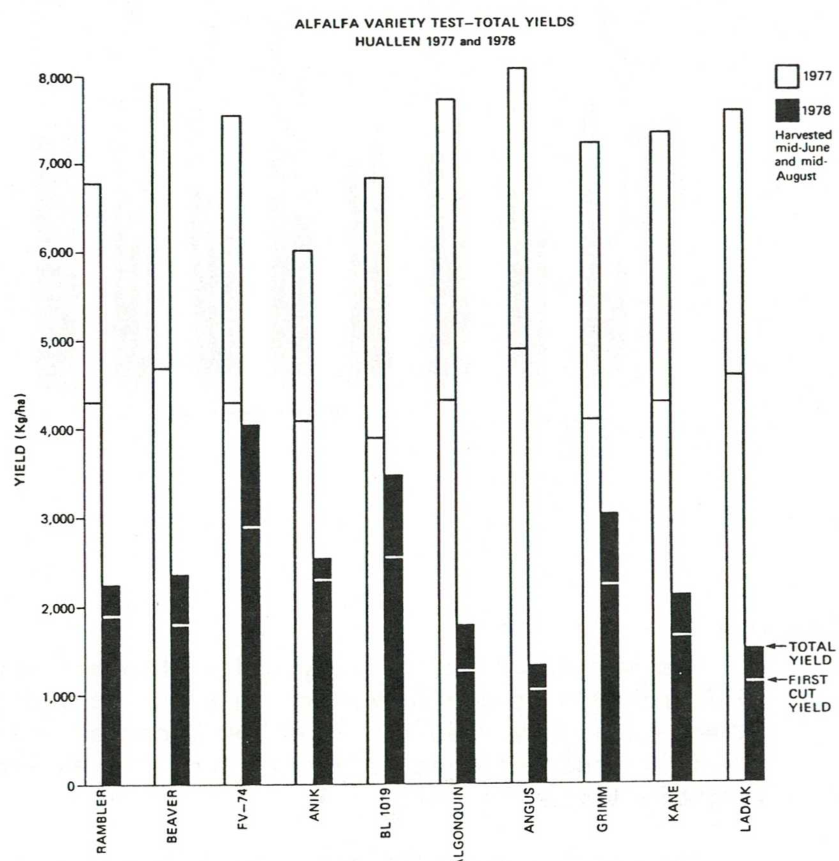


The marked reduction in yield within all varieties between 1977 and 1978 is due to winter injury. During the 1977-78 winter, extensive injury resulted from low December soil temperatures and low fall food reserves as a result of harvesting during August or early September in 1977.

The results indicate that the 3 varieties Grimm, FV-74 and BL-1019 had the highest yield in 1978 due to increased winter hardiness. These varieties were more resistant to the 1977-78 winter stresses than the remaining varieties. Clearly FV-74 had the highest overall yield at all 5 location in 1978. In Figure 2 a more detailed response of the 10 varieties is outlined for the HuAllen plot. We are now obtaining a license for FV-74 which was developed at the Beaverlodge Research Station and Fort Vermilion Experimental Farm by Dr. Peter Pankiw and Mr. Ben Siemens. It will be licensed under the name Peace.

The 1977 and 1978 yield graph for HuAllen (Figure 2) is typical of what happend to alfalfa in northern Alberta as a result of the 1977-78 winter. Yields in 1977 were quite high and fairly uniform for all varieties. Because of injury in the 1977-78 winter, there was significantly more variation in first cut yields and total yields in 1978.

Figure 2



Use of Companion Crops

Alfalfa can be seeded with and without a companion crop. Companion crops are generally used to provide an income from the acreage during the year of seeding. However, companion crops are also very useful to reduce emergence problems with alfalfa on low organic matter soils which tend to crust. Companion crops also provide competition for weeds. Unfortunately the companion crop also compete with the alfalfa for moisture, nutrients and sunlight. Unlike some of the weeds, alfalfa seedlings are partially shade tolerant. Thus when soil moisture is not limiting, a companion crop can be used to good advantage as a means of weed control.

A trial at Melfort, Saskatchewan showed that wheat was less detrimental to alfalfa yields than rape when both were used as a companion crop with alfalfa (Table 2, from Beacom, 1974).

Table 2

Effect of Companion Crops on Yield of Alfalfa Seeded in 1972, at Melfort, Saskatchewan.

Companion Crop	Alfalfa Yield lb/A				Companion Crop Yield lb/A
	1972	1973	1974 2 cuts	Total	1972
None	2420	5340	5320	13080	---
Wheat 1 1/2 bu/A	154	3232	5081	8467	2665
Wheat 3/4 bu/A	214	3696	5739	9649	2601
Napus rape (Zephyr)	46	2439	4396	6791	1748
Campestris rape (Span)	47	2019	4032	6098	1355

Beacom, 1974 Research Report

Companion crops should be seeded at between 1/2 to 3/4 of the rate of seeding normally used, e.g. barley should be seeded at 50-65 pounds per acre instead of 90-100 lbs per acre. The alfalfa and companion crop may be seeded in alternate rows by plugging every other run in a grain drill and plugging the alternate runs in the g grass seed attachment. The companion crop may also be cross seeded to the alfalfa thus assuring that each is planted at its own proper depth and there is space between competing plants. It is advantageous to the alfalfa to remove the companion crop as early as possible thus allowing the alfalfa to grow during the fall during which it can build up its root reserves. Where feasible, the companion crop should be removed as hay or silage rather than waiting until the grain is mature.

Research at Beaverlodge has indicated that for alfalfa seed production, flax is a better companion crop than wheat since it is not as competitve with alfalfa. Wheat and rapeseed compete similarly with alfalfa. Oats and late maturing barley are the most competitive companion crops for alfalfa and will have the greatest effect on reducing alfalfa yields.

Grass-Legume Mixtures

Not everyone wants a pure stand of alfalfa. Alfalfa-grass mixtures are easier to make into hay because the grass keeps the swath more open and allows for quicker drying. However, only in a few instances does the grass increase the total yield. A desired balance of alfalfa with grass may be partially achieved by the choice of species, density of seeding, and fertilization of the stand. In the Peace region, bromegrass is the most common species used with alfalfa in a hay mix. In most instances the brome takes over after 3 or 4 seasons to the detriment of the alfalfa stand. Table 3 shows comparative results at Beaverlodge of grass-legume mixtures with the grass or legume seeded alone, however the plots were cultivated between the rows as a means of weed control. Table 4 shows results from alfalfa-grass mixtures at Melfort, Saskatchewan.

Table 3

Yields (kg/ha) from alternate row seeding (50 cm spacing) at Beaverlodge.

	3 Year Average		
	Legume	Grass	Total Forage
Alfalfa	8091	--	8091
Trefoil	7323	--	7323
Slender wheatgrass	--	5672	5672
Reed Canarygrass	--	5808	5808
Bromegrass	--	6161	6161
Alfalfa + Slender wheatgrass	4792	2046	6838
Alfalfa + Reed canarygrass	3296	3304	6600
Alfalfa + Bromegrass	4924	2588	7512
Trefoil + Slender wheatgrass	3074	3457	6531
Trefoil + Reed canarygrass	2423	4278	6701
Trefoil + Bromegrass	2689	3471	7160

Table 4

Alfalfa-Grass Mixtures. Melfort, Sask. Yield in lb DM/A.

Mixture	Average 1971-74		
	Legume	Grass	Total
Alfalfa - bromegrass	161	3568	3729
Alfalfa - crested wheatgrass	1121	2889	4010
Alfalfa - intermediate wheatgrass	610	3864	4474
Alfalfa - Russian wildrye	2421	1441	3862
Alfalfa - Slender wheatgrass	1646	2260	3906
Alfalfa - Reed canarygrass	450	3269	3719
Alfalfa - Timothy	1376	1907	3283

(Beacom, 1974 Research Report)

INOCULATION, NODULATION AND NITROGEN FIXATION

Wendell Rice
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INTRODUCTION

Alfalfa is a very important forage crop in western Canada because of its unique ability to produce high yields of nutritious, palatable forage under a wide range of environmental conditions. The growth of the alfalfa dehydration industry, with domestic and foreign markets, reflects the significance of this crop as a source of plant protein in animal nutrition. One of the many factors that contribute to this crop's desirable qualities is the ability to use free nitrogen from the atmosphere (N_2 fixation) in symbiotic association with the nodule bacteria.

THE RHIZOBIA:ALFALFA ASSOCIATION

There are many kinds of nodule bacteria and the various legume plants have become adapted to certain species of bacteria. The bacterium that nodulates alfalfa (*Medicago sativa*) also nodulates sweet clover (*Melilotus* sp.), fenugreek (*Trigonella* sp.) and other species of *Medicago*, but no other species of legumes. The legume plants that are nodulated by the same type of bacteria are called cross-inoculation groups. The rhizobia capable of nodulating plants within a group are considered a species. Alfalfa rhizobia, known as *Rhizobium meliloti* is one of six designated species of legume nodule bacteria. The rhizobia are quite similar to other soil bacteria, which differ from the root nodule bacteria only in certain minor cultural traits and their inability to infect legume roots.

The ability of rhizobia to induce nodulation is called infectiveness; effectiveness refers to the capacity to fix nitrogen. Both factors are important criteria for selecting improved strains of *Rhizobium meliloti* for alfalfa inoculants.

NODULATION

Infection and Nodule Formation

The root zone is the focal point of reaction between the rhizobia and the alfalfa plant. The sequence of events leading to nodule formation and N_2 fixation has been studied extensively. Although there are many unknowns, the general pattern of development is known. The rhizobia proliferate on the root surface, root hairs increase in number and length, and some root hairs curl or otherwise become deformed. The bacteria enter the deformed root hairs, generally at a point where the cell wall is creased, and an infection tube is initiated. In the narrow infection tube, the rhizobia multiply and then proceed along the tube as it grows down the root hair and branches into the central portions of the developing nodule. The bacteria are released into the host's cytoplasm, where they multiply rapidly and change to bacteroids. Rapid cell division occurs in the root at this point and a nodule is formed. The final structure consists of a central core containing the rhizobia and a surrounding cortical area containing the plant's vascular system.

In order for the infection process to occur, the rhizobia must be present in the soil where they can come in contact with the developing root of the alfalfa seedling. Soil acidity (low soil pH) seriously limits the growth of alfalfa rhizobia, which causes poor nodulation as a result of impaired infection (Fig. 1). The alfalfa rhizobia are much more sensitive to soil acidity than clover rhizobia. Screening of strains of *R. meliloti* for the ability to nodulate under acid conditions has revealed that their tolerance to low pH varies, and some strains are capable of providing adequate nodulation at low soil pH (Fig. 2). The use of alfalfa seed inoculated with highly infective bacteria ensures that proper nodulation occurs.

Nodule Effectiveness

The presence of nodules is in itself no guarantee of N_2 fixation, as it is important that the strain of rhizobia infecting the root be of high N_2-fixing capacity. Effectiveness may range from completely ineffective to highly effective, depending on the strain of rhizobia infecting the alfalfa roots. Mature effective alfalfa nodules are large, elongated (2-4 x 4-8 mm), often clustered on the primary roots, and have pink to red centers. The red color is attributed to leghemoglobin which is confined to those nodule cells that contain rhizobia and are fixing nitrogen. Ineffective nodules are small ($<$ 2 mm diameter), usually numerous, and are scattered over the entire root system, or in some cases they are very large ($>$ 8 mm diameter) and few in number. They have white or pale green centers.

Even when nodules appear to be effective, they may not be fixing nitrogen at their maximum potential. The effectiveness can vary considerably from one strain of *R. meliloti* to another, and the effectiveness of one strain can vary depending on the alfalfa variety (Table 1). Strains of *R. meliloti* used in inoculants must be highly effective on a range of alfalfa varieties.

INOCULATION

Inoculants

Inoculation is the process of implanting highly infective and effective rhizobia into the soil where they will contact the roots of the young legume seedling. Rhizobia are usually applied to the seeds prior to planting. The peat-base inoculant is the most popular type of inoculant

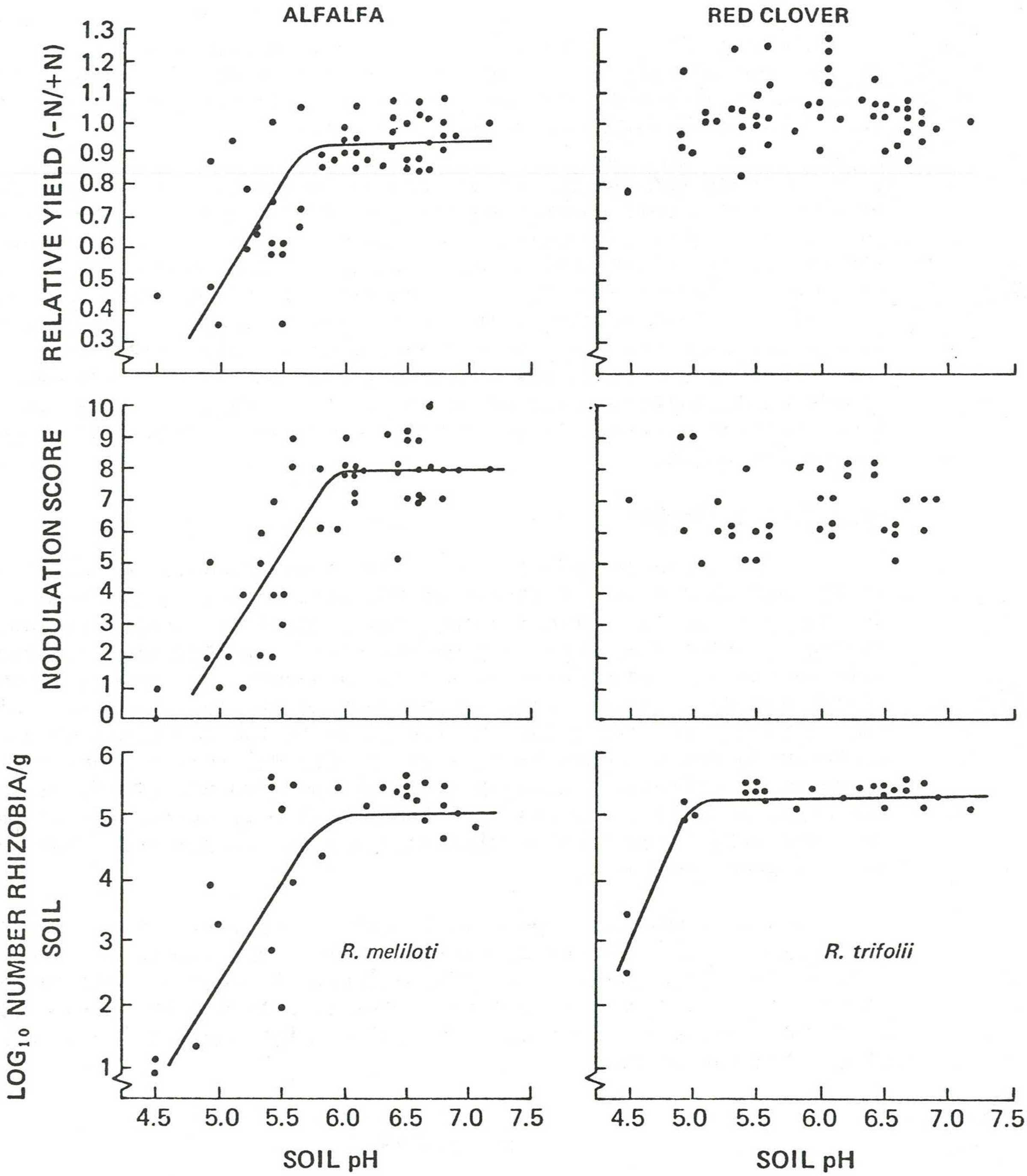

Fig. 1. The effect of soil pH on rhizobia numbers, nodulation and relative yields (yield without added N/yield with 224 kg N/ha per year) of alfalfa and red clover grown at 28 locations in Alberta and northeastern British Columbia.

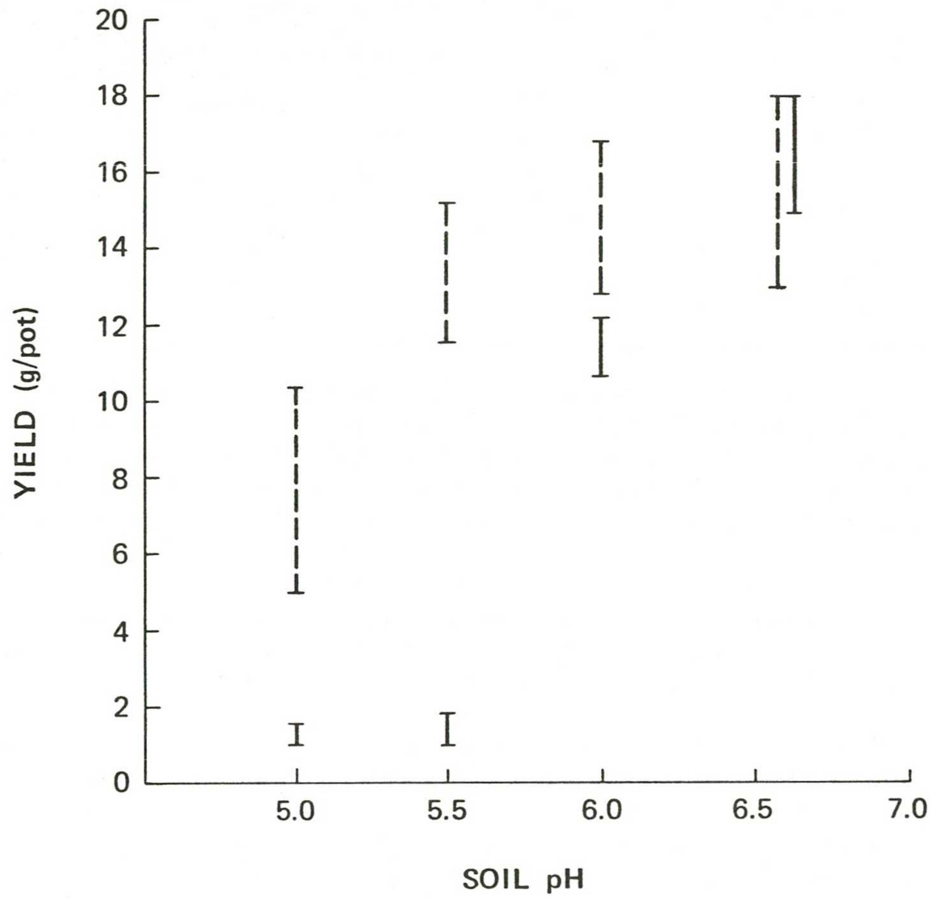

Fig. 2. Yield ranges produced by alfalfa inoculated with 12 strains of *R. meliloti* and grown at different soil pH levels. The acid sensitive group (solid lines) consisted of 4 strains and the acid tolerant group (broken lines) consisted of 8 strains.

Table I. Variability in nitrogen-fixing effectiveness of strains of rhizobia and alfalfa varieties.

Ladak alfalfa		Rhizobia strain A	
Rhizobia strain	Yield relative to strain A = 100	Variety	Yield relative to Beaver = 100
A	100	Beaver	100
B	92	Angus	95
C	84	Grimm	95
D	78	Ladak	86
E	72	Rambler	84
F	70	Anik	39
G	64		

used because it assures good rhizobial survival in the package and on the seed. Peat-base inoculants are made by adding large numbers of rhizobia, growing in broth culture, to a thoroughly pulverized, neutralized, and sterilized organic peat. The rhizobia increase about tenfold in the peat and become adapted to conditions approximating that of the soil.

The number of rhizobia required varies with the seed, form of inoculant and soil conditions. Inoculants that provide 1000 viable rhizobia per seed are considered satisfactory for alfalfa grown under most conditions. The approximate equivalent per gram of peat culture is 10^8 viable cells/g.

Alfalfa yields on moderately acid soils (pH 5.5-6.0) can be increased substantially by inoculating with high numbers of rhizobia. Inoculant applied at 1000 times the minimum requirement of 1000 rhizobia/seed (i.e. 1 million rhizobia/seed) results in yields approaching the maximum attainable yield (Fig. 3). This can be achieved with very high quality inoculants containing more than 5×10^9 rhizobia/gram. These high numbers of rhizobia are required to compete with numerous ineffective rhizobia usually present in acid soils and to provide sufficient viable rhizobia in the root zone to produce adequate nodulation.

Methods of Inoculating

On-the-farm inoculation: Alfalfa seed is commonly inoculated by the sprinkle, slurry or waterless method. In the sprinkle method the seed is moistened with a little water and the inoculant powder is mixed thoroughly with the seed. In the slurry method the inoculant is suspended in water and then is mixed thoroughly with the seed. In the third method the powdered inoculant is added directly to the seed without using water.

Certain sugars such as sucrose and maltose reduce the death rate of rhizobia caused by drying on the seed. Accordingly, the application of

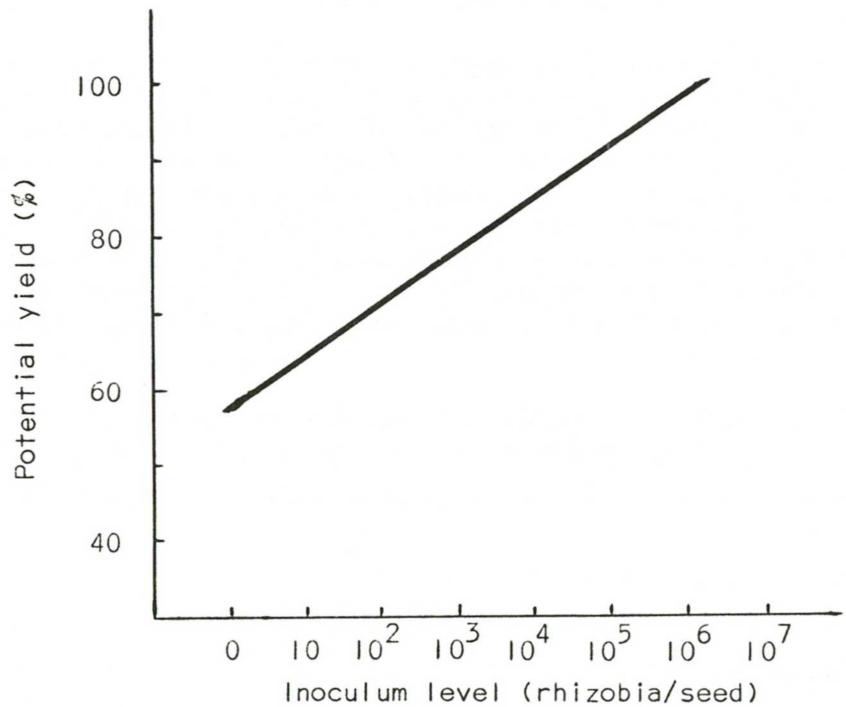

Fig. 3. Effect of inoculum level on the yield of alfalfa grown on moderately acid soil (pH 5.5-6.0).

peat-base inoculants as a slurry in sugar (10% sucrose and 9% maltose) and gum (45% acacia gum) solutions has been used effectively to achieve good nodulation when legume seeds are planted under adverse conditions. Also, the sugar-gum solutions are very effective in binding the inoculant to the seed, ensuring a high population of rhizobia in the root zone. As much as 10 times the normally recommended rate of peat-base inoculant can be applied if binding agents are used.

A recent survey indicated that less than 10% of the alfalfa fields in the Peace River region had good nodulation. Alfalfa planted in May and June is likely to be subjected to extremes in temperatures which are well outside the limits for growth of rhizobia, and are undoubtedly quite detrimental to survival. The results of a field test with Beaver alfalfa using different methods of inoculation show that applying the inoculant without a binding agent was almost completely ineffective (Table 2). Binding agents (sugar-gum solutions) are available commercially, but material such as skim milk, sugar and syrup solutions are equally useful.

Table 2. Effect of method of inoculation on the yield of Angus alfalfa grown on a Black Solod soil with pH 5.8.

Method of inoculation	Yield, 2 cuts kg D.M./ha (tons/acre)
No inoculant	1370 (0.61)
Applied to dry seed (waterless)	1406 (0.63)
Applied with sticker	2197 (0.98)
Applied with sticker @ 10 x recommended rate	2536 (1.13)
Pre-inoculated with seed coating	2236 (1.00)

It is important to sow alfalfa seed as soon after inoculation as possible. If planting is delayed, the inoculated seed may be stored in a cool, dark place for 3 or 4 days, but it is advisable to reinoculate if more inoculant is available.

For established stands with inadequate nodulation: Ineffective nodulation resulting from use of low quality inoculant, poor inoculation technique or lack of inoculation possibly can be corrected by applying inoculant to the soil surface. A high quality peat-base inoculant should be mixed with a carrier such as ground wheat and broadcast at a rate equivalent to 2 to 3 kg inoculant/ha, preferably on a cloudy or rainy day. This method is dependent on a good rain or sprinkle irrigation to carry the rhizobia down into the root zone.

Inoculation costs: The cost of inoculating alfalfa seed is low. Inoculant for on-the-farm application costs about $0.40/ha. This cost can be recovered with an increase of about 15 kg alfalfa hay/ha.

Pre-inoculated Seed

Pre-inoculated alfalfa seed is becoming more common on the market. Pre-inoculation refers to the process of inoculating seed in bulk well in advance of the planting date. Various procedures such as pelleting or coating, lyophilization, a vacuum process that forces the rhizobia under the seed coat, and using a clay-base inoculant that adheres to the seed by electrostatic forces. Pre-inoculated seed eliminates the extra time and effort required to apply inoculants on the farm, but has a major disadvantage in that the viability of rhizobia declines rapidly once applied to the seed. Also, it is more difficult to keep large lots of pre-inoculated seed under suitable storage conditions.

Inoculant manufacturers and seed processors have been working to produce a pre-inoculation process that will maintain viability of the rhizobia on the seed. The incorporation of inoculant into a pellet or seed coat containing lime neutralizes soil acidity, improves survival and facilitates the growth of rhizobia. This greatly increases chances of securing successful nodulation under relatively difficult conditions such as planting in acid soil (Table 2). If the viability of the rhizobia in any method of pre-inoculation can be maintained, the results should be similar to the results with coated seed shown in Table 2. In the past, tests on the viability of commercial samples of pre-inoculated seed have shown that a high proportion have less than the minimum required level of viable rhizobia. However, there has been definite improvement in the quality of some pre-inoculated seeds, particularly coated seed.

Seed Treatment with Thiram:

Federal regulations now require that all alfalfa seed sold in Canada must be treated with Thiram. This regulation was introduced to control the spread of *Verticillium* wilt. There has been some concern about the effect of Thiram on rhizobia. Tests by the Research Branch, Agriculture Canada and inoculant manufacturers have shown that Thiram does not affect nodulation if the seed is properly inoculated with a high quality inoculant. In some cases there may be an improvement in nodulation from the Thiram treatment.

Inoculant Quality

The Food Production and Inspection Branch (Plant Products Division) in cooperation with the Research Branch of Agriculture Canada conducts an inspection, sampling and testing program for legume inoculants and pre-inoculated seeds. This program ensures that the products sold in Canada will give sufficient nodulation if properly handled. The program has been very effective in encouraging inoculant manufacturers to maintain high quality standards for their products.

The Fertilizer Regulations (Canada Fertilizer Act) provided the following regulations for legume inoculants and pre-inoculated seed:

1. Peat-based inoculants:

   (a) The recommended application rates of such inoculants shall contain, per gram of product, sufficient viable cells of the nodule inducing species to provide at least 10^3 viable cells per seed for alfalfa, clover and birdsfoot trefoil, 10^4 viable cells per seed for sainfoin and 10^5 viable cells per seed for beans, peas and soybeans.

   (b) Such inoculants shall be prepared so that the amount of the product to be applied to the seed of any crop will not interfere with the commonly used rates of seeding for that crop.

   (c) Such inoculants shall be prepared so that the number of viable cells of microbial species other than the desired nodule inducing *Rhizobium* species are at a level that will not affect the viability or performance of such desired species.

2. Pre-Inoculated Seed Products

   (a) Such products shall induce nodulation in 95% of the plants grown from the treated seeds.

   (b) Such products shall provide the number of viable cells per seed as stated in 1 (a) above.

   (c) Such products shall not contain a substance that would inhibit nodulation and nitrogen fixation.

   (d) As 1 (c) above.

3. Legume inoculants and pre-inoculated seed must be registered before being offered for sale in Canada. The registration number must appear on the package label.

4. The package label shall also contain the following information:

   (a) Name and address of manufacturer

   (b) Name of the inoculant

   (c) Weight of the inoculant

   (d) Directions for use

   (e) Lot number

(f) Guarantee statement showing genus of species, name of the microorganism, the minimum number of active viable cells per gram of product.

(g) The date beyond which the inoculant is not intended for use.

(h) For pre-inoculated seed (d) and (f) do not apply if the package label states that the product is treated with (species name or genus of the active microorganism) inoculum.

The Fertilizer regulations help to ensure the sale of high quality inoculants and pre-inoculated seed, but the legume grower can do much to ensure this quality is maintained after purchase. It must be remembered that inoculants are alive and thus are perishable. Inoculants should be stored under refrigeration (4 C or 40 F) until required. Exposing inoculants to fluctuating temperatures, high temperatures, sunlight and drying causes a rapid deterioration in the quality. Ideally, pre-inoculated seed should be stored under refrigeration, but this is not always practical. Pre-inoculated seed should be stored away from direct sunlight in a cool place.

SUMMARY

1. Benefits from an effective, well established symbiotic N_2-fixation system include:

   (a) Increased dry matter yields

   (b) Higher protein content

   (c) Improved plant survival

   (d) More luxuriant growth of a companion crop

   (e) Addition of more readily available N to the soil

2. The establishment of the N_2-fixation systems depends upon the presence of infective and effective strains of rhizobia in the legume rhizosphere. Thus, the rhizobia must be present in the soil or applied through inoculation. Recommendations on inoculation vary, but in general there is little doubt that inoculation is required on most agricultural soils.

3. Even when the soil appears to have sufficient rhizobia to produce reasonable nodulation and N_2 fixation, inoculation may be of further benefit by introducing a strain of bacteria that is more effective than those already present in the soil.

4. Inoculation is very inexpensive relative to the equivalent cost of fertilizer nitrogen that would be required to replace the nitrogen gained through symbiotic fixation.

5. Improved regulatory measures are helping to ensure high quality inoculants and pre-inoculated seed are available to Canadian farmers.

6. For on-the-farm application of inoculants, the following points are important:

   (a) Make sure the inoculant package states that the rhizobia contained therein are compatible with the legume seed to be inoculated.

   (b) Proper storage of inoculants is necessary if quality is to be maintained. Store under refrigeration (4 C or 40 F) and keep out of direct sunlight. Even a few hours of high temperature or sunlight will seriously decrease the viability of the rhizobia.

   (c) Peat-based inoculants should be applied with sticking agents which bind the inoculant to the seed. The use of commercial sticking agents, 10% sugar or syrup solutions or skim milk can be used. For adverse conditions sucn as moderately acid soils or low soil moisture, it is advisable to increase the inoculant rate by up to 10 times the normally recommended rate.

   (d) Planting should be done as soon as possible after inoculation.

7. Pre-inoculated seed can save time and effort during planting, but is susceptable to loss of rhizobia viability. Pelleted or coated seed provides extra protection for the rhizobia with the added benefit of a small amount of lime to neutralize soil acidity immediately around the seedling root. Pre-inoculated seed should be stored in a cool dark place.

8. Thiram treated seed does not inhibit nodulation if high quality inoculant is used with proper inoculation techniques.

DISEASES OF ALFALFA IN THE PEACE RIVER REGION OF ALBERTA AND BRITISH COLUMBIA

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INTRODUCTION

Numerous diseases of alfalfa have been investigated in many regions of North America, and control measures have been developed for some of the more significant ones. Little work, however, has so far been done on them north of the 55th parallel and less still in the Peace River region. Consequently, our current control recommendations are extrapolated from work done elsewhere.

Methods of Disease Control available to farmers are primarily cultural - selection of suitable sub-climates and soils, and proper land preparation, seeding, cutting regimes, and crop rotation - and the use of resistant varieties when available. For example, a useful degree of resistance has been developed for at least one region of North America for bacterial wilt, anthracnose, common leaf spot, downy mildew, *Phytophthora* root rot, rust, spring blackstem, yellow leaf blotch, and the stem and bulb nematode, whereas no resistance has so far been found for *Rhizoctonia* root and crown rot, *Fusarium* root rot, *Fusarium* wilt, *Sclerotinia* crown and stem rot, bacterial leafspot, witches' broom, or for alfalfa dwarf and mosaic viruses. For the most part, varieties suitable for the Peace River region have few resistances other than those involved in winter survival. Chemical controls, except insofar as liming or other fertilizers affect disease development, have either not been developed or are not economic on a field scale at present. Seed treatment, however, with thiram to control seed-borne *Verticillium* wilt is now required. An additional benefit is that thiram also reduces damping-off.

Disease Surveys that we have carried out in recent summers, plus earlier ones by scientists from Lacombe and Edmonton, have established the presence and relative frequency in the Peace River region of the diseases outlined in the rest of this report. The crown and root rot complex is by far the most serious disease problem in established stands, and it constitutes the disease component of the general problem of stand survival. Damping-off, which is the disease component of stand establishment, is next in significance. Of the leaf spots that cause some defoliation, yellow leaf blotch is the only one to cause significant losses in recent years, but all the leaf spots may become more important as stand management for dehydration plants becomes more intensive. Finally, *Verticillium* wilt has not yet been found in the Peace but is potentially devastating and appears to be on its way here. It is dealt with separately by Dr. J. Yorston following the other diseases.

Alfalfa Diseases of Importance in the Peace River Region outlined below with current suggestions for control are considered to cause significant losses or to be sufficiently widespread as to pose a real threat.

ROOT AND CROWN DISEASES

CROWN AND ROOT ROT COMPLEX

Symptoms: four main types of injury occurring singly or in various combinations have been distinguished, but their causal agents have only partially been determined for this region and are sometimes complex: -

1. *Internal Crown Rot*

Causal agents: undetermined.

Internal crown rot occurs frequently in older stands. Dark brown necrotic (dead) areas are initiated in the crown at the site of the cut stems or in axils. The necrosis proceeds into the crown to form a wedge-shaped, rather dry decayed area. This eventually progresses into the central stele of the taproot. The vigor of plants is reduced because fewer shoots originate from the reduced crown surface. Normally, crown buds originate in the fall, then develop rapidly in early spring, but in severely affected crowns new shoots arise only from the lower part of the crown in late spring. Internal crown rot is prevalent throughout the region and is the most important rot of this complex except in the area from Manning northwards.

2. *External Crown Rot*

Causal agents: undetermined.

External crown rot injury is characterized by a rather dry necrosis in the transition zone of the crown and root cortex. It appears to begin as an external lesion which expands and results in partial girdling and partial killing of the crown and crown buds. After 2 or more seasons, girdling is complete, resulting in death of most of the crown. A marked increase in the extent of external crown rot has been observed in the fall, prior to freeze-up. External crown rot occurs sporadically throughout the region, usually lightly. It is more common and more severe in the area from Manning northwards.

3. *Winter Crown Rot*

Causal agents: Low Temperature Basidiomycete, *Plenodomus meliloti*, *Fusarium nivale*.

Winter crown rot is characteristic of both old and young stands. It occurs primarily in patches within a field. Crown tissue becomes soft, brownish yellow in appearance, then disintegrates until the whole crown is rotted off. It is not selective of tissues within the crown, and taproots are usually not damaged. It appears more common in low wet areas and completely kills the crown, apparently in a single winter. It is associated with snow mold. Winter crown rot occurs sporadically throughout the region.

4. *Brown Root Rot*

Causal agent: Plenodomus meliloti

Root rot injury is characterized by roughly circular brown lesions with darker margins appearing on root surfaces, usually expanding from where a lateral root emerges from a taproot or a main root. These lesions progress until they completely rot through the root. Root rot is common in all parts of the region but is generally light in areas south of Manning. From Manning northwards, however, it is frequently severe and is the most important part of the crown/root rot complex.

Control of the crown and root rot complex - Avoid excessive cutting, overgrazing and grazing in the fall prior to freeze-up. Maintain good nutritional status by proper fertilization. Severely damaged fields should be plowed and seeded to spring cereals or grasses for at least two years before re-seeding with any legume. Use winter hardy, i.e. resistant, varieties: Anik; Grimm is moderately resistant.

DAMPING-OFF

Causal agents: species of *Pythium, Rhizoctonia,* and *Fusarium.*

Symptoms: Seeds decay in soil or seedlings wilt and die.

Damping-off occurs throughout the region, and can be important in cool, moist conditions.

Control - Treat seed with thiram or captan seed protectants. Avoid heavy irrigation prior to the three to four-leaf stage. Avoid low, wet spots, and heavy clay soils. Provide balanced fertilizers, including nitrogen, before seeding.

STEM DISEASES

These diseases are prevalent, but so far no serious outbreaks have been reported in the Peace River region.

SPRING BLACK STEM AND BLACK LEAF SPOT

Causal agent: Ascochyta imperfecta (Phoma medicaginis).

Symptoms: Small brown or black spots on lower leaves in mid-summer with similar spots on crown buds and lower portions of the stems. Severe infections girdle and kill older stems and cause leaf defoliation. In cool, moist seasons flower stalks and seed pods are infected, causing loss of seed. It is potentially serious under cool, moist conditions.

Control - Rotate with cereals and grasses. Destroy or plow under all debris and plants. Harvest severely affected crops early before defoliation is extensive. Use resistant varieties: Beaver, Rambler, Rhizoma, or Vernal.

WITCHES' BROOM

Causal agent: Probably a mycoplasma.

Symptoms: Plants produce a thick mat of short shoots and have an erect, bunched appearance. Leaves are small, rounded, and yellowish. Plants are short-lived. It has a minor occurrence throughout the region.

Control - Fall-plow affected fields, and rotate with non-legumes. Destroy volunteer plants.

FOLIAGE DISEASES

Yellow Leaf Blotch and Common Leaf Spot are found more commonly and more intensively than the other two, but all four occur throughout the region. Yellow Leaf Blotch is the most serious.

COMMON LEAF SPOT

Causal agent: *Pseudopeziza trifolii f.sp. medicaginis-sativae.*

Symptoms: Small dark brown, circular spots develop initially on lower leaves and may spread to all foliage. The spots are different from those caused by the Black Stem fungus in that they are confined to leaves, are brown, do not coalesce to form irregularly shaped spots, and at maturity develop a raised disc in the centre which is the fruiting body of the fungus. In severe cases most of the lower leaves drop prematurely. Infected foliage gives a poorer quality hay. Disease development is favored by cool, wet weather.

Control - Hay crops in which the leaves become badly spotted should be harvested before defoliation becomes severe. Destroy or plow under all debris and plants. Rotate with non-legumes. Use resistant varieties: Rambler.

YELLOW LEAF BLOTCH

Causal agent: *Leptotrochila medicaginis.*

Symptoms: Affected leaves develop yellow or orange blotches that run parallel to the veins. Very small dark brown or orange dots, which are fungus fruiting structures, are scattered with these blotches. Severe infection results in heavy defoliation and is favored by cool, wet summers. This is the most serious leaf spot in the Peace River region.

Control - as for Common Leaf Spot. Resistant varieties: Rambler, Rhizoma.

STAGONOSPORA OR GREY LEAF SPOT

Symptoms: Spots on leaves are grey, roughly circular, 1/4 to 1/8 inch in diameter. In the centres of these spots numerous small black dots appear which are the fruiting bodies of the fungus. Similar spots occasionally occur on stems.

Control - as for Common Leaf Spot.

PEPPER SPOT

Causal agent: Pseudoplea trifolii.

Symptoms: Similar to Common Leaf Spot, but the spots are very small (hence the common name) and a light brown.

Control - as for Common Leaf Spot.

DOWNY MILDEW

Causal agent: Peronospora aestivalis.

Symptoms: Infected leaves at the top of the plant are light green and a greyish-white fuzz occurs on their undersides. When severe, stems are retarded and leaves become twisted and rolled. Moderate infections have been reported from Fort St. John and Beaverlodge, but in most years it is uncommon. It occurs in cool, moist conditions.

Control - as for Common Leaf Spot.

OTHER DISEASES

The following diseases have also been recorded in the Peace River region:

Alfalfa "Sickness" *(? Phytophthora sp.)*
Bacterial Wilt *(Corynebacterium insidiosum)*
Botrytis Snow Mold *(Botrytis cinerea)*
Pin Nematode *(Paratylenchus projectus)*
Sclerotinia Crown and Stem Rot *(Sclerotinia trifoliorum or S. sclerotiorum)*
White Leaf Spot (potassium deficiency induced by excess moisture)

VERTICILLIUM WILT

Causal agent: Verticillium albo-atrum

Symptoms: see attached Pest Control Note by Dr. J. Yorston, B.C. Ministry of Agriculture.

Control: since publication of Dr. Yorston's Pest Control Note was. published in November 1979. a new formulation of Thiram has been released and some additional information on seed treatment with Thiram has become available that is important for those treating seed themselves.

Please note that all seed in the trade will be pre-treated, but all seed held over by the farmer or purchased directly from other farms needs to be treated.

Manufacture of Thiram 75 WP (wettable powder) for alfalfa has ceased, but there are still stocks on the shelves and on the farm. Trade names include Arasan, Thiram, Thylate.

Thiram 320 FW (flowable) is the new formulation registered for treating alfalfa seed. It is produced by Uniroyal and marketed by Green Cross. It is designed to get around health hazards caused by inhalation of dust from the WP formulation. Even so, vapors should not be inhaled. Of commonly used pesticides, thiram is considered to be one of the least toxic in its long-term effects, but it has one unusual short-term effect: it reacts with alcohol. Thiram is related to the drug Antabuse which is used in aversion therapy for alcoholism and, if thiram is inhaled or ingested in significant amounts, it produces a similar effect when alcohol is consumed within 24 hours of exposure to the fungicide. Therefore READ THE LABEL before using thiram, and follow all precautions.

If you have:-

1. Pre-treated, pre-inoculated seed: do not treat with anything else.

2. Pre-treated, uninoculated seed: add Rhizobium + recommended sticker, regardless of whether it was treated with the wettable powder or with the flowable formulation.

3. Untreated, uninoculated seed, and you have:

   (a) Thiram 320 Flowable: treat the seed with Thiram and allow it to dry. The manufacturer has indicated to us that Thiram 320 is a precisely prepared formulation, and that any dilution may adversely affect its efficacy and adherence. It already contains a sticker, so DO NOT ADD A STICKER; DO NOT DILUTE.

   (b) Then, just before seeding, add Rhizobium inoculant + recommended sticker.

   (b) Thiram 75 WP: either, apply the wettable powder with a little mineral oil at your convenience, and then add Rhizobium + recommended sticker just before seeding
   or, apply powder + Rhizobium + sticker just before seeding.

N.B. Thiram-treated seed is also protected from seed decay, although not from seedling damping-off, and should therefore have improved emergence.

WEED CONTROL

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Weeds constitute a complex problem in the production of alfalfa forage in many parts of the Peace River region. There are conflicting viewpoints on the importance of the problem. Some growers consider alfalfa as a crop that will clean up the land rather than as a crop where weed control is required. Other growers are asking for methods they can use to control weeds in the crop. The frequency of alfalfa fields that are heavily polluted with weeds in the Peace River region would seem to indicate a need for weed control. However, close inspection of many of these heavily polluted fields often reveals the presence of a poor crop stand. The question in these fields is whether the problem is one of weed control or one of crop establishment and maintenance. Although there are information gaps in the following it is hoped that it will provide some insight into the problems of weeds and their control.

The Weed Problem

Weed problems in alfalfa can be divided into 2 categories: problems of seedling stands and problems of established stands.

1. Problems of seedling stands.

Annual weeds are the most serious weed problem in seedling alfalfa. The seedlings of perennials also may be present but they usually grow slowly and seldom cause serious competition problems in the seedling year. Alfalfa seedlings are small and weak and are, therefore, very poor competitors with weeds. Weeds growing in stands seeded without a companion crop are more difficult to control by herbicides than those growing in stands established with a competitive companion crop.

Weeds occurring in seedling stands of alfalfa are the same as those occurring in annual cereal and oilseed crops. According to the Alberta weed survey, 1973-76 (D.A. Dew, Lacombe Research Station and provincial agricultural fieldmen) the most prevalent weeds in the Peace River region are wild oats, stinkweed, dandelion, field horsetail, wild buckwheat, lamb's-quarters and rapeseed (in crops other than rapeseed). Since 1976 several annual weed species have shown marked increases in the region. These include chickweed, corn spurry, cleavers and hemp nettle. Although the annual species predominate during the establishment phase, perennials such as Canada thistle, perennial sowthistle and quack grass can also be problems.

2. Problems of established stands.

Perennial species are usually the most troublesome weeds in established stands of alfalfa, although annuals, winter annuals and biennials can also be problems. In a preliminary survey of 15 alfalfa fields in the Peace River region in 1974 dandelions were the most frequently encountered and abundant weed found in established alfalfa. Yarrow, lamb's-quarters, rough cinquefoil, biennial wormwood and plantain were also frequently encountered in these fields. Since only 15 fields were surveyed a number of weeds which are important do not appear on the list. These include weeds such as stinkweed, quack grass, Canada thistle and perennial sow thistle. The most serious weed problems were usually encountered in fields where winter survival of the alfalfa plants was poor. In healthy vigorous stands weed populations were generally small.

Losses Caused by Weeds in Alfalfa Grown for Dehydration

Weeds affect the production of alfalfa in a number of ways:

1. In seedling stands, weeds can reduce yields through competition for water, nutrients and light. Because alfalfa seedlings grow slowly they are very weak competitors. If a stand is weakened during its early stages of development, its productivity will frequently be reduced throughout its existence.

   In established stands weeds also compete for water, nutrients and light. Losses in forage caused by weeds are harder to determine at this stage than at the seedling stage. Many weeds will produce as much dry matter per day as do the forage plants. However, the dry matter produced by weeds is often placed in a position where it is lost by normal methods of harvest. For example, in an Ontario study young dandelion leaves were found to be nutritious as forage. However, only 1000 lbs of dry leaves per acre were harvested from a poor dandelion stand compared to 4 to 10 times this much from the forage plants (G.W. Anderson, Crop Science Department, Ontario Agricultural College, Guelph).

2. Weeds reduce the quality of alfalfa grown for dehydration. Dehydrated alfalfa must have high protein and other nutritive qualities. Most weeds, being non-legumes, have a lower average protein content than alfalfa. Winter annual weeds, such as stinkweed, are frequently quite mature by the time the alfalfa is ready for first cut and this further decreases protein content. Weeds such as stinkweed may also impart an unpleasant flavour in the final product.

3. Certain weeds can produce inhibitors that prevent or delay the growth of alfalfa. In Minnesota, it has been shown that it is often difficult to establish alfalfa on newly plowed land previously infested with quack grass. Alfalfa growing on such land is low in vigor and yield.

4. Weeds can serve as alternate hosts for disease and insect pests that infest alfalfa.

Weed Control Methods

The control of weeds in alfalfa depends on the age of the stand, the weed species present, and the abundance and distribution of weeds in the field. For small patches or occasional plants hand-pulling or spot treatment is useful. Cultural treatments for establishing new stands are different from those used on old fields. The type of herbicide to be used will also vary between new and old stands and for the weed species to be controlled.

I. Cultural control

At present cultural control procedures constitute the most important method of controlling weeds in alfalfa in the Peace River region. The production of strong, healthy stands must form the basis of any weed control system in alfalfa.

In seedling alfalfa several cultural control methods can be used:

(a) Prevent the introduction of weeds into a field by using clean seed and clean tillage and harvesting equipment.

(b) Use good tillage practices and cropping sequences that will deplete the supply of weed seeds or vegetative parts in the soil. Summerfallow the year prior to planting alfalfa plus delayed seeding during the year of planting will help to destroy weed seeds prior to seeding. Perennial weeds, such as Canada thistle, should be controlled before alfalfa is seeded.

(c) The alfalfa should be planted at the proper time of the year. See other sections of this bulletin for details.

(d) Proper fertility practices will promote greater vigor of seedling alfalfa and render it more competitive with weeds.

(e) In years when moisture supplies are adequate the use of a companion crop is helpful in controlling weeds. However, in dry years companion crops tend to set back the development of the alfalfa seedlings and the stand is poorer. Subsequent weed problems are usually greater than where companion crops are not used.

(f) Clipping or mowing done at the proper time is an effective method for controlling annual broadleaf weeds. It helps to reduce weed seed production and will permit better penetration of light to the alfalfa seedlings. The mower should be set to cut just above the tops of the alfalfa seedlings.

In established stands of alfalfa, competition is the main factor involved in keeping weeds out. A healthy, vigorous, established stand of alfalfa will usually provide enough shade to kill weed seedlings during the growing season. Winter annuals are about the only weeds that may come into dense stands of alfalfa. Early spring cultivation with a spring tooth harrow has been used in some areas to control these weeds. However, the efficiency of this method under Peace River region conditions is unknown. If a stand is thin because of poor establishment or disease and insect damage and becomes heavily infested with perennial weeds only breaking and summerfallowing of the field will solve the problems.

Where small patches of persistent perennials such as toadflax or Canada thistle occur in established stands of alfalfa, hand-pulling and cutting or digging can be used.

II. Chemical control

Information on the chemical control of weeds in forage crops is updated and published annually by the Alberta Department of Agriculture. Information provided here is taken from that source. Herbicides which control weeds which are not major problems in the Peace River region have not been included.

RATES ARE IN FLUID OR AVOIRDUPOIS OUNCES - AS THE MATERIAL COMES FROM THE PAIL OR BAG.

A. Herbicides for the establishment of seedling alfalfa.

(i) Herbicides applied and incorporated prior to planting.

1. Eptam

Available as: Liquid concentrate (128 oz EPTC/gal) and granules (10% EPTC)

Rate per acre: Liquid concentrate - 60 fl oz., granules - 30 lb

Chemical required for 40 acres: Liquid concentrate 15 gal, granules - 1200 lb

Weeds controlled: Chickweed, corn spurry, lamb's-quarters, redroot pigweed, wild oats, volunteer cereals.

Application instructions: Apply before seeding and incorporate at once as directed on the label. When applying a liquid, use at least 10 gallons of water per acre.

Precautions: DO NOT use Eptam if a grass or cereal is used as a nurse crop. Temporary crop stunting and cupping of first leaves will occur if conditions for growth and germination are not optimum.

(ii) Herbicides applied after alfalfa emergence

1. Embutox E

Available as: Liquid concentrate (64 oz 2,4-DB/gal)

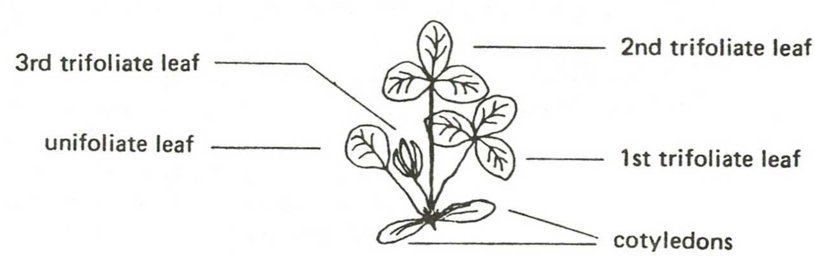
Rate per acre: 40-50 fl oz

Chemical required for 40 acres: 10-12 1/2 gal

Weeds controlled: Lamb's-quarters, redroot pigweed, shepherd's-purse, stinkweed, wild mustard, Canada thistle, dandelion*

Application instructions: Apply when alfalfa is in the 1-3 trifoliate leaf stage (see sketch) and while weeds are in the 2-5 true leaf stage. Apply embutox E in 15-20 gallons of water per acre.

*Control may vary from fair to good, depending upon growing conditions.



Precautions: Damage may occur if treatment is delayed beyond the third trifoliate leaf stage, and will likely increase in severity the longer treatment is delayed.

2. Carbyne

Available as: Liquid concentrate (19.2 oz barban/gal)

Rate per acre: 34-50 fl oz

Chemical required for 40 acres: 10 3/4 - 12 1/2 gal

Weeds controlled: Wild oats

Application instructions: Apply when most of the wild oats are in the 2-leaf stage and before the legume reaches the 4 trifoliate leaf stage. Use 4-5 gallons of water per acre and a pressure of 45 psi.

Precautions: DO NOT feed crop as forage or allow livestock to graze until at least 5 weeks after treatment.

3. Hoe-Grass

Available as: Liquid concentrate (28.8 oz dichlofop-methyl/gal)

Rate per acre: 53 fl oz

Chemical required for 40 acres: 13.2 gal (4 pails)

Weeds controlled: Persian darnel and wild oats

Application instructions: Apply when grassy weeds are in the 1-4 leaf stage(1-3 leaf stage in the case of Persian darnel). Apply in 10 gallons of water per acre, using a pressure of 40 psi. To ensure better penetration and coverage and increased weed control, tilt the boom forward at an angle of 45°. Hoe-grass must be applied before tillering (stooling) of grassy weeds. Optimum yield increases will be obtained if application is made when the majority of the grassy weeds are in the 2-3 leaf stage.

Precautions: DO NOT tank mix Hoe-Grass with any herbicides, insecticides or fertilizer. DO NOT apply if rain is forecast within 4 hours after application. DO NOT graze treated areas before the crop matures.

4. Asulox F

Available as: Liquid concentrate (62 oz asulam/gal)

Rate per acre: 40 fl oz

Chemical required for 40 acres. 4 1/2 gal (1 pail)

Weeds controlled: Wild oats plus suppression of wild mustard, stinkweed, wild buckwheat, smartweed

Application instructions: Apply when wild oats are in 2- to 4-leaf stage. Use 5 to 10 gallons of water per acre. Avoid spraying when crop is wet or rain is expected within 4 hours. Flax may be used as a companion crop. Do not apply to crops under stress.

B. Herbicides for established alfalfa

(i) Herbicides Applied in the Fall

1. Embutox E

Available as: Liquid concentrate (64 oz 2,4-DB/gal)

Rate per acre: 40-50 fl oz

Chemical required for 40 acres: 10-12 1/2 gal

Weeds controlled: Narrow-leaved hawk's-beard, shepherd's purse, stinkweed

Application instructions: Apply in 15-20 gallons of water per acre, after alfalfa has become dormant, but while weeds are still growing.

2. Princep

Available as: Wettable powder (80% simazine)

Rate per acre: 1 1/4 lb

Chemical required for 40 acres: 50 lb

Weeds controlled: Smartweed, lamb's-quarters, wild buckwheat

Application instructions: Apply after last cutting and before freeze-up. Apply in 30 gallons of water per acre. Use on established stands of alfalfa only.

Precautions: DO NOT graze for 30 days after spraying. DO NOT cut for forage for 60 days after spraying. DO NOT apply Gramoxone within one year of treating with Princep.

3. Kerb 50W

Available as: Wettable powder (50% pronamide)

Rate per acre: 2-3 lb

Chemical required for 40 acres: 80-120 lb

Weeds controlled: Chickweed, lamb's-quarters, shepherd's purse, quack grass, timothy, volunteer cereals, wild oats.

Application instructions: Apply late in the fall, just before the ground freezes. Apply in 30-50 gallons of water per acre. Weed killing activity will be increased by rain or a light irrigation.

Precautions: Weed control will not be consistent if applied to soils with greater than 5% organic matter. If less than 3 lb per acres is applied, do not graze or use for forage for 60 days. If 3 lb or more per acre is applied, do not graze or use for forage for 90 days.

4. Sinbar

Available as: Wettable powder (80% terbacil)

Rate per acre: 5/8-1 1/4 lb

Chemical required for 40 acres: 25-50 lb

Weeds controlled: Annual sowthistle, shepherd's purse, stinkweed, foxtail barley, wild mustard

Application instructions: Apply after alfalfa is dormant in the fall. Use lower rate on sandy loam and loam soils and the higher rate on clay loam and clay soils. Apply in at least 20 gallons of water per acre. Best weed control will be obtained if moisture is supplied (1/2 to 1 inch of rainfall or sprinkler irrigation) within two weeks after treatment.

Precautions: DO NOT plant treated areas to any crop within two years following the last treatment, since injury to the subsequent crop may result.

(ii) Herbicides applied in the spring.

1. Embutox E

Registered for:	Alfalfa (in permanent and established pastures)
Available as:	Liquid concentrate (64 oz 2,4-DB/gal)
Rate per acre:	40-50 fl oz
Chemical required for 40 acres:	10-12 1/2 gal
Weeds controlled:	Canada thistle*, dandelion*, lamb's-quarters, shepherd's purse, stinkweed, wild mustard.
Application instructions:	Apply either before early growth stage of legumes in the spring or after cutting. Apply in 15-20 gallons of water per acre.

2. Sinbar

Available as:	Wettable powder (80% terbacil)
Rate per acre:	5/8-1 1/4 lb
Chemical required for 40 acres:	25-50 lb
Weeds controlled:	Stinkweed, foxtail barley, wild mustard, sheperd's purse, annual sowthistle
Application instructions:	Apply before alfalfa begins new growth. For further details see instructions for fall applied Sinbar.
Precautions:	See precautions for fall applied Sinbar.

3. Carbyne

Available as:	Liquid concentrate (19.2 oz barban/gal)
Rate per acre:	34-50 fl oz
Chemical required for 40 acres:	10 3/4-12 1/2 gal
Weeds controlled:	Wild oats
Application instructions:	Apply when most of the wild oats are in the 2-leaf stage and before the legume reaches the 4 trifoliate leaf stage. Use 4-5 gallons of water per acre and a pressure of 45 psi.
Precautions:	DO NOT feed crop as forage or allow livestock to graze until at least 5 weeks after treatment.

III. Biological control

Examples of biological control of weeds in alfalfa are not numerous. However, in the Codesa and Berwyn areas toadflax is being attacked by the seed-eating weevil, *Gymnetron antirrhini* and the flower-feeding beetle, *Brachyterolus pulicarius*. These insects, while not completely destroying the weed, have reduced its vigor and seed production.

Summary and Conclusions

Competition of weeds and alfalfa for water, nutrients and light causes serious reductions in yields of alfalfa forage. Weeds also reduce the quality of alfalfa forage. Alfalfa is most vulnerable to weed competition when it is in the seedling stage.

The major key to weed control in alfalfa grown for dehydration involves obtaining good seedling establishment and maintaining the crop in a healthy, strongly competitive condition. If establishment is poor or if the alfalfa stand is thinned by winter injury, disease or insects, weed invasion can be expected.

Cultural practices such as clean seed, good tillage and cropping sequence practices, planting at the proper time of the year, good fertility practices and mowing or clipping play valuable roles in reducing weed competition in alfalfa.

Herbicides can also play a role in weed control in alfalfa. However, since the tolerance of alfalfa to many herbicides is low in comparison to cereal crops, extreme care must be exercised in their use. Individual herbicides sometimes do not control a wide enough range of weed species. Finally, the high cost of herbicides relative to returns from alfalfa used for dehydration sometimes does not permit their use.

STAND ESTABLISHMENT, FALL CUTTING MANAGEMENT AND WINTER INJURY

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A. STAND ESTABLISHMENT

The single most important factor in producing alfalfa efficiently is in establishing the stand. Without a full stand you cannot hope to achieve good production. Successful stand establishment is measured by the number of plants that emerge and the vigor of those plants as they grow and mature. A first year stand of alfalfa may have from 15-24 plants per square foot and in subsequent years this number may be reduced to 8-10 plants.

An ideal seedbed is moist and fairly firm. A good test for correct firmness is when a person leaves visible footprints but does not sink into the soil surface. The soil should be fine and granular but not powdery. If crusting is a problem as on heavy textured Grey Wooded soils, the seedbed is best left cloddy. Alfalfa prefers and grows best in lighter textured, well drained soils.

The seedbed may be prepared on plowed ground or on cultivated or disced land. Harrowing will tend to smooth the surface and should leave a smooth, satisfactory seedbed. If the land is too soft a corrugated roller may be used to firm the surface.

The objective in seeding is to place the seed in moist soil deep enough that it will not dry out before it produces feeding roots. Alfalfa should be seeded no deeper than 1 inch and preferably between 1/2 - 1 inch.

The spring is the best time of the year to seed alfalfa in the Peace region. Alfalfa should be seeded when the soil has warmed and is still moist or at a time when rainfall is expected. Long term weather records at Beaverlodge indicate late to mid June meets these conditions. By mid June there has been sufficent time to prepare a good seed bed and if weeds are a problem the area may be disced and harrowed a second time. In addition, the soil is usually warm enough for rapid germination.

The most satisfactory seeding equipment for alfalfa is a packer seeder, such as the Brillion. A good seed drill with packer wheels also performs a satisfactory job. Most drills do not have grass seed attachments and so the seed if placed in the grain box must be mixed with cracked grain or some inert filler

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Prince George, B.C.

so that the rate is not too heavy. If the seed is merely broadcast behind the discs or hoes of the drill and packer wheels are absent then harrows or a packer should follow the drill.

The recommended rate of seeding is 5-8 lbs/acre. Alfafla contains approximately 220,000 seeds per pound. On one acre, a 5 pound seeding rate will provide 25 seeds per square foot. Good seed (80% germination) will produce the required 20 seedlings per square foot. However, if the soil is dry or temperatures cool, the rate at which alfalfa seeds germinate will be reduced and some seedlings may fail to emerge due to disease organisms, soil crusting or competition from weeds; therefore, the higher seeding rates are recommended.

Proper inoculation at seeding insures good nodulation and adequate nitrogen for the crop. Improper inoculation can contribute to winter injury during the first winter, particularly under conditions of low soil nitrogen.

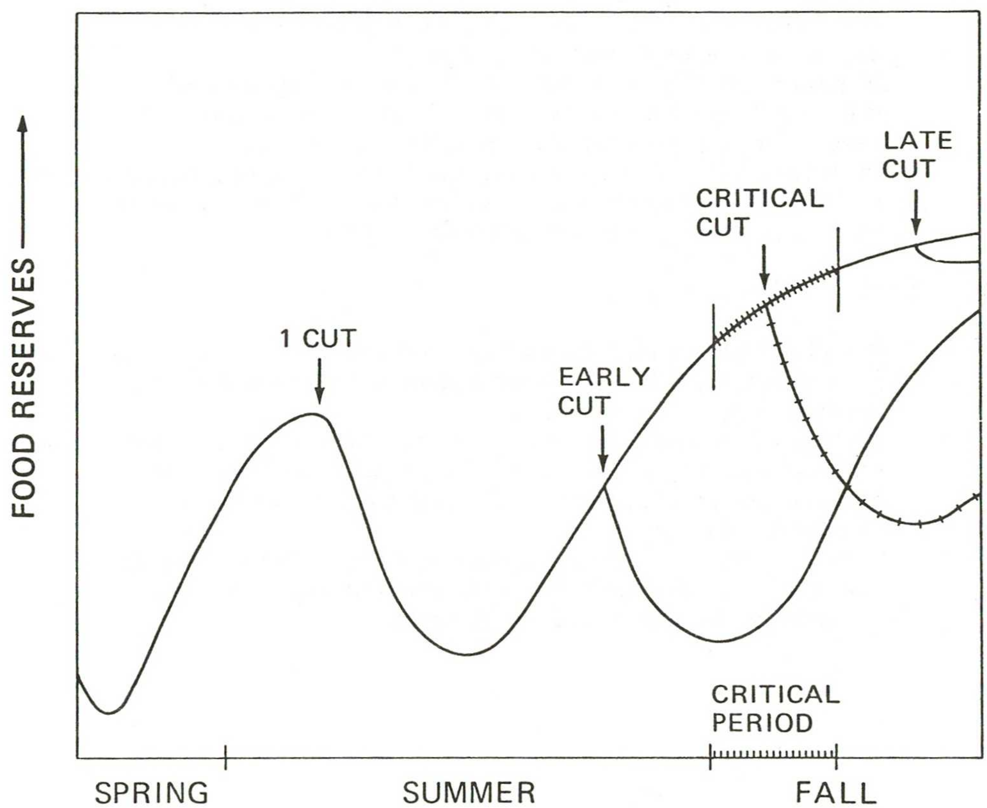
B. FALL CUTTING MANAGEMENT AND WINTER INJURY

Winter injury is a major hazard when growing alfalfa in many parts of the world. In the Peace River region, severe winter kill was recorded following the winters of 1922-23, 1926-27, 1955-56, 1973-74 and 1977-78.

Winter injury is the result of numerous factors operating either singly or jointly. These include smothering, soil heaving, low soil temperatures, diseases and desiccation. Soil pH, fertility and fall cutting management also influence the stands ability to withstand these stresses. Studies at Beaverlodge have indicated that fall cutting management is by far the single most important factor influencing the potential for winter injury.

Fall cutting management is important!

When an alfalfa field is cut in the fall, the storage of food reserves in the roots immediately cease. This is because the top growth is no longer available and the existing root reserves are used to produce new leaves and stems. These reserves continue to be depleted until the plant is large enough to produce extra food material. The excess is then stored again in the roots. There is then a slow gain in root food reserves (depending upon temperatures) until the leaves are either killed by frost, or the plant is again harvested. The final fall cut should be timed to allow reserves to either again build up prior to freeze up or cut when fall temperatures prevent additional growth from occurring (see Figure 1).



SCHEMATIC DIAGRAM OF THE EFFECT OF FALL CUTTING ON THE LEVEL OF FOOD RESERVES IN ALFALFA ROOTS

Figure 1

<u>How do you know if your plants have high food reserves</u>?

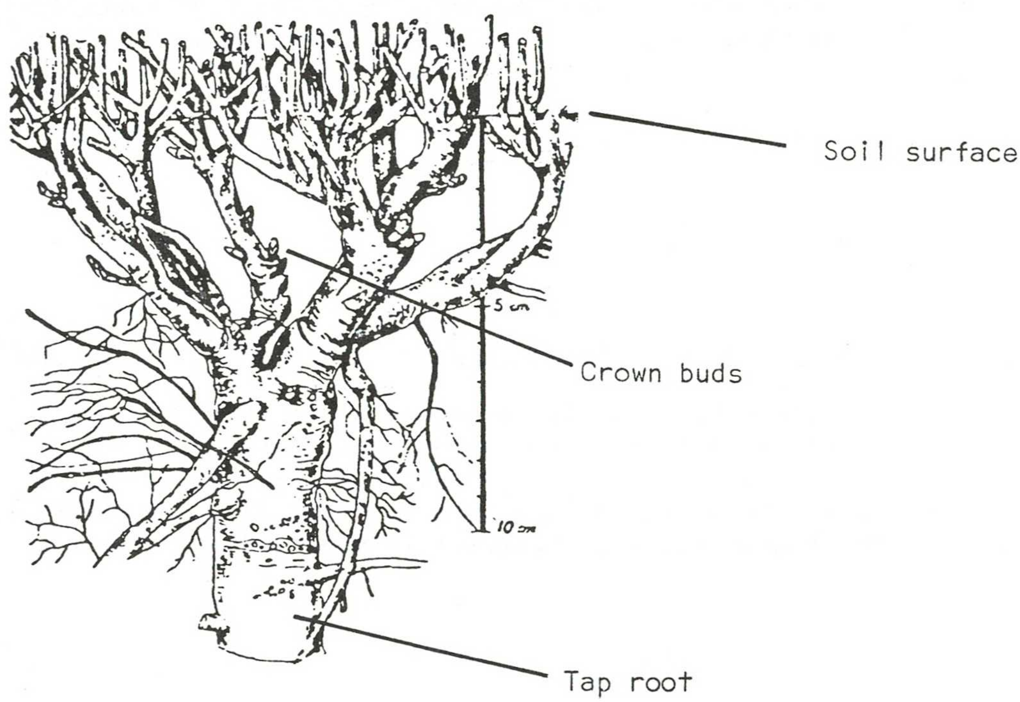
One simple way is to dig plants in the fall and observe the development of the crown buds (see Figure 2). If these buds are well developed and elongated, food reserves are high. Another way is to check the percent bloom on your field. The higher the bloom, the higher the food reserves in the roots.

CROWN BUDS

- underground buds on the crowns of alfalfa plants from which next years shoots will emerge.
- initiate during the late fall (12 mm long in September).
- dormant from October until late February after which time they start to grow regardless of soil temperature.
- by spring they will have grown and produced green leaves.
- if damaged during the fall or winter they will die and new buds may develop late the following spring.

Problems may arise if:

- buds have not developed by late September, indicating root food reserves are low and plants have a high potential for winter injury.
- buds develop into green shoots in late fall and form a late second flush of growth. This will cause food reserves to be depleted prior to winter. (This occurred in 1976 in Northern Alberta.)
- buds elongate (3 to 5 cm) underground in late fall they are susceptible to damage from pasturing animals. This problem occurred in 1978 in Northern Alberta.



AN ALFALFA CROWN

Figure 2

When is the critical harvest period?

The four to six week period before the first killing frost in the fall is a critical period for alfalfa. Cutting during this period may interfere with the plants' ability to accummulate winter food reserves since new growth is produced at the expense of winter reserves (see Figure 1). In northern Alberta, the period from early August to mid September is critical because the average date of the first fall killing frost occurs during the second or third week in September.

We cannot predict the date of the first killing frost. This date varies considerably from year to year and within any one year at individual locations. This is one of the reasons you may find that a successful cutting during this critical harvest period one year may, depending on the time of the killing frost and type of winter, be very detrimental, during a different fall and winter period. Nevertheless, the potential for winter injury increases markedly if the alfalfa is cut during the critical harvest period.

The situation is analogous to operating a vehicle in winter with an old battery. If the winter is mild you will probably have few difficulties starting your vehicle. On the other hand, if the winter is very severe, you are guaranteed to have many problems starting your car. Just as an old battery increases the potential for problems starting your car in winter, plants entering winter with low fall food reserves also have a high potential for winter injury. Thus when harvesting alfalfa during August or early September, one must remember that the potential for deteriorating the stand is increasing. This does not, however, guarantee that you will have winter injury. Injury always depends upon many other factors interacting with low food reserves during the fall, winter and spring periods.

Why are food reserves important?

A very important role of food reserves is to provide energy for the plant during the fall hardening period so that the plant can survive the freezing winter soil temperatures. Food reserves are also required to maintain the alfalfa plant during the winter dormant period and to provide a source of energy for growth in the spring.

There are a number of other conditions that also influence the alfalfa plants' ability to prepare for and survive the winter freezing soil temperatures. These include temperature, soil moisture, the length of the day and the particular stage of development of that plant during the early fall.

How does alfalfa prepare for winter?

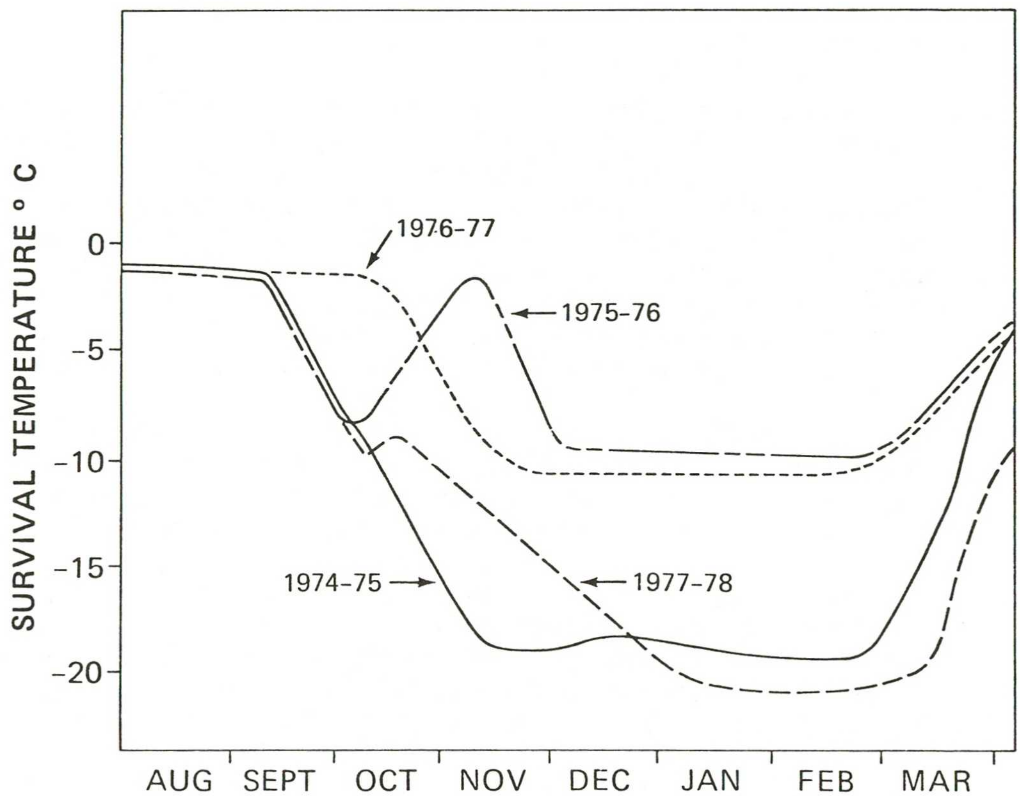
In the fall, the days become cooler and shorter. These conditions help prepare alfalfa for winter and promote the development of cold hardiness in the roots and crowns. These parts of the plant change in such a way that they can better survive the winter freezing conditions. In northern Alberta, alfalfa starts to prepare for winter in mid September. By mid November, maximum hardiness is achieved after soil temperatures remain below freezing. Alfalfa usually remains at its maximum hardiness level until early to mid March. At that time, plants deharden as soil temperatures gradually warm up. Hardiness is lost very rapidly after the soil thaws and temperatures remain above freezing.

This pattern, however, is not consistent every year. The hardiness of an alfalfa field can change from year to year depending upon environmental conditions. The alfalfa in your field may be able to survive soil temperatures as low as -20° C one year but the next year they might only survive -8° C. Soils becoming saturated with water in the late fall, will cause alfalfa to either start hardening later than normal or to deharden after some hardening has occurred. These conditions will cause the plants to be less hardy during mid-winter. Similarly, good moisture and warm temperatures during the late summer growing season may stimulate fall growth in those plants having high food reserves. This occurred during the fall of 1977 in many fields in northern Alberta. This, in effect, caused plants to loose fall food reserves because reserves were used for additional herbage production. As a result, the plants entered the winter dormant period in a less vigorous state. Plants were also less hardy in mid-winter. Figure 3 outlines how the hardiness of Anik alfalfa changed from year to year during 4 consecutive winters at Beaverlodge.

Many varieties of alfalfa differ in their ability to tolerate freezing temperatures. Flemish varieties start hardening later in the fall than *M. media* or *M. falcata* varieties. Saturated soil conditions in the fall are more detrimental to some Flemish varieties than to *M. media* or *M. falcata* varieties.

Soil temperatures are important.

Early and deep snow cover is the best protector against lethal mid-winter soil temperatures. This explains why soil temperatures in southern areas are colder than in northern areas. Northern regions receive snowfall much earlier than southern regions. Soil temperatures below -15° C occur every year at Swift Current, Saskatchewan. At Saskatoon, in the last 10 years, 4 winters had soil temperatures below -15° C. At Beaverlodge in northern Alberta, only two of the last 23 years had soil temperatures below -15° C. The first occurred during the 1955-56 winter and there was extensive injury to all forage crops. The second occurred in 1977-78 and again, extensive injury was reported. The extreme frequency of very low soil temperatures at Swift Current is undoubtedly part of the reason why winter injury is more severe at Swift Current than elsewhere in Western Canada. The warmer mid-winter soil temperatures are also the reason why more tender (Flemish) varieties of alfalfa are being introduce into northern Alberta.



CHANGES IN THE HARDINESS OF ANIK ALFALFA DURING FOUR CONSECUTIVE WINTER PERIODS

Figure 3

In 1974, optimum hardening conditions occurred. This resulted in:

- plants started hardening in mid September,
- maximum hardiness level attained in mid November after permanent soil freezing,
- plants started dehardening in the spring in repsonse to the warm soil temperatures.

In October, 1975 the soil became saturated with water for three weeks. This resulted in:

- the immediate loss of hardiness,
- plants had to wait until permanent soil freezing before hardening continued,
- plants were less hardy in mid-winter.

In 1976, crown buds continued to develop in the fall and produced a second flush of growth in late September. This resulted in:

- lower fall food reserves,
- late fall hardening,
- less hardy plants in mid-winter.

In 1977, the soil became saturated with water for one week in October, the extended fall was followed by an early December cold spell. This resulted in:

- a short dehardening period in October,
- a changed rate of hardening,
- the maximum hardiness level being attained in mid January.

What caused the winter kill during the 1977-78 winter?

In northern Alberta, a general killing frost occurred on September 1, 1977. In addition, by the last week in November there was little or no appreciable snow cover in many areas. The early December -40° C air temperatures caused soil temperatures to drop very quickly to -19° C. This was the coldest soil temperature ever recorded at Beaverlodge and was without doubt part of the cause for extensive injury. However, in our experimental plots at Beaverlodge, we found that some very hardy varieties (Anik) were injured extensively while some supposedly tender Flemish varieties (Saranac) survived.

The common factor in most surviving alfalfa varieties that year was a high level of food reserve in the late fall. It appeared that regardless of the variety, high food reserves enabled all varieties to harden more rapidly and escape the low December soil temperatures.

In fall cutting management studies, following the 1977-78 winter, extensive injury was reported where the second cut had been obtained during August through to early September in 1977. Alfalfa harvested between mid September and early October or harvested only once in the bud or bloom stage in June, escaped injury from low soil temperatures because food reserves were sufficiently high in the late fall 1977 (See Figures 4 and 5).

The two common factors associated with winter injury in 1977-78 were low December soil temperatures and low food reserves as a result of cutting during August or early September. Fields having snow cover prior to December, suffered no winter injury regardless of when the second cut was obtained. In addition, fields harvested in mid to late September in 1977 or fields in which a second cut was not obtained also were not injured, even though soil temperatures dropped very quickly in early December. Both low soil temperatures and low food reserves were essential for winter injury. Neither freezing soil temperatures nor low winter food reserves alone caused injury. This is why cutting during the critical period does not always cause injury. Low food reserves must always interact with some other factor to cause injury. Thus the critical harvest period for alfalfa includes the month of August and early September.

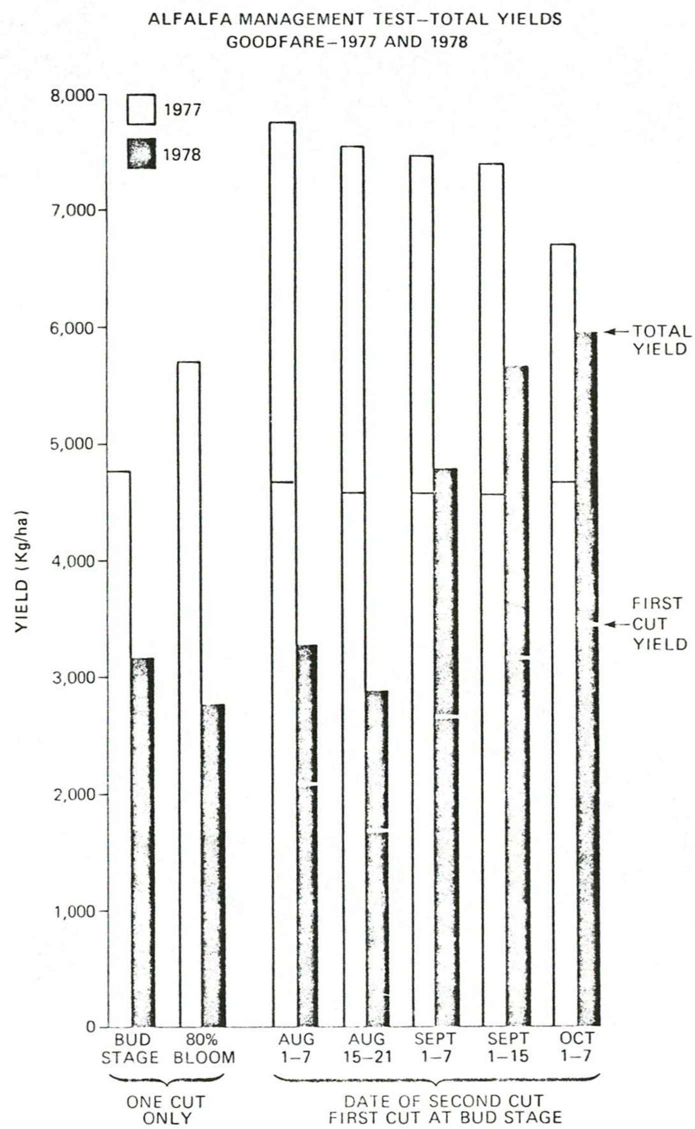
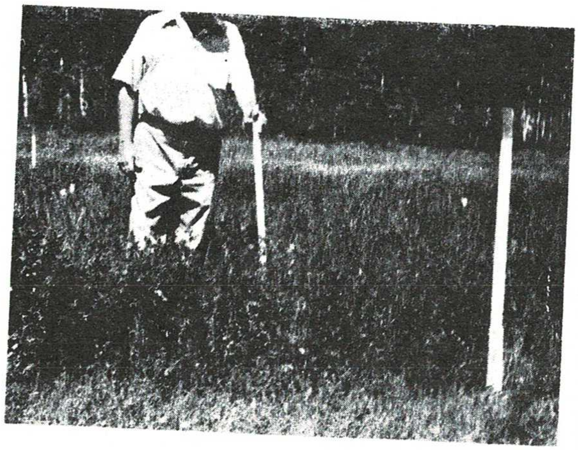
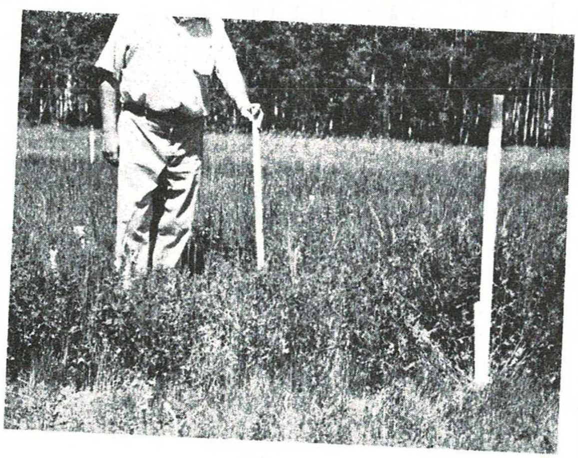


Figure 4. A Comparison of total yields of Beaver alfalfa prior to and following the severe 1977-78 winter at Goodfare, Alberta.



One cut at 80% bloom
in July 1977.

Second cut August 1, 1977,
first cut at bud stage in June.



Second cut September 1, 1977,
first cut at bud stage in June.

Second cut September 15, 1977,
first cut at bud stage in June.

Figure 5. The effect of harvesting Beaver alfalfa during the August - early September critical harvest period, prior to the severe 1977/78 winter, on survival and productivity in June 1978.

SUMMARY - WINTER SURVIVAL

1. Proper inoculation at seeding insures good nodulation and adequate nitrogen for the crop. Improper inoculation can contribute to winter injury during the first winter, particularly under conditions of nitrogen stress. A number of factors can contribute to nitrogen stress:
   a) improper inoculation methods
   b) competition from companion crops or weeds
   c) low soil fertility
   d) low soil pH.

2. Fall cutting management.
   a) In northern Alberta and British Columbia the critical harvest period for alfalfa extends for 4 to 6 weeks from August to early September.
   b) Cutting during this period may not permit sufficient time for plants to build up food reserves before winter.
   c) By cutting before or after the critical harvest periods, plants have a greater chance of entering winter with high food reserves.
   d) Plants left for seed production will have higher food reserves in the fall than plants harvested twice for herbage.

3. Low fall food reserves increase the potential for winter injury. Under conditions of low food reserves, plants are more susceptible to winter injury caused by:
   a) low soil temperatures
   b) disease organisms
   c) lengthy snow cover
   d) icing conditions
   e) freezing and thawing
   f) cool, wet spring growing conditions.

4. Conditions which contribute to a lower winter hardiness level for alfalfa in northern Alberta and British Columbia:
   a) High precipitation in October. If the soil becomes saturated with water for a period of 14-21 days, the alfalfa will completely loose all ability to survive freezing soil temperatures. Plants will not start to re-harden until the soil becomes permanently frozen. Plants will be less hardy in mid-winter under these conditions.
   b) A second flush of growth from crown buds in September. If August and September environmental conditions stimulate the crown buds to develop into green shoots in late fall and develop sufficiently to produce 6 to 8 inches of growth in September, this will result in low fall food reserves, delayed hardening in the fall and plants that are less hardy in mid-winter.
   c) If conditions contribute to the elongation of crown buds in the fall (underground 3-4 cm long) these buds are susceptible to damage by pasturing animals if the ground becomes wet.

FORAGE LEGUME RESEARCH CONDUCTED BY AGRICULTURE CANADA AT BEAVERLODGE, FT. VERMILION AND LACOMBE IN ALBERTA, MELFORT AND SASKATOON IN SASKATCHEWAN AND AT BRANDON, MANITOBA

J.S. McKenzie
Agriculture Canada
Research Station, Beaverlodge, Alta

A significant portion of the research program in the Northern Research Group at Beaverlodge and Fort Vermilion, Alberta is concerned with forage crops. In addition, much of the forage research at the Lacombe, Melfort, Saskatoon and Brandon Research Stations is also relevant to agriculture in the Peace River region. For that reason, goals of specific programs at these other Agriculture Canada Research Stations are also outlined.

The objective of Agriculture Canada's forage research program in Western Canada is: by 1984, to have developed new information and technology through multidisciplinary research that will make possible a 10% increase in potential yield of digestible dry matter from forage legumes and grasses by developing new cultivars, improved management practices and increased seed production; to have reduced non nutritional components of forages and defined new factors responsible for legume bloat; and to have developed more effective ways of fixing atmospheric nitrogen by studying hosts, bacteria and the biological process.

Specific Research Goals at 5 Agriculture Canada Research Stations

1. Beaverlodge and Fort Vermilion, Alberta

By 1984, to increase the efficiency of legume production for herbage and seed by obtaining fundamental information on environmental, pathological and physiological factors influencing winter hardiness and crop growth; refining procedures for use of companion crops, row spacing and pollinators in seed production; evaluating introductions as seed specialities; provide improved recommendations for use of lime and phosphorus fertilizers to increase yield and longevity of alfalfa; develop an improved variety of sainfoin; determine the major factors limiting nitrogen fixation in northwestern Canada; select improved strains of Rhizobium and develop more effective inoculants and inoculation methods; and to obtain essential information on the climatic resources for agriculture in northwestern Canada and ascertain the role of these resources in crop production.

2. Lacombe, Alberta

By 1984, increase the yield of legume crops by 5%, disease resistance by 5% and persistance by 20% over standard check varieties by introducing improved varieties through the cooperative testing program, by selecting at least five lines of trefoil superior to the check variety, by developing improved management practices related to establishment and renovation of stands and to time and frequency of harvesting and by optimizing time and rate of fertilizer application.

3. Melfort, Saskatchewan

By 1984, increase the value of legume crops for forage and seed by 10% by introducing, evaluating and developing improved cultivars and management practices.

4. Saskatoon, Saskatchewan

By 1984, license and release a low coumarin cultivar of sweet clover, develop a bloat safe alfalfa synthetic and develop integrated control of pest insects for alfalfa.

5. Brandon, Manitoba

By 1984, elucidate the mechanism for controlling nitrogen fixation by legumes, determine the effect of macro and micro nutrients on bloat producing factors in alfalfa and determine the potential for management in improving quality and yield of forage legumes through cultivar evaluation and management.

How the individual Research Stations hope to achieve their goals.

(1) Beaverlodge and Ft. Vermilion, Alberta

1. Develop management techniques to maximize legume seed production.

2. Obtain fundamental information on major environmental pathological and physiological factors influencing winter hardiness in northwestern Canada.

3. Develop an improved variety of sainfoin for northwestern Canada and provide a continuous supply of breeder seed of Dawn Alsike clover (released in 1974) as required by the Canadian Forage Seed Project.

4. Continue evaluation of new legume cultivars from OECD scheme and Canadian breeders for northwestern Canada.

5. Increase the efficiency of liming for legumes through correlation of crop response with laboratory analysis to determine soil acidity characteristics, and investigate

the fertilizer requirement of alfalfa on lime amended soils.

6. Determine the effects of phosphorus fertilizer on dry matter yield and longevity of alfalfa in seedlings made on several different soil types.

7. Evaluate, the influence of some environmental factors on symbiotic nitrogen fixation and growth of legumes.

8. Evaluate, nitrogen immobilization-mineralization relationships in legume sod breaking.

9. Assess the role of climatic factors on forage legumes production in northwestern Canada.

(2) Lacombe, Alberta

1. Identify and monitor levels of disease in legumes and establish severity, host range, availability of genetic resistance and determine methods of control.

2. Evaluate annuals for agronomic adaptability and produce lines with sufficient earliness, yield and disease resistance for production in Central Alberta.

3. Assess the impact of sulphur gas emissions from processing and sulphur extractions in Central Alberta on agriculture crops and soils.

4. Develop effective weed control practices to improve the yield and quality of forage legume and grass crops in Central Alberta.

5. Determine yield response curves for forage species to nitrogen and phosphorus fertilization.

6. Compare forage production and longevity from a single large application of phosphorus at time of establishment with repeated annual applications of phosphorus.

7. Evaluate the long term effect of lime on soil pH and alfalfa production on acidic gray wood soils of Central Alberta.

8. Develop effective weed control practices to improve the yield and quality of forage legume and grass crops in Central Alberta.

(3) Melfort, Saskatchewan

1. Investigate the effects of differing management practices on forage growth and yield quality.

2. Measure the effects of weed competition on legume establishment.

3. Investigate the response of legumes to herbicides.

(4) Saskatoon, Saskatchewan

1. Develop an alfalfa which is bloat safe, wilt resistant, and has improved resistance to forage diseases and agronomic characteristics equal to the best current varieties.

2. Develop and release a low coumarin variety of sweet clover.

3. Update integrated control procedures for alfalfa plant bug and lygus bugs, including the introduction of biological control agents, evaluation of alternative insecticides and the determination of economic threshold populations and damage potential.

4. Determine the causes of losses due to low temperature diseases in forage legumes, develop methods for screening forage legume strains for low temperature disease resistance under dryland and irrigated conditions.

5. Increase seed yields of alfalfa by improved management of pollinators and crops.

(5) Brandon, Manitoba

1. Evaluate alfalfa cultivars for multiple cuts annually to maximize production capability of Manitoba soil-climatic conditions.

2. Evaluate alfalfa cultivars for long term production currently in seventh production year.

3. Evaluate alfalfa cultivars developed for special purposes, e.g. high protein content for the dehydration industry, self fertilizing alfalfa for seed production without pollinator bees.

4. Evaluate sweet clover cultivars of low coumarin content for production capability to reduce producer concern for sweet clover disease when feeding livestock.

5. Determine the nutrient requirement of alfalfa and other perennial legumes for maximum yield of high quality forage.

6. Develop techniques for the fertilization of legumes in the year of establishment and for established stands.

7. Determine the effect of macro and micro nutrients (P, S K, and Mo, Cu, Fe) on bloat producing factors in alfalfa.

8. Determine the soil and environmental factors that effect nitrogen fixation by alfalfa and clovers, and the contribution of residual nitrogen from these legumes to non-nitrogen fixing crops grown in association with or following in a cropping rotation.

9. Study the efficiency of use of fertilizer phosphorus by perennial (alfalfa), biennial (clover), and annual (soybeans, fababeans) legumes, when the fertilizer is applied at different times (fall versus spring), using different techniques (one large application for several years versus annual applications of small rates) and with different methods (drilled versus broadcast).

TITLES AND LOCATIONS OF AGRICULTURE CANADA'S ALFALFA RESEARCH PLOTS OF INTEREST TO PRODUCERS IN THE PEACE RIVER REGION*

	Cooperator and Location	Title
1. Beaverlodge, Alta	Beaverlodge Research Station NE-36-71-10-W6	1. Alfalfa fall cutting management study (seeded 1975) 2. Alfalfa variety longevity study (21 varieties seeded 1979) 3. Alfalfa variety tests for seed and herbage (seeded each year) 4. Alfalfa winter injury simulation tests (seeded 1978, 79 and 80) 5. Effect of methods of inoculation on alfalfa production (seeded 1978) 6. Effect of acid tolerant Rhizobia on alfalfa production (seeded 1978) 7. Breeders seed of Anik and Rangelander alfalfa 8. Forage introductions nursery
	B. Nychka SE6-72-9-W6 (seeded 1979)	1. Effect of different strains of Rhizobia on alfalfa varieties 2. Evaluation of nitrogen fixation on forage legumes 3. Effect of inoculation types and methods of application on alfalfa and red clover production 4. Forage legume productivity study. 5. Alfalfa var. - fall cutting mngt. interaction study (1979)
	M. Nelson SW30-72-9-W6	1. Effect of legumes on sub soil permeability

	N. Foster SE25-71-10-W6	1. Forage introductions nursery
2. Goodfare, Alta	J. Langan SW21-77-12-W6 (seeded 1979)	1. Effect of different strains of Rhizobia on alfalfa varieties 2. Evaluation of nitrogen fixation on forage legumes 3. Effect of inoculation types and methods of application on alfalfa and red clover production 4. Forage legume productivity study.
3. Wembley, Alta	D. Nofziger NW26-70-8-W6 (seeded 1977)	1. Alfalfa variety test 2. Alfalfa fall cutting management study 3. Effect of time of application of nitrogen fertilizer on alfalfa production (initiated 1980)
	J. Heikel SW14-71-9-W6	1. Effect of legumes on sub soil permeability
4. HuAllen, Alta	A. Schultz NW17-70-9-W6	1. Effect of different strains of Rhizobia on alfalfa varieties 2. Evaluation of nitrogen fixation on forage legumes 3. Effect of inoculation types and methods of application on alfalfa and red clover production) 4. Forage legume productivity study. 5. Alfalfa var.-fall cutting mngt. interaction study (1979)
5. Grovedale, Alta	R. Orbanski SW2-69-7-W6	1. Effect of legumes on sub soil permeability

6. Sexsmith, Alta	I. Vekved NW16-73-7-W6	1. Effect of legumes on sub soil permeability
	A. Balisky NW7-73-7-W6	1. Effect of legumes on sub soil permeability
7. Debolt, Alta	J. Bandzul SW32-72-26-W5	1. Effect of lime and fertilizer on alfalfa and barley production
8. Spirit River, Alta	I. Rudl SW28-81-8-W6	1. Effect of lime and fertilizer on alfalfa and barley production 2. Long term effect of lime on legume, cereal and oilseed production
	C. Little SW25-81-8-W6	1. Effect of lime and fertilizer on alfalfa and barley production
9. Valleyview, Alta	D. Penson SW29-69-22-W5	1. Long term effect of lime on legume, cereal and oilseed production
	V. Lehman SW26-70-22-W5	1. Long term effect of lime on legume cereal and oilseed production

10.	McLennan, Alta	N. Lamoureau SE2-78-20-W5	1. Effect of lime and fertilizer on alfalfa and barley production
11.	Falher, Alta	N. Erickson SE14-78-21-W5	1. Alfalfa variety test 2. Alfalfa fall cutting management test
		L. Cloutier NE22-78-20-W5	1. Effect of lime on alfalfa production
12.	Donnely, Alta	G. Beaupre NW1-78-21-W5	1. Forage introductions nursery
13.	High Level, Alta	B. Fedeyko NW35-109-17-W5 (seeded 1979)	1. Alfalfa variety - fall cutting management interaction test 2. Forage introductions nursery
		J. Sarapuk SW5-110-14-W5	1. Effect of legumes on sub soil permeability
14.	Ft. Vermilion, Alta	Experimental Farm NW14-108-13-W5	1. Alfalfa fall cutting management study (seeded 1975) 2. Alfalfa variety test for seed and herbage (seeded each year) 3. Alfalfa variety - fall cutting management interaction test (seeded 1979)

			4. Breeders seed of Peace and Anik alfalfa 5. Forage introductions nursery
		H. Wieler SE5-107-4-W5 (seeded 1975)	1. Alfalfa variety test
		A. Schmidt SW27-107-13-W5	1. Effect of legumes on sub soil permeability
15.	Arras, B.C.	R. Jerome SE22-78-17-W6	1. Effect of lime on alfalfa productivity
16.	Ft. St. John, B.C.	R. Hastings SW1-112-19-W6 NE2-112-19-W6	1. Long term effect of lime on legume, cereal and oilseed production

* Please Note:
Visitors are welcome at all plots! Please seek permission from cooperators.

RESEARCH BRANCH, AGRICULTURE CANADA

NORTHERN RESEARCH GROUP

RESEARCH STATION, BEAVERLODGE, ALBERTA

ADMINISTRATION

L.P.S. Spangelo, B.S.A., M. Sc., Ph. D.	Director
W.H. Marshall	Administrative Officer
J.V. Tetarenko	Office Manager

CEREAL AND OILSEED CROPS

R.I. Wolfe, Ph.D.	Head of Section, Barley
J.B. Thomas, B.Sc., M. Sc., Ph.D.	Wheat and Rapeseed

ENVIRONMENT AND SOILS

W.A. Rice, B.S.A., M. Sc., Ph.D.	Head of Section, Microbiology
W.G. Bailey, B.Sc., Ph.D.	Micrometeorologist
A.L. Darwent, B.S.A., M. Sc., Ph. D.	Weed Control (on CIDA assignment in Sri Lanka)
J.G.N. Davidson, B.S.F., M. Sc., Ph.D.	Plant Pathology
A.M.F. Hennig, B.Sc.	Crop Management
J.S. McKenzie, B.S.A., M.Sc., Ph.D.	Plant Survival
Vacant	Organic Matter Relationships

FORAGE CROPS AND APICULTURE

C.R. Elliott, B.Sc., M. Sc., Ph.D.	Head of Section, Grass Seed Management
S.G. Bonin, B.S.A., Ph.D.	Grass Breeding
P. Pankiw, B.S.A., M.Sc., Ph.D. (Emeritus)	Legume Seed Management
Vacant	Agronomist
D.L. Nelson, B.S.A., M.Sc.	Apiculture (Head of Unit)
T.I. Szabo, B.A.E., M.Sc., Ph.D.	Apiculture
Vacant	Apiculture Pathology

EXPERIMENTAL FARM, FORT VERMILION, ALBERTA

B. Siemens, B.S.A., M.Sc.	Superintendent
Vacant	Crop Production Specialist

September, 1980