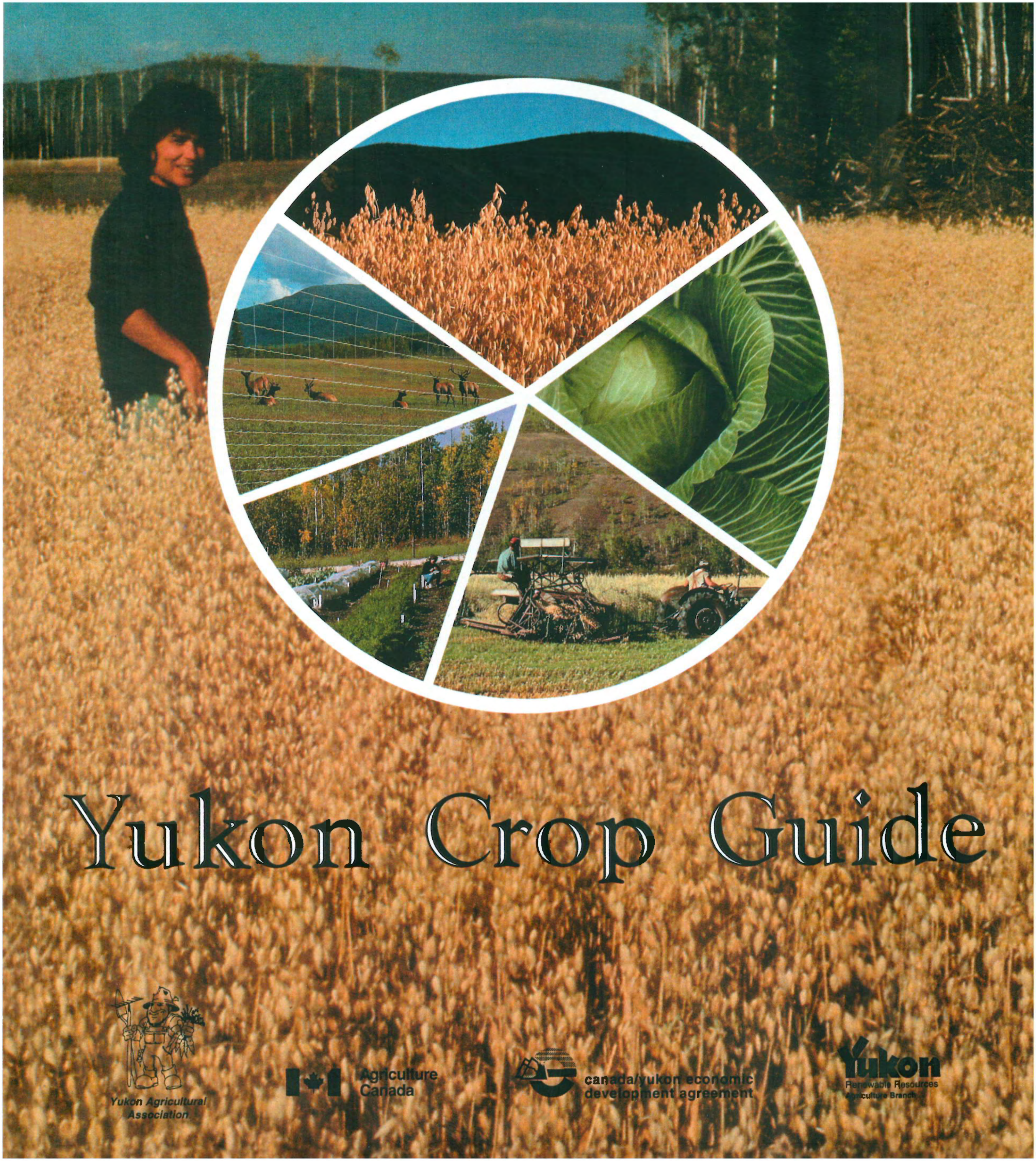

# Yukon Crop Guide

Yukon Agricultural Association

Agriculture Canada

canada/yukon economic development agreement

Yukon Renewable Resources Agriculture Branch

# YUKON CROP GUIDE
# 1994

*Prepared By*

KATHY BISSET, B.Sc., P.Ag
K. BISSET & ASSOCIATES
BOX 4793, WHITEHORSE, YUKON
Y1A 4N6

*For*

YUKON AGRICULTURAL ASSOCIATION
BOX 4703, WHITEHORSE, YUKON
Y1A 3V7

Copies of the Yukon Crop Guide are available from:


*Mail:* Yukon Agricultural Association
Box 4703
Whitehorse, Yukon Y1A 3V7
Canada

*Office:* Room 103 T.C. Richards Building – 302 Steele Street
Whitehorse, Yukon

*Telephone:* (403) 668-6864

*Fax:* (403) 667-4507

## PREFACE

In 1990, the Yukon Agricultural Association (YAA) proposed to Agriculture Canada to prepare a crop guide which would summarize agricultural research and assist the existing and prospective growers of the Yukon, who generally have to contend with many more variables and obstacles than growers in the south.

In 1992, agreements for funding were approved under the Canadian Agri-food Development Initiative (CAFDI), Agriculture Canada, under the Canadian Yukon Economic Development Agreement, Government of Yukon and from the Agriculture Branch, Government of Yukon.

A wide range of information has been compiled from farm development to management of soils and field crops. This includes results from the New Crop Development Program (NCDP) (1985-1987), the Yukon Crop Development Program (YCDP) (1988-1990), the Agriculture Canada Research Station near Haines Junction (1945-1967), and studies completed by the Agriculture Branch, Government of Yukon (1988-1994). Also included is relevant agricultural research and experience from the Atlantic provinces west to British Columbia, and Alaska.

Future additions to this manual will cover areas such as marketing and storage, greenhousing and livestock production. Further research is needed to determine the best practices for the Yukon to encourage a sustainable and environmentally friendly agriculture industry.

*Kathy Bisset*
*Whitehorse, Yukon*
*December 1994*

# ACKNOWLEDGEMENTS

## THE YUKON AGRICULTURAL ASSOCIATION

The Yukon Agricultural Association (YAA) was established in Whitehorse in April 1974 to foster and promote the agricultural industry in the Yukon. In 1984, two new chapters were added to the Association, the Klondike Chapter in Dawson and the Stewart Valley Chapter in Mayo.

The Association has acted as a lobby group for Yukon farmers and assisted Government with the development of an agricultural policy. In 1982, the Agricultural Development Council (ADC) was established to liaise with Government to develop policy guidelines and assist with the acceptance of agricultural applications. In 1985, the Agricultural Policy Advisory Committee (APAC) was created to provide a forum for YAA and Government of Yukon to work together to develop government policy and resolve agricultural issues.

In 1983, the Whitehorse chapter formally established the Six Carrot Farmers Market which is open every Saturday during the summer as an outlet for farmer's produce. Between 1985 - 1990, the Association administrated the New Crop Development Program and the Yukon Crop Development Program. New varieties of cereals, forages, and vegetables were tested, soil and crop management practices were investigated on farms throughout the Yukon. Each spring, agricultural seminars have been arranged in conjunction with the Yukon Agriculture Branch. In September 1992, YAA hosted the First Circumpolar Agricultural Conference where over 400 specialists in northern agriculture gathered to share their knowledge. The Association has recently been involved in the proposed development of an abbatoir, educational awareness programs and the establishment of a permanent place for the Farmer's Market on the Whitehorse waterfront.

## THE AUTHOR

Kathy Bisset,B.Sc, P.Ag, has been involved with agricultural research in the Yukon since 1986. She was the Project Manager for both the New Crop Development Program (1986-1987) and the Yukon Crop Development Program (1988-1990). Between 1990-1993, Kathy worked at the Agriculture Branch research plots near Whitehorse and assisted Agriculture Canada - Yukon Soil Survey Unit with local initiatives under the National Soil Conservation Program. She presented results of the Yukon Crop Development Program at the First Circumpolar Agricultural Conference held in Whitehorse in 1992. Recently, Kathy has worked on the Yukon Farm Survey and soil moisture projects funded under the Green Plan. She is currently developing her own farm in the Whitehorse area.

The author would like to thank all those people involved in this project between 1992-1994.

**PROJECT FUNDING:**

- Yukon Agricultural Association
- Agriculture Canada, Agri-Food Market & Industry Services Branch, Canadian Agri-food Development Initiative (CAFDI) Program
- Economic Development, Government of Yukon
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- Project Co-ordinator

Scott Smith, P.Ag - Agriculture Canada, Yukon Soil Survey Unit
- Editorial Assistance

All the Yukon growers who contributed growing tips and other producer information.

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# INTRODUCTION

## MANUAL FORMAT AND SOURCES

This manual is intended to be an easy to use reference for those interested in developing a farm and producing field crops in the Yukon. Relevant agricultural research and important management principles have been summarized. Topics are arranged into sections covering climate and soil capability, farm development, soil and crop management and the production of forages, cereals, vegetables and berries. Comments from Yukon producers have been incorporated as growing tips to add local expertise on management practices. The notebook format allows for future additions to the manual, which will hopefully include livestock and greenhouse production.

A complete list of the information sources that have been utilized in the preparation of this manual is presented in Appendix A.

This includes publications from the author's personal library, local agricultural research project reports from Agriculture Canada Haines Junction Mile 1019 Experimental Farm, the Yukon Agricultural Branch, and private individuals including:

- New Crop Development Program (NCDP) Field Season Reports 1985-1986.
- Yukon Crop Development Program (YCDP) Field Season Reports 1987-1990.
- Yukon Agriculture Branch Research Reports 1988-1990.
- Haines Junction Mile 1019 Experimental Farm Reports 1945-1952, 1953-1959, 1960-1964.
- Research projects funded by the Agri-Food Component of Green Plan, 1993.

Publications, pamphlets and research notes were used from agricultural departments and research stations across Canada and from the University of Alaska. Agricultural textbooks were utilized for details on management practices. The books, crop guides and publications specifically used for the Figures and Tables are indicated throughout this manual.

> *"A major goal is to develop the Yukon agricultural industry in a sustainable manner."*
>
> - Yukon Agricultural Association 1994.
>
> ---
>
> *"Agriculture Canada defines sustainable agriculture as 'Agri-food systems that are economically viable, and meet society's need for safe and nutritious food, while conserving or enhancing natural resources and the quality of the environment for future generations.'"*
>
> - *Growing Together - Report to Ministers of Agriculture,* Federal-Provincial Agriculture Committee on Environmental Sustainability, 1990.

> *"A goal of the Yukon agricultural industry is to replace 25 percent of imported foodstuffs with local products. Figures of food consumed in the Yukon per year for our population of roughly 30,000 include: 1000 tons of potatoes, 400 tons of other root vegetables, 300 tons of leaf, pod and bulb vegetables, 350,000 dozen eggs, 2,500,000 litres of milk, 4,500 beef animals, 9,500 hogs and 430,000 fowl and chickens."*
>
> - D. Filteau, 1986.

## YUKON AGRICULTURAL INDUSTRY

During the gold rush period, initiated in 1896, the influx of prospectors to the Yukon created a demand for agricultural crops. During this time several thousand acres of land were cleared and seeded to vegetable and forage crops. Much of this land was in the vicinity of Swede Creek, five miles upstream from Dawson City. After the goldrush, from 1901-1911, the population of the Yukon declined rapidly from 27,219 to 8,512. The demand for and the production of farm produce dropped considerably. Agricultural activity continued on a small scale. In the 1920s and 30's on farms throughout the territory the ability to raise crops and livestock was demonstrated: wheat, vegetables and livestock were raised in Dawson City and Pelly Farm, hay was raised in quantity in the Indian River valley, and vegetables and hay were produced in Mayo. In 1931 there were 41 active farms in the Yukon with 5135 acres of farmland. By 1961, 15 farms were active on 7979 acres. In the 1971 census, twelve farms were listed with a total of 2,271 acres of which 1,418 acres were improved with a total value of sales at $18,380. In 1975, a moratorium was imposed on the allocation of federal crown land for agricultural and grazing purposes.

***Past Yukon Populations***

| | |
|---|---|
| 1992 | 31,395 |
| 1981 | 23,153 |
| 1971 | 18,390 |
| 1961 | 14,628 |
| 1951 | 9,096 |
| 1941 | 4,914 |
| 1931 | 4,230 |
| 1921 | 4,157 |
| 1911 | 8,512 |
| 1901 | 27,219 |

- *Yukon R.V. Traveller,* Government of Yukon, 1994.

In 1982, the Agriculture Development Council (ADC), consisting of the president of YAA and two other persons from the private sector, began to develop an agricultural land disposition policy. This policy was adopted by the Yukon Government in May 1982 at which time the Yukon Government began accepting applications for agricultural land. Since then the industry has undergone a period of rapid growth and the number of producers and land area in production has increased significantly. Since 1985, the progress of the agricultural industry has been presented in the State of the Industry Reports prepared by Agriculture Canada-Yukon Survey Unit and the Yukon Agriculture Branch. Reports are available for 1984, 1985, 1986-1987, 1988-1989, and 1990-1991.

> Practically all the vegetables now consumed in the territory are home grown and the quality is unsurpassed.
>
> - *The Yukon Territory 1926* Department of the Interior Report, Ottawa 1926.

Statistics Canada 1984 census figures indicate that from 1986 to 1991 farm numbers have increased from 38 to 113, land in crops has expanded from 1330 to 3446 acres and that agricultural sales have increased from $487,000 to 1.98 million.

## YUKON FARM SURVEY 1991 STATISTICS

The Yukon Farm Survey is the most current survey of the Yukon agricultural industry. Between October 1991 to April 1992 Yukon farmers were interviewed for the results of the 1991 growing season and to acquire up to date statistics on land areas developed and types of production. A total of 137 farms were reported in the Yukon Farm Survey.

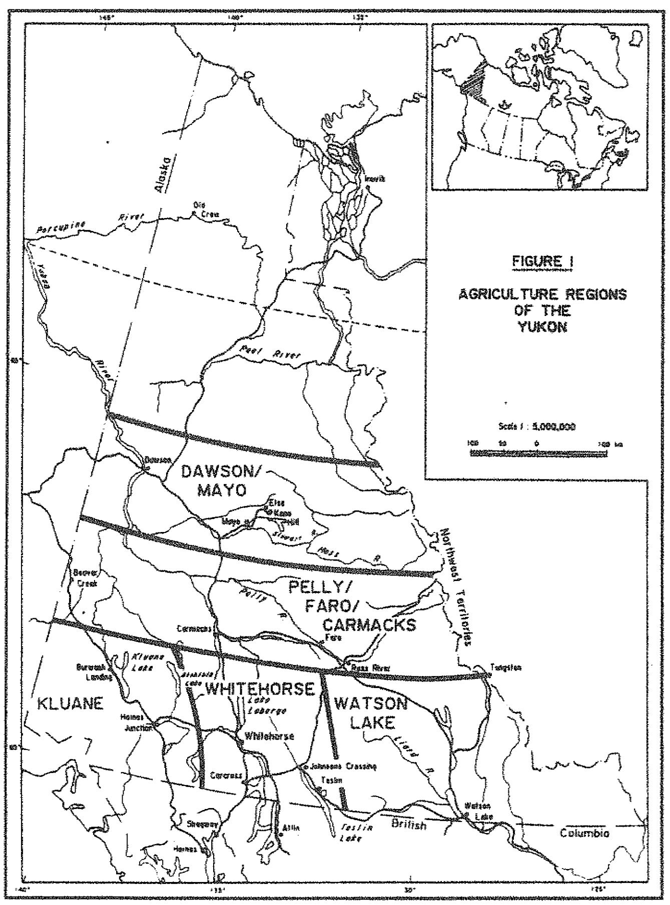



Figure 1.1 Agricultural Regions of the Yukon

### *Agricultural Land Use*

Agricultural production extends from Watson Lake near the British Columbia border at a latitude of 60 degrees to Dawson City at 64 degrees latitude. For the Farm Survey, the Yukon was divided into five agricultural regions as shown in Figure 1.1. A total of 18,387 acres were reported as farmland; 71% of all farmland is within the Whitehorse region producing 71% of agricultural sales. Dawson/Mayo is the second largest agricultural region, representing 11% of agricultural development.

Table 1.1 Agricultural Land Use by Region

| Region | # Reporting Farms | Area in Farmland ha/ac | Value of Farmland Sales $ |
|---|---|---|---|
| Whitehorse | 98 | 5261/13152 | 1,228,350 |
| Dawson/Mayo | 15 | 805/2012 | 188,012 |
| Kluane | 10 | 537/1342 | 125,341 |
| Pelly/Faro/Carmacks | 8 | 430/1075 | 100,273 |
| Watson Lake | 6 | 322/805 | 75,205 |
| TOTAL | 137 | 7355/18387 | 1,717,181 |

### *Farmland Use*

The areas of farmland used for crops, livestock and game-farming and that which is under development is indicated Table 1.2. A total of 8850 acres are in crops or used for livestock and game farming. Another 7057 acres of current farmland are under development or suitable for production.

Table 1.2 Farmland Use

| | Area Hectares/Acres |
|---|---|
| - Land in Crops | 1114/2785 |
| - Land used for Livestock & Game Farming | 2426/6065 |
| - Land under development for Production | 1665/4162 |
| - Land suitable but not in Production | 1158/2895 |
| - Land not suitable for Production | 610/1525 |
| - Other Lands | 382/955 |
| TOTAL FARMLAND | 7355/18387 |

In 1991, 33% of farmland was used for livestock production and 15% was planted to crops. Another 23% of farmland was under development for production and 16% suitable for production but not being farmed. 88% of farm operators indicated that they intended to further develop their holdings in the next 3-5 years.

A total of 39 farms reported development as their primary activity. Producers indicated that available time and financing are the most limiting factors to further farm development. An additional 5% is defined as "other lands" and includes buildings, structures, roads and penned areas.

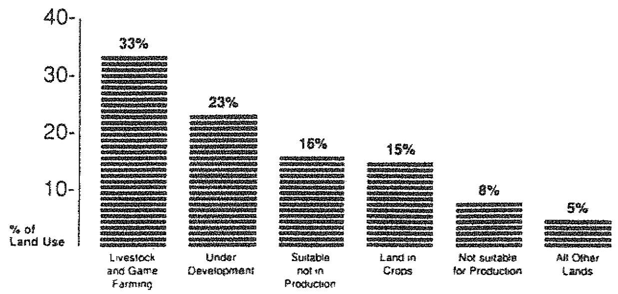



Figure 1.2 Percent Farmland Use

### *Farm Receipts By Sector*

Out of 137 Reporting Farms, 106 Farms reported sales of a total of 1.71 million dollars. The value of additional production used on the farm (not sold) is estimated to be $600,000. Including this on-farm consumption, it is estimated that the agricultural production is valued at 2.3 million. Over 1/2 of sales are from the livestock and products sector. Exported sales of Yukon grown products for 1991 were $100,000.

Table 1.3 Farm Receipts by Sector

| Sector | # Reporting Farms | Value of Sales $ |
|---|---|---|
| Livestock & Products | 28 | 914,945 |
| Field Crops | 30 | 279,054 |
| Game Farming | 9 | 228,500 |
| Horticulture | 27 | 188,535 |
| Other Agric. Products | 12 | 106,150 |
| TOTAL | 106 | 1,717,184 |

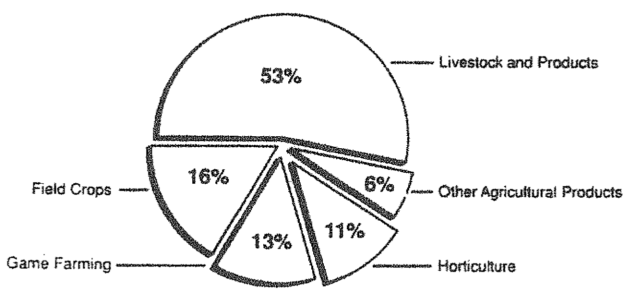



Figure 1.3: Percent of Receipts by Agricultural Sector

The livestock sector represents 53% of sales for domestic animal production and the raising of field crops 16%. Game farming, including the raising of elk brings 13% of the total sales. Horticulture, including greenhousing and field scale vegetables and berries represents 11% of sales. Other agricultural products including sod, honey, topsoil, and compost/manure account to 6%.

### *Yukon Farm Profile*

The 1991 Farm Survey revealed the average Yukon farm profile:

- Average Yukon farm is 135 acres.
- Average farm sales in 1991 were $12,500.
- Average farm capital is $175,000.
- 15% of farms are full time operations.
- 50% of farms reported hiring seasonal labour.
- 60% of agricultural holdings are titled.

Source: *Yukon Farm Survey 1991*, M. White, K. Bisset, YAA and Yukon Agriculture Branch, 1993.

## YUKON AGRICULTURAL RESEARCH

In 1917, the Dominion Department of Agriculture established an experimental substation at Swede Creek, which joins the left bank of the Yukon River six miles above Dawson. Experiments were devoted to soil improvements and different tests of grains, grasses and vegetables. Results confirmed that a variety of crops could be grown successfully at Latitude 64 degrees north and that yields and quality of the produce compared favorably with those obtained in southern parts of Canada. The Swede Creek substation continued to function until the end of the 1925 crop season.

In 1944, an area was selected for an experimental farm near Pine Creek (Haines Junction) at Mile 1019 of the Alaska Highway. Some land was broken in 1945 and the first seedings made in 1946. Compared with Dawson, the summers at Mile 1019 are cooler and the growing season shorter. It was realized that if crops could grow successfully at Mile 1019 they would be more successful in more favorable locations in the Yukon. The Experimental Farm was closed in 1968. During its operation experiments were conducted with animals and poultry, forage and cereal crops, vegetables and flowers.

Formal agricultural research did not occur again until 1985 with the creation of the New Crop Development Program, operating from 1985 to 1987, and the Yukon Crop Development Program from 1988-1990. Both projects involved on farm trials in the major farming regions, testing a variety of cereal, forage and vegetable crops under various soil and crop management techniques. In 1988, the Yukon Agricultural Branch started a research plot north of Whitehorse to test a variety of crops, which is still continuing today. From 1990-1993, the Yukon Soil Survey Unit, Agriculture Canada, conducted a salinity research project, funded by the National soil Conservation Program. Several agricultural research projects were funded under the Agri-Food Component of the Green Plan during the summer of 1993. Relevant information from the Experimental Farm reports and agricultural research projects has been presented throughout this manual.

# AGRICULTURAL CAPABILITY

The Yukon Territory covers a diverse area including 478,970 sq km of land and 4,480 sq km of fresh water, a total of 483,450 sq km (186,675 sq miles). Of this, approximately 668,000 ha (1,650,605 acres) of land exist which are capable of producing agricultural crops. An additional 136,000 ha (336,000 acres) offer some potential for grazing. The remainder is not suitable for agriculture due to climate, terrain or soil type limitations.

The major river valleys and areas near communities have been surveyed for agricultural potential. The surveyed areas where climatic conditions are judged suitable for agriculture are illustrated in Figure 2.1. In these major valley systems the growing climate is suitable and suitable soils may be found distributed throughout these areas.

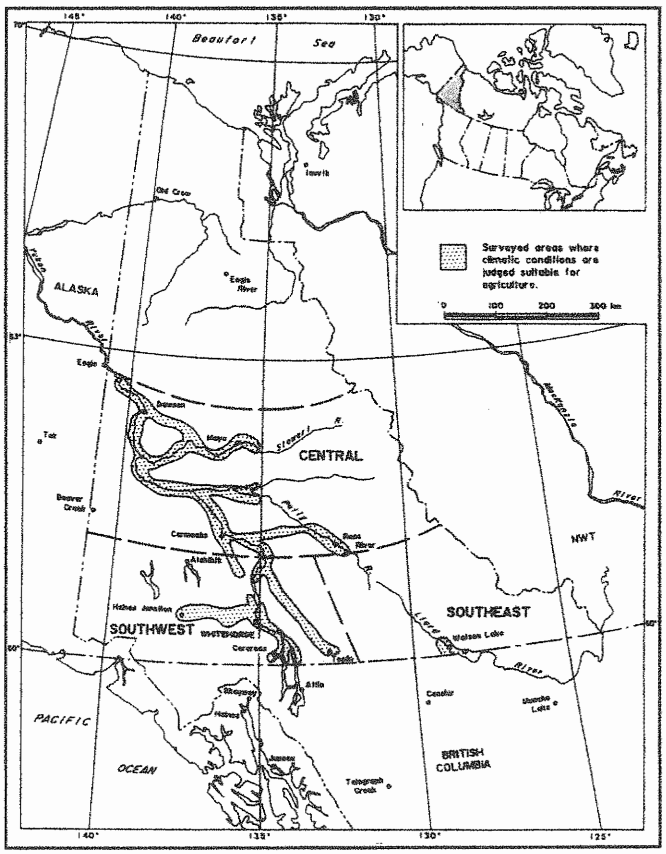



Figure 2.1 Surveyed Areas Suitable for Agriculture

Source: *Agroclimate and Soil Resources in the Yukon*, C.A.S. Smith, Proceedings – 1st Circumpolar Agriculture Conference, 1994

## AGRICULTURAL CAPABILITY CLASSES

The capability of a land area for agriculture is determined by the climate, soil and landscape characteristics. In general, the climate determines the range of crops possible in an area, the soils and landscape govern the type and relative level of management practices required. Land is grouped into seven classes according to their potentialities and limitations for agricultural use.

Table 2.1 Agricultural Capability Classes

Class 1 - These lands have no significant limitations for a full range of common agricultural crops.

Class 2 - These lands have slight limitations that restrict the range of some crops or require modified management practices, but still allow the production of grain and warm season vegetables.

Class 3 - These lands have moderate limitations that restrict the range of crops or require special management practices; capable of producing small grain cereals and vegetables.

Class 4 - These lands have severe limitations that restrict the range of crops to forages, cold-hardy grain and vegetables or require special management practices or both.

Class 5 - These lands have very severe limitations that restrict the range of crops to forages,improved pastures and cold hardy vegetables.

Class 6 - These lands have such severe limitations for cultivated agriculture that cropping is not feasible. The lands may be suitable for native range.

Class 7 - These lands have no capability for cultivated agriculture or range for domestic animals.

Source: *Agricultural Potential and Climate Change in the Yukon*, C.Tarnocai, C.A.S. Smith, D. Beckman, in Proceedings of the Third Meeting on Northern Climate, Agriculture Canada, 1988.

In the Yukon, there are no Class 1 and 2 agricultural lands. Lands have been identified as belonging to agroclimatic capability class 3, 4, and 5. Class 3 lands are defined as those with the capability to produce small grain cereals and class 4 is classified as marginal for cereal production primarily within valleys of central Yukon. Class 3 and 4 land is in small localized areas usually along rivers or lakeshores. Class 5 is the most common class of agricultural land, suitable for forage production and cold hardy vegetables. Class 6 lands are not suitable for cultivated agriculture but may have potential for native grazing. Class 7 land is not suitable for cultivated agriculture and is not able to sustain grazing due to topography (steep slopes or surface pattern), elevation and climatic factors, or excessively stony soils. Any site above 820 metres (2690 ft) in elevation slope/aspect is considered to be non-arable due to climate restrictions.

## CLIMATE CAPABILITY

Climate is the greatest limiting factor to agriculture in the Yukon, due to the short frost free period and cool temperatures during the growing season. Low growing season heat accumulation, described as growing degree days (GDD) is the principal limitation to agriculture in the Yukon. Precipitation is low throughout the territory and soil moisture deficits during the growing season also limit agricultural potential. Most soils in the south-central Yukon will suffer moderate droughts on occasion. Irrigation is necessary to ensure good yields for many field crops. In the Whitehorse area, where the majority of farming occurs, precipitation is usually limited in the spring, requiring irrigation to establish most crops.

### *Climatic Regions*

The parameters of climate in the Yukon are presented in an Environment Canada report, Climate of Yukon. The Yukon has been divided into nine climatic regions which have certain long term climatic differences from one region to the other. These regions are illustrated in Figure 2.2.

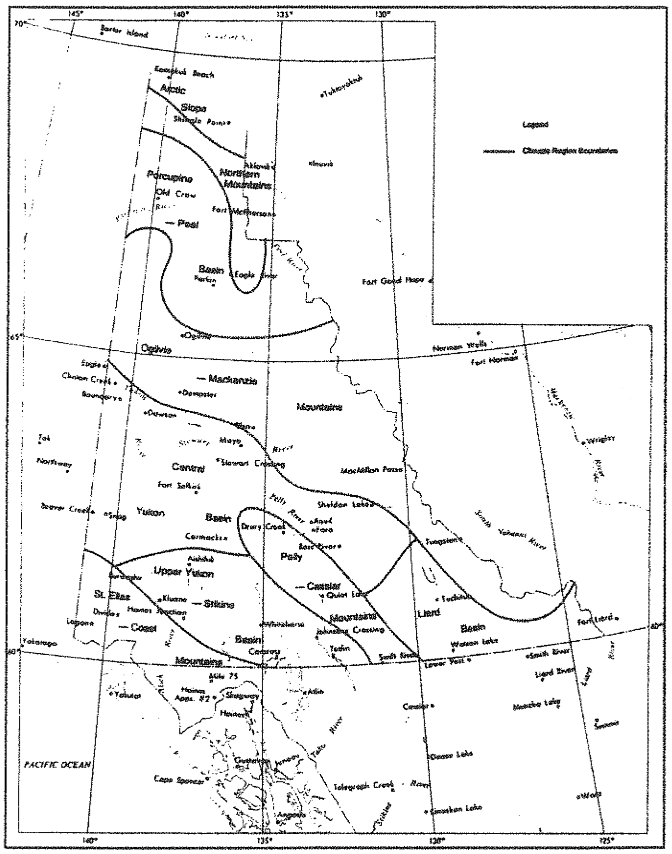



Figure 2.2 Climatic Regions of the Yukon

Source: *Climate of the Yukon*, H. Wahl et al, Environment Canada, 1987.

Cultivated agricultural activities are limited to three of the nine regions which are as follows:

**1. Liard Basin**

The broad valley of the Liard River is relatively flat with elevations between 700 and 1000 meters. Precipitation is moderate, between 400-600mm annually with more days of precipitation than in the interior of the Yukon. Summers are warm and winds are moderate. Weather data for the region is collected by the Watson Lake Airport. Several farms are located near Watson Lake which produce forages and vegetables. Home gardening also occurs in this community.

**2. Upper Yukon-Stikine Basin**

This region is a relatively high elevation plateau lying between the St.Elias mountains and the Cassiar-Pelly Mountains. This plateau is dissected by deep river valleys with a general elevation of 600 to 1200 m. The most significant climatological feature of the region is low precipitation, a result of the rain shadow effect of the St. Elias Coast Mountain barrier. The majority of the population and agricultural activity in the Yukon lies within this region which extends from Teslin in the southeast, west to Carcross, Whitehorse, Haines Junction and Burwash Landing. This region is represented by the Whitehorse Airport and Haines Junction Environment Canada data.

**3. Central Yukon Basin**

This region consists of the Pelly River, Yukon River and Stewart River watersheds. It is a northward extension of the Yukon-Stikine Region with a lower average elevation. It extends from Carmacks north to Mayo and Dawson, east to Ross River and west to Beaver Creek. Its greater distance from the Gulf of Alaska and the St. Elias mountains gives the Central Yukon basin different climatological characteristics than to the south. Precipitation is relatively moderate at 300 to 400mm, mostly falling in summer showers. Temperatures are more variable and extreme with warm summers and severe cold periods in winter. Winds tend to be light. Weather data is collected by the Carmacks Highway station, Fort Selkirk station at Pelly Farm, the Mayo Airport and Dawson Airport. The major communities of Beaver Creek, Carmacks, Faro, Ross River, Pelly Crossing, Stewart Crossing, Mayo, and Dawson are included. The longest operating farm in the Yukon is Pelly Farm located west of Pelly Crossing along the Pelly River. Near Mayo, Stewart Crossing and Dawson there are a number of agricultural operations with home gardening occurring in each of the communities.

The following climatic regions have no cultivated agriculture as they are mostly mountainous terrain and in remote areas not near settlements. There is some home gardening in the community of Old Crow which is within the Porcupine-Peel Basin.

**4. Pelly Cassiar Mountains**

**5. Saint Elias- Coast Mountains**

**6. Ogilvie Mackenzie Mountains**

**7. Porcupine-Peel Basin**

**8. Northern Mountain**

**9. Arctic Slope**

The climatic regions (Figure 2.2) correlate with the agricultural regions in the Yukon Farm Survey (Figure 1.1) and the agricultural regions for soil surveys (Figure 2.1.) in the following manner:

| Climatic Region | Yukon Farm Survey Agricultural Region | Agricultural Region |
|---|---|---|
| Liard Basin | Watson Lake | Southeast |
| Upper Yukon-Stikine Basin | Whitehorse | Southwest |
| Upper Yukon-Stikine Basin | Kluane | Southwest |
| Central Yukon Basin | Pelly/Faro Carmacks | Central |
| Central Yukon Basin | Dawson/Mayo | Central |

## CLIMATIC DATA

A review of regional climate data for the major farming areas appears in Table 2.1. These are normals from May-September recorded for the 1951-1980 period by Environment Canada at airports and by private recorders on farms. These normals were also used as part of the climate assessment in the YCDP trials.

Table 2.2 Climactic Data - Normals - Environment Canada (1951-1980)

| | Watson Lake | Whitehorse | Haines Jct. | Carmacks | Fort Selkirk | Mayo | Dawson |
|---|---|---|---|---|---|---|---|
| **July Mean Temp.** | | | | | | | |
| | 14.9 | 14.1 | 12.5 | 14.5 | 14.8 | 15.2 | 14.7 |
| **May-September Total Precipitation (mm)** | | | | | | | |
| | 224.9 | 145.7 | 139.6 | 154.4 | 161.0 | 178.3 | 183.3 |
| **Growing Degree Days (GDD)** | | | | | | | |
| | 960.8 | 881.6 | 672.4 | 901.9 | 926.9 | 970.4 | 897.8 |
| **Frost Free Period (Days)** | | | | | | | |
| | 93 | 82 | 21 | 74 | 61 | 71 | 64 |
| **Last Frost (Spring)** | | | | | | | |
| | June 2 | June 8 | July 6 | June 6 | June 16 | June 8 | June 13 |
| **First Frost (Fall)** | | | | | | | |
| | Sept 4 | Aug 30 | July 26 | Aug 20 | Aug 17 | Aug 19 | Aug 17 |

Table 2.3 Locations of Major Yukon Weather Stations

| Station | Latitude | Longitude | Height (Metres above sea level) |
|---|---|---|---|
| Watson Lake Airport | 60°07' | 128°49' | 689 |
| Whitehorse Airport | 60°43' | 135°04' | 703 |
| Haines Junction | 60°46' | 137°35' | 599 |
| Carmacks | 62°06' | 136°18' | 523 |
| Fort Selkirk (Pelly Farm) | 62°49' | 137°22' | 454 (Pelly Farm) |
| Haines Junction | 60°46' | 137°35' | 599 |
| Mayo Airport | 63°37' | 135°52' | 504 |
| Dawson Airport | 64°03' | 139°08' | 369 |

### *Daily Mean Temperature*

For the growing season from May - September, the month of July is the warmest month with the mean temperature ranging from 12.5 °C, the lowest in Haines Junction to 15.2 °C, the warmest in Mayo.

Whitehorse is the second coldest area during July. Watson Lake, Fort Selkirk (Pelly Farm) and Dawson have similar mean temperatures during July. Haines Junction is the coldest spot in May with Whitehorse, second. The Mayo and Dawson areas have the warmest temperatures in May.

### *Precipitation*

From May-September, all rainfall stations have the lowest rainfall during the month of May. Moisture is the least during planting time and is a limiting factor for crop growth in the Yukon. In May, the Watson Lake area normally has the most precipitation with the lowest recorded in the Whitehorse area. The highest precipitation occurs during the month of July at all stations. (See Soil Moisture Deficits – Soil Management)

### *Growing Degree Days*

Growing Degree Days are a measure of heat units available for plant growth. The GDD normals from Environment Canada are based on 5 degrees Celsius, the basic temperature below which cool season crops will not grow. For the Yukon Crop Development Program, a GDD was calculated for each day that the mean daily temperature exceeded 5 degrees Celsius. For example a day with a mean temperature of 10 degrees Celsius would have 5 GDD. No adjustments for day length or the actual frost free period were incorporated into the normals for GDD from 1951-80.

The relationship of growing degree days and crop growth is not linear. A few warm days together are required to achieve certain plant stages, i.e. flowering or fruiting. Areas with a long growing season but with uniformly low temperatures will not produce a wide range of crops.

The GDD accumulations for the normals (1951-80) were in order from highest to lowest; Mayo, Watson Lake, Pelly Farm (Fort Selkirk), Carmacks, Dawson, Whitehorse and Haines Junction. Haines Junction area has the coldest climate, limited by low mean daily temperatures. July is the month of the most GDD for each station.

During the YCDP trials it was noted that in most of the areas the total Growing Degree Days accumulated during the growing season (May-September) were greater than the 1951-80 normals.

GDD calculated in 1988, 1989, and 1990 for the YCDP trials versus the normals (1951-1980) for the months May-September were as follows:

Table 2.4 Growing Degree Days – YCDP Trials – 1988-1990

| | Whitehorse Airport | Carmacks | Fort Selkirk | Mayo | Dawson |
|---|---|---|---|---|---|
| GDD-1988 | 744.3 | No Trials | No Trials | 1052.4 | 1007.4 |
| GDD-1989 | 1128.2 | 1223.1 | 1086.8 | 1277.6 | 1167.4 |
| GDD-1990 | 1019.4 | 1160.5 | 1148.9 | 1173.6 | 1099.0 |
| GDD-Normal | 881.6 | 901.9 | 926.9 | 970.4 | 897.8 |

### *Frost Free Period*

Frost free period is a limiting factor in most agricultural areas. It is determined from the date of the last killing frost in the spring to the first killing frost in the fall. A killing frost is considered as below – 2.20 °C.

From the data collected during the NCDP and YCDP trials, it appears that the frost free period (FFP) has extended in many of the agricultural areas. For the 1988, 1989, 1990 seasons there was a notable difference in frost free period compared to the normal, from May-September.

Table 2.5 Frost Free Period - YCDP Trials (1988-1990)

| | 1988 | 1989 | 1990 | Normal (1951-80) |
|---|---|---|---|---|
| Whitehorse Airport | 98 | 138 | 117 | 82 |
| Carmacks | No Trial | 121 | 146 | 74 |
| Ft.Selkirk/Pelly | No Trial | 119 | 111 | 61 |
| Mayo | 136 | 125 | 100 | 71 |
| Dawson | 126 | 126 | 108 | 64 |

Terrain and site conditions affect length of frost free season. The influence of local topographic forms on the settling and pooling of cold air, and therefore temperature is important for frost free periods. Frost may occur on concave-shaped landforms, though not elsewhere.

### *Photoperiod*

For many plants the short northern growing season is compensated by the extended daylength period of the early summer months. Photoperiod and degrees north are now incorporated into calculations of growing degree days. The hours of daylight during the growing season are considerably greater than in the south and this factor is known to accelerate growth of certain crops and affect maturity dates. However, not all plants respond favorably to prolonged light exposure, some being short day, long day or day neutral plants. Spinach for example tends to bolt earlier in the north due to the long daylength period.

### *Landform and Microclimates*

The effect of slopes on climate are related to their steepness, morphology and the direction they face (aspect). Steeper slopes and those with convex shapes have relatively better cold air drainage and so have higher minimum temperatures than shallow or concave slopes. Well drained slopes are also subject to increased mixing of their surface air with the surrounding air-mass in the daytime. These slopes have less risk of frost and a longer frost free season. Concave landforms, such as hollows or ravines and particularly those with no slopes are most susceptible to "pooling" of cool air, to reach very low temperatures on quiet nights (ie. no winds and mixing of air). Slopes which face south collect more radiation than level ground and considerably more radiation than north-facing slopes. There is an increase in the total radiation received by rough, broken land surfaces compared to smooth flat land.

### *Agro-climatic Capability*

In 1975 and 1976, a climatological survey was conducted in the Yukon to determine agroclimatic capability. In 1977, a report and maps were prepared indicating the capability classes for agriculture. This was called the Agroclimatic Capability of Southern Portions of the Yukon Territory and Mackenzie District, N.W.T. by F.J. Eley, B.F. Finlay.

In this study a total of 28,831,476 ha were mapped according to climate capability in the Yukon. No class 1 or 2 climate capability were mapped in the Yukon, the majority being class 5-6. A myriad of microclimates was found to occur within the transects used to plot landform variations. Analysis showed a consistent decrease of mean daily maximum temperature with elevation. The rate of decrease with elevation was observed to be between .75-.85 °C per 100 metres. The mean daily temperature was found to vary considerably with topographic form and proximity to bodies of water. It was estimated that maximum temperatures on south facing slopes were .5 °C warmer than the valley floor sites and the maximum temperature on the north facing slopes were .5 °C cooler than valley floor locations. There was a warming effect from large rivers and lakes.

***Typical Hours of Daylight***

| | |
|---|---|
| January | 6 |
| February | 8 |
| March | 10.5 |
| April | 13.5 |
| May | 16 |
| June | 18 |
| July | 19 |
| August | 17 |
| September | 14 |
| October | 11.5 |
| November | 8.5 |
| December | 6 |

- *Yukon R.V. Traveler*, Government of Yukon, 1994.

## CROP RESPONSE TO GROWING SEASON CLIMATE

It has been found that successful production can indeed occur with less frost free or growing degree days with certain management practices. The use of row covers and mulch have proven to provide for excellent winter storage cabbage production, even with limiting climatic factors, such as frost. (See Vegetable Production) Forages and cereals have reached maturity with less than 1000 growing degree days.

### *Growing Degree Day Accumulations*

Actual Growing Degree Days (Actual GDD) were calculated for the different crop types for the YCDP trials completed in Whitehorse, Pelly, Mayo and Dawson between 1989-1990, presented in Table 2.6. The actual GDD accumulated (based on 5 degree Celsius) was determined for each day from the date of planting through until harvest for each crop type. The actual frost free period was also determined. This was localized for each site by noting when the farmer stated that a frost occurred at the trial site. Different microclimates occurred at each site which were not represented in the regional data available. Often the recording site was 10-20 km away from the trial site with a different landform or

In 1972, the requirements for successful crop production north of 55 degree latitude were stated as:

- A period of 80 days free of a killing frost
- A vegetative period of 110 days
- An accumulation of 1,000 growing degree days
- Adequate precipitation during the growing season

Source: *Farming Potential of the Canadian Northwest*, Agriculture Canada, Publication 1466, 1972

aspect etc. Crops varied in their maturity levels along with different growing degree day accumulations in each region.

Table 2.6 Growing Degree Day Accumulations - YCDP Trials

| | Actual GDD 1988 | Actual GDD 1989 | Actual GDD 1990 |
|---|---|---|---|
| **Forages:** | | | |
| Watson Lake | No Harvest | 532.3 | No Crop |
| Whitehorse | " | 646.0 | 545.9 |
| Ft.Selkirk/Pelly | " | 745.4 | 745.4 |
| Mayo | " | 711.2 | 672.2 |
| Dawson | " | 632.0 | 700.0 |
| **Cereals:** | | | |
| Whitehorse | No Crop | No Crop | 796.0 |
| Ft.Selkirk/Pelly | No Crop | 1004.6 | 991.7 |
| Mayo | 866.6 | 1127.7 | 1020.6 |
| Dawson | 857.1 | 1023.1 | 962.9 |
| **Vegetables:** | | | |
| Watson Lake | 623.8 | 896.9 | No Crop |
| Whitehorse | 615.0 | 906.1 | 785.0 |
| Carmacks | No Crop | 965.8 | 950.9 |
| Mayo | No Crop | 949.5 | 885.8 |
| Dawson | 514.3 | 853.1 | 847.4 |

**Forages:**

In the first year of the Yukon Development Program trials, the forages were planted and no harvests were made. Forages were mature in all regions requiring approximately 500-650 GDD to reach maturity. Perhaps more of a limiting factor than actual GDD was moisture conditions appearing to affect yields and maturity dates. Bromegrass was the most successful in all regions. Alfalfa suffered from winterkill in the northern areas, with the most success in the Whitehorse area.

**Cereals:**

During this period, cereals were mature at all sites. There was remarkable cereal growth in the Whitehorse area in 1990 where the best yields and mature grain production occurred with only 796 actual growing degree days accumulated. There was ample soil moisture when the cereals were planted on June 4th, with good levels of moisture throughout the growing season, with a total growth period of 96 days, of which 87 days were frost free. Grain does not always mature in the Whitehorse area. For the Pelly, Mayo and Dawson areas grain usually matured with more than 850 actual GDD accumulated. Grain production is generally more suitable in these areas than Whitehorse, Haines Junction or Watson Lake. Grain did not mature in Watson Lake during the 1986-1987 NCDP trials. Cereal production for green feed purposes was found to be suitable in all areas where trials were held.

*" It is generally thought that cereals grains and vegetables need about 60 frost-free days and approximately 1000 growing degree days to mature. All stations except Haines Junction have enough frost free days , but none have adequate growing degree days, although some are very close. Except for Watson Lake and Dawson, most stations in the Yukon have very low summer precipitation (136-165mm). Due to the lower growing season temperatures, the moisture efficiency of most plants will be high. Even so, most soils in the south-central Yukon will suffer moderate droughts on occasion. Forages and garden crops would benefit from supplemental irrigation in most years."*

- *Soil Survey and Land Evaluation of the Yukon Territory*, H.P.W. Rostad, L.M. Kozak, D.F. Acton, Saskatchewan Institute of Pedology Publications S174, 1977.

**Vegetables:**

A winter storage variety of cabbage *(Quick Green Storage)* was grown throughout the Yukon from 1988-1990, using different row covers to improve growth. (See Vegetable Production) In 1988, plots were planted later than normal and there was not enough GDD accumulated to mature the cabbages, at less than 625 actual GDD. In 1989 and 1990 approximately 800-950 GDD were sufficient to develop good sized, mature cabbages with the use of row covers.

## SOIL CAPABILITY

Soils are assessed for agriculture according to the following characteristics: water holding capacity/texture, soil structure, organic matter, depth of topsoil, soil reaction, salinity, drainage, and degree of stoniness. The pattern of the landscape, the steepness of slopes and the climatic characteristics are considered in the soil capability for agriculture rating.

### *Soil Surveys*

A number of soil surveys have been completed to assess the capability for agriculture. In 1977, the Saskatchewan

Institute of Pedology (Rostad et al) completed a reconnaissance survey for soils of most of the agricultural areas within the Territory. A series of 12 interpretive maps are available at 1:125,000 scale for each region. This included the areas around Watson Lake, Whitehorse, Carcross, Haines Junction, Beaver Creek, Carmacks - Ross River, Pelly Crossing, Stewart Crossing - Mayo, and Dawson. This is still the major source for soils information in the Yukon. The maps of importance to agriculture are the soil associations, soil capability for agriculture and grazing, crop suitability, suitability for irrigation, suitability as a source of topsoil and surface texture. These are available from the Canada Map Office in Whitehorse.

Between 1987-1991, in the areas north and south of Whitehorse a detailed soil survey was completed by Agriculture Canada, Yukon Soil Survey Unit. These maps are available at 1:20,000 scale.

A soil survey was also completed for the Klondike Valley area near Dawson at 1:20,000 scale. Both of these surveys give agricultural ratings for the different soil types.

Soil maps from these surveys are available from Agriculture Canada, Yukon Soil Survey Unit, in Whitehorse.

According to Agriculture Canada, Yukon Soil Survey Unit, the distribution of potentially arable soils in the Yukon by region and soil capability class in thousands of hectares is the following:

Table 2.7 Distribution of Arable Soils

| Region | Class 3 | Class 4 | Class 5 |
|---|---|---|---|
| Central | 2.5 | 21.2 | 79.8 |
| Southwest | – | – | 199.4 |
| Southeast | 4.4 | 6.0 | 209.3 |

*Source: Agroclimate and Soil Resources in the Yukon*, C.A.S. Smith, Proceedings - 1st Circumpolar Agriculture Conference, 1994.

# FARM DEVELOPMENT

The development of your farm involves many considerations in the initial design, in clearing and developing the land, and in the management according to proper sustainable and ecological practices.

## FARM DESIGN

The design of the farmstead is very important. Good planning can make a farmstead pleasing in appearance as well as efficient in operation. For the farmstead site, the most suitable access and the location closest to water and power must be considered. In order to maximize the development of the farm, one must choose the most appropriate areas for specific purposes, according to location and best use of the land. Consideration must also be given to the effects of topography, sunlight, wind and snow accumulations.

A comprehensive plan drawn to scale, with the use of aerial photographs and simple surveying methods will assist in the development of the farmstead. Aerial photographs can be reviewed at the Lands Branch, Government of Yukon, Forest Resources, Northern Affairs Program, and at the Regional Surveyor's Office, in Whitehorse. The flight line, photograph number, year and scale of the photography should be determined. Photographs can be ordered from the National Airphoto Library 615 Booth Street, Ottawa, Ontario K1A OE9.

> *"To farm successfully in the 1990's we will need to adopt new principles and procedures to ensure that we keep farming ecologically and economically sound."*
>
> (Synergy, Spring 1990)

If the farmstead is planned in zones it will help to define and layout areas more easily. The farmstead can be divided into four concentric rings or activity zones as shown in Figure 3.1. This can include :

Zone 1- Family Living (house, parking, recreation area, garden)

Zone 2- Machinery storage and service (farm workshop, equipment parking, fuel centre, transformer pole)

Zone 3- Small animal buildings and storage (general purpose barns, handling and drying facilities, grain storage and handling)

Zone 4- Major livestock facilities (feedlots, pastures, manure storage, forage and silage storage)

The anticipated power needs of the farmstead should be considered during the planning phase. The location of the transformer pole, service entrances and powerlines should be considered in relation to proposed building sites, shelterbelts and roadways. An adequate transformer size should be selected to meet the farm power requirements into the future.

Access to water is essential to any farmstead. Investigate to ensure beyond doubt, that enough water is available before you start any other farmstead development. The water source can be a drilled well, dugout, dam or spring. Dams and dugouts must be located where they will collect enough runoff to refill each spring.

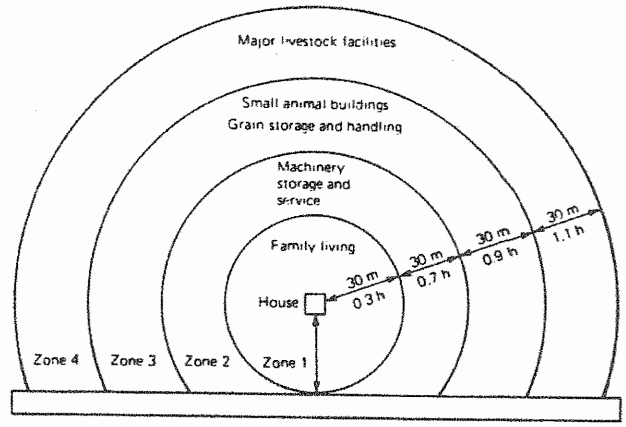



Figure 3.1 Farmstead Planning Zones
Source: *Farmstead Planning*, Agriculture Canada, Publication 1674/E

### *Topography and Microclimate*

A farmstead site should be well drained with a slope of 2 to 4% in a southerly direction. This amount of slope is sufficient for drainage and will not cause erosion or problems with vehicle movement during wet or icy conditions. A southward slope provides air drainage and maximum sun exposure. If the desired slope does not exist naturally, earth movement and grading should be considered prior to construction. Farm shops with doors opening to the south will have fewer problems with icing and freezing of sliding doors and will be partially heated by the sun. If higher land drains

> Dr. Stuart B. Hill (Associate Professor, Department of Natural Resource Sciences, Director of Ecological Agricultural Projects Macdonald Campus of McGill University) is a leading authority in the concepts of sustainable agriculture. In a agriculture seminar held in Whitehorse in 1991, Dr. Hill defined sustainable agriculture as:
>
> *" Sustainable Agriculture is a philosophy and system of farming based on a set of values that reflect a state of awareness and empowerment. It involves benign designs and management procedures that work with natural process to conserve all resources, minimize waste and environmental impact, prevent problems and promote agroecosytem resilience, self-regulation, evolution and sustained production for the nourishment and fulfilment of all."*

into the selected site it may be necessary to build diversion ditches to intercept runoff water.

The microclimate on a farm consists of many factors, aspect, contour or topography, soils, and vegetation types. Localized temperature and moisture can be different from that of the surrounding areas. Remember that south facing convex slopes are the best for air drainage and lower areas in the field will tend to collect the cold air.

*For literature on sustainable and ecological agriculture write to:*

Ecological Agriculture Projects (EAP)
Macdonald Campus
McGill University
Ste-Anne-de-Bellevue
Quebec, Canada
H9X 3V9

### *Shelterbelts*

Shelterbelts are an important component of a properly planned farm to control the effects of cold winter winds and snow accumulations. They can be used to create microclimates. Plants of varied habits and shapes can be used in various ways to create a microclimate. Trees, shrubs, grasses can be used to control air circulation and snow accumulations. High board fences or shelterbelt trees along the perimeter of the farmstead provide effective protection. A snow fence should be placed a distance equivalent to ten times its height away from access routes, roadways or farmstead areas which need protection.

#### Multi-Row Shelterbelts

One of the most important effects of multi-row shelterbelts is a reduction in heating costs for livestock production facilities and farm homes. Shelterbelts tend to stabilize wind velocity, reducing temperature fluctuations due to changes in wind speed.

Basically the typical belt is a series of three to five rows of trees on the perimeter of the farmstead. Shorter growing trees or small deciduous (Poplar, Caragana, Vilosa Lilac, Honeysuckle) should be on the outside to direct the wind up over the shelterbelt. The second row consists of fast growing deciduous trees (Willow, Poplar) of intermediate height. The third row should be of long lived deciduous trees. Two rows of long lived tall growing conifers (white spruce) are planted on the inside.

Do not extend five row shelterbelts around the entire farmstead as this could cause stagnation of air around the farmstead. In Figure 3.2 a typical shelterbelt design is illustrated.

#### Field Shelterbelts

Trees grown at the edges of fields will greatly assist in wind erosion control by reducing wind speeds. In addition tree belts trap more snow on fields during winter to give more moisture for the following crop.

The mature height of a shelterbelt has a great bearing on the sheltering effect received. Experimental work shows that wind protection is obtained for a distance approximately 20 times the height of the trees. Reduction of wind speed is greatest near the shelterbelt. Trees grown in rows at 200 metre (656 ft) intervals have proven effective on the prairies.

> *I cleared my 160 acre farm into approximately 17 acre sized areas and left a strip of pine and poplar trees as shelterbelts between the fields.*
>
> -Whitehorse Producer

The Agriculture Branch provides shelterbelt trees for farmers, owners of small rural holdings, charitable and government organizations. The trees are provided free of charge from the PFRA Shelterbelt Centre tree nursery in Indianhead, Saskatchewan. Species available include: Green Ash, Caraganna, Manitoba Maple, Siberian Elm, Sea Buckthorn, Villosa Lilac, Buffaloberry, Chokecherry, Walker Poplar, Northwest Poplar, Acute Willow, Scots Pine, Colorado Spruce and White spruce.

#### Shelterbelt Research

At the Agriculture Branch research plots, located near Mile 3 of the Mayo Road north of Whitehorse, 14 shelterbelt tree species were grown to test for hardiness and growth

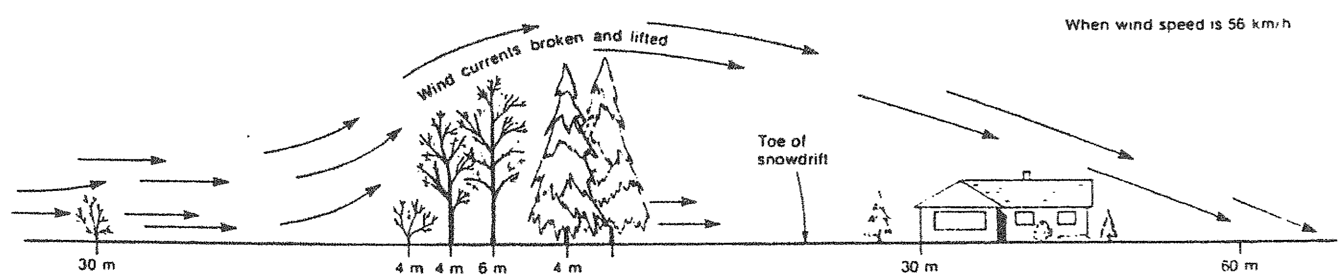



Figure 3.2 Shelterbelt Design
Source: *Farmstead Planning*, Agriculture Canada, Publication 1674/E

characteristics. Most of these were from the PFRA Shelterbelt Centre. Those with more than 50% success rate included:

| | |
|---|---|
| Vilosa Lilac | Acute Willow |
| Caragana | Silverleaf Willow |
| Red Elder | Northwest Poplar |
| Hedge Rose | Assiniboine Poplar |
| Siberian Elm | |

Source: *Yukon Agricultural Research and Demonstration Report 1990*, M.P. White, Yukon Agriculture Branch, Renewable Resources, 1990.

## LAND CLEARING

### *Requirements of Good Land Clearing*

Although growth cover, topography, and soil conditions may vary from area to area the requirements of clearing land not underlain by permafrost are similar and can be summarized as follows:

1. Complete removal of all tree growth.
2. Complete removal of all rocks, stumps, and other debris.
3. Do not remove excessive topsoil. 1 inch of surface soil removed from an acre equals 150 tons of valuable nutrients and organic matter.
4. Make soil-free brush piles to ensure complete removal by burning or other methods.
5. Complete sufficient leveling to permit easy operation of farm equipment.

For soils with permafrost a different approach is often taken in order to allow time for permafrost thaw and drainage.

A quality development job is one in which all trees, stumps, rocks and debris have been removed from the land and most importantly the valuable topsoil left in place. The matter of not removing soil during the clearing process cannot be overstressed.

> *I cleared my land in November after the ground was frozen and was able to keep more of the topsoil than if I had done it in the summer months.*
>
> -Whitehorse Producer

Good standing timber should be salvaged whenever possible prior to clearing. Timber can be sold to a local sawmill or utilized in the future for construction of cabins, fencing, barns etc. Selective cutting is encouraged as much as possible to extract the good quality trees for lumber, fenceposts or fuelwood prior to starting clearing procedures.

### *Equipment Used for Land Clearing*

**Crawler Tractors**

Crawler tractors or "Cat" in the medium sized range is the most efficient and economical to clear treed areas. Crawlers should be fitted with adequate guards to protect the operator and tractor. It is recommended to have a protective canopy, radiator guards, complete engine side cover plates, shift lever guards, protective hydraulic lines, canopy screens and foot guards.

**Rear Winches**

Tractors used for clearing should have a heavy single-drum rear winch with adequate guarding. The winch can be used if the tractor becomes bogged down in soft, wet areas or becomes high centered on a stump. A rear winch also gives the tractor a better balance.

**Piling Blade**

A piling blade is also referred to as a land clearing blade, brush blade, skeleton piler or root rake. Piling blades consist of a heavy boxed steel frame with hooked or curved teeth that are spaced so as to permit soil to pass through and allow a clean job of piling. The teeth should extend 36-41cm (14-16") below the bottom of the frame and the points should extend 25-36cm (10-14") ahead of the bottom frame to give the tooth adequate curvature. A constant curvature of the blade is desirable rather than an abrupt change in curvature. A good tooth spacing is 38-51cm with a 41cm (16") spacing being quite common. The height of these blades will vary from 1.5-1.8m (5-6 ft) with the centre section being built up higher. It is advisable to have the top portion of the blade slope forward to encourage a rolling motion of the brush being piled. The centre sections of the blade should be closed in. These factors all encourage a rolling action, and filling the center sections prevents costly "jill-pokes" into the radiator or hydraulic hoses. This is an important tool in land clearing and should be carefully chosen.

**Brush Cutters**

Brush cutters are used to cut the tree growth by a sheering action. These are either of a V-type or a one way type, mounted on heavy framed blades. These cutters are limited to lighter growth areas with a smooth forest floor. Their use should be avoided in rocky areas.

**Breaking Discs**

Breaking Discs or cutting discs are heavier and stronger than the conventional farm disc harrow. The discs blades vary from 71-81cm (28-32") in diameter and the weight per disc can vary from 300-136-249kg (550lbs). Disc blades can be either notched or solid and should have a minimum thickness of 5/16 inch. Disc spacing will vary from 25-41cm (10-16"). Breaking discs are available in a number of styles and sizes varying from 2.4-4.9m (8-16 ft) wide in singles or tandems. They should be sized to the machine used to pull them.

**Flex Harrows**

Flex Harrows or bull harrows are flexible, tubular steel frame harrows used to loosen roots after breaking. These harrows can be built to any desired size and are normally used immediately behind breaking discs in the clearing operation.

**Root Windrowers**

Root windrowers, wheel rakes or root rakes are used after the initial breaking for windrowing roots and other debris. These machines are available in 4, 5, 6, and 7 wheel models. The machine can windrow loose sticks and other trash and is capable of moving rocks over 45kg (100lbs).

**Moldboard Plows**

Moldboard or breaking plows have one to four bottoms of 51-66cm (20-26")in width and require 35-40 horsepower per bottom. These are used to invert small stumps or brush which are not deep rooted. Depth of plowing will vary from 15-25cm (6-10"), depending on the soil type.

**Power Drum Rake**

The Power drum rake has a large rotating drum with heavy teeth and is used for cleaning up the debris behind the bulldozer. These do the same job as wheel rakes.

**Stump Extractors**

These are mounted on the tractor and are a lower investment machine, though they are slower and less efficient than a crawler tractor.

**Rotary Brush Mowers**

Rotary brush mowers have been used for removing light tree growth or shrubs in areas which are not rocky.

### *Clearing Areas with Standing Timber:*

1. Walk Down and Pile Method:

The first step in removing tree growth is known as "walking down". The trees are knocked down parallel to each other and should also be parallel to the direction of the windrow to be built. The trees can then be cross piled with a piling blade.

Using the piling blade and crawler, the trees are placed in windrows by operating the tractor at right angles to the direction in which the trees were knocked down. When the trees are walked down half of the root system is loosened from the soil and taken out of the ground when the trees are knocked over. The remainder of the root system is removed with the piling operation. The trees are then rolled into a pile enabling the operator to remove all of the soil from the roots. During this process the limbs are broken and the trunks split to allow the operator to build a more compact pile.

> ***Haines Junction Mile 1019 1945-1952 Research Report***
>
> *"When possible the clearing and piling of heavy stands of green forest material should be done two or three years before cultural conversion of the area is attempted. After that period the piled material would burn more readily and native organic life in the soil would no doubt be more active."*

Figure 3.3 Land Clearing

Source: *Land Clearing for Agricultural Production*, Atlantic Agricultural Engineering Committee, Publication No. 7, 1977.

The walking down method works best on tree species from 5-25cm (2-10") in diameter. On trees less than two inches the tree will often spring back up after the tractor has run over it. On trees greater than ten inches the tractor requires more power to tip over the tree and may prevent a steady forward motion of the tractor. These trees should be cut prior to this operation, then walking down the remainder of the stand works well. Trees should not be walked down and left for a period of time to dry before piling. A good rule to follow is to walk down only as much as can be piled in one or two days.

Piles or windrows should be mud free and wood should be well packed into the pile. Windrows should be located at least 30m (100 ft) from the field boundary and at least 45m (150 ft) apart. Windrows should have breaks at least 6m (20 ft) wide every 182-305m (600-1000 ft) to permit the passage of equipment.

Mud-free piles can be disposed of by burning. This can be done at the time of piling or later on after the piles have been left to dry for a period of time. In order to achieve a 100 % burn the piles should be re-piled with a crawler. A 70-80 % burn can be expected, at best, without a crawler.

Many small sticks and other debris will be left behind in the piling process. The area should then be disced with a heavy breaking disc to cut up the debris. A flex harrow may also be hauled behind the disc. Following this, the area can then be raked with a wheel, root or drum rake. The windrows left from raking can then be piled and burned or hauled from the site if they are not burnable. A seed bed can then be prepared using regular farm equipment.

*To clear my farm in the Takhini valley, I used a D-6 "Cat" (a D-7 is too big) in the late fall when the ground was frozen to remove the larger poplar and pine growth an piled it in windrows. I removed the remaining smaller trees and willow with a root rake, then I did alot of hand picking of roots. I then applied a good amount of nitrogen fertilizer to assist with the breakdown of woody material, prior to further field preparation.*

-Whitehorse Producer

### *Clearing Cut Over Areas*

In these areas the timber has been harvested prior to undertaking any clearing operations.

1. Grubbing & Piling

The stumps are all uprooted from the soil and slash are pushed into piles or windrows with the tractor and piling blade. Each load should be rolled over several times to shake out as much soil as possible. Conditions at the site will dictate how many times to roll and dump each load. Generally material should not be pushed much over 45m (150 ft), as the efficiency of the operation is reduced. The burning of the piles or windrows is similar to that described in the Walk Down & Pile Method. Stumps and roots will burn well provided they are piled cleanly. Many people prefer to uproot and overturn the stumps and leave them to dry out for a period of time before piling. Round piles often burn better than windrows.

*I cleared a wet meadow area with willow cover on my farm. I used a "Cat" with a straight blade in late spring when there was still 2 ft of snow. The top growth was bushed into windrows. I lost very little topsoil from the meadow area*

-Whitehorse Producer

The heavy breaking disc is an effective tool in cut over areas where there are not any number of large heavy stumps or any amount of slash. One advantage of the heavy disc over the plow is that it mixes the topsoil thoroughly with the subsoil, leaving a better seedbed.

### *Clearing Light Tree Growth/Shrubs*

Willow less than 1 m (3.2 ft) high can be plowed under by using a breaking plow with high clearance. For willow 3-3.6 m (10-12 ft) high and 5-7.6cm (2-3") in diameter, a rotary mower is best for clearing. A 3 point hitch mounted brush mower is more desirable than a pull-type due to its manoeuverability.

In areas with low, bushy growth a heavy breaking disc can effectively be used. Several passes may have to be made over the material to chop and mulch it into the soil. Additional heavy discing may be required the following season to complete the job.

### *Chemical Control*

Chemical control on various types of growth has proven to be successful if used in conjunction with mechanical means. Chemicals can be used on deciduous growth in the year following initial cutting. Regrowth is sprayed upon coming into full leaf which effectively kills the root system and promotes a fairly fast kill. The dead trees and roots can then be removed by mechanical means as previously described.

### *Field Preparation*

Existing native growth must be removed down to the soil surface layer for proper seed establishment and growth.

Plowing is preferred over rototilling as it buries most existing vegetation, minimizing competition during establishment of the new crop. When done parallel to the slope of the land, plowing provides some underground drainage along the bottom of the furrow.

Discing the plowed area afterwards, the first pass should be parallel to the direction of the plowing to avoid catching furrows and to roll them back over, leaving the sod face up. To adapt to varying soil conditions it is advantageous to have a lighter disc and add weights, or have a disc where the "gang angle" can be adjusted. Under most conditions a double pass with the disc is necessary. Additional passes may be required to level the field especially over the ridges and valleys created when starting and finishing the plowing of an area. Spot use of rotovators may be useful to break up some of the problematic root masses. Harrowing and roller packing may be necessary to prepare a firm seedbed.

Clearing the land for the first time will often dramatically change the drainage patterns. Removal of the vegetation cover results in less snow pack and allows for the sun and wind to more quickly affect evaporation in the spring. As the root systems break down there may also be better subsurface drainage.

## WIND AND WATER EROSION CONTROL

### *Contour Strip Cropping*

Farmer experience has indicated improvement in wind and water erosion control through the use of modified contour strip cropping. Contour stripping means adapting a regular field design by planting crops in strips, across a slope to control water erosion and across a filed to control wind erosion. Arrangements and width of strips needed for contour farming varies with degree and length of slope, texture of soil and origin of the soil, ie. lacustrine or glacial till.

**_Conservation in Alaska:_**

In the Delta agricultural area in Alaska where strong winds have significant potential for wind erosion, a conservation program was established which incorporated mandatory windbreaks, spaced at one quarter mile intervals, and voluntary use of conservation tillage systems which utilize the previous year's crop residue to protect the soil from erosion. The Soil Conservation Service helps to prepare a conservation plan with new landowners which helps prevent many problems before they occur. Practices in present plans include windbreaks (left at time of clearing and/or replanted) greenbelts, grassed waterways, hayland seeding and management, conservation tillage, cover crops, strip cropping and proper grazing systems.

To control wind erosion, the width of the strip is determined mainly by soil texture. For loam soils field strips 100-150m metre wide are adequate. In sandy loam soils, 50-100 metre strips, and for sandy soils, 50 metre strips or less are necessary. Field strips of 150-200 metres are usually adequate where special care is taken to keep a lumpy surface and trash cover; where shelterbelts are planted; where cover crops and grass legumes are used in rotation.

Field shelterbelts make strip cropping more effective. A plan followed is to established a tree belt along the edge of every other strip in a strip cropped field. Thus, where strips are 100 metres wide, tree rows would be 200 metres apart. This arrangement provides additional soil drifting control.

Alternate strips of summerfallow and crop arranged approximately at right angles to the slope acts to lessen the severity of erosion. Closest arrangement to the contour and the narrowest strips are needed for silty textured lacustrine soils on long, moderately steep slopes. Tillage and seeding across the slope, combined with contour strip cropping provide additional checks on run-off water and make field operations easier.

### Grassed Waterways

Waterways and diversion channels should be protected by grass or grass-legume cover to prevent soil erosion and gullying. Grassed waterways are broad, shallow channels that carry surface runoff with a minimum of erosion. Runoff following rainstorms and spring snowmelt removes tons of valuable topsoil from unprotected farmland. Grassed waterways are most effective where contour strip cropping is practiced.

Recognize gullies while they are still small and take immediate steps to grass them and correct the land use practices that are causing them. Eroded or gullied waterways should be filled, shaped, leveled and seeded. A grassed waterway should be constructed in late spring to ensure a good catch of grass before the following spring runoff. For filling small gullies farm machines are quite satisfactory. Heavy equipment is needed for filling large gullies, particularly for brush clearing and straightening of large meandering channels. The entire length of the channel should have a wide saucer-shaped appearance before seeding. The side slopes should rise no more than 25 per cent (one foot vertical to four feet horizontal). The waterway must have sufficient width and depth to accommodate the expected runoff volume. Proper shaping and packing of the water course is vital since this is the only protection against erosion until a cover crop is established. Edges of grassed waterways should be left jagged or saw-toothed to direct water from nearby slopes onto grassed areas.

For seeding waterways and gullies, a brome and alfalfa mixture with a nurse crop, seeded at double the normal rate is recommended. A recommended rate of seeding is 150-200kg (330-440 lbs) of grain (nurse crop) with 18 kg (40 lbs) of brome and 5 kg (11 lbs) of alfalfa per hectare. A mixed fertilizer (N,P,K) is recommended prior to seeding to promote establishment. Seeding should be done across the channel to provide added resistance to the water flow. Forage growth in grassed waterways should be mowed at the usual haying time. Tall growth left standing over winter traps snow and will block the flow of spring runoff.

Figure 3.4 Grassed Waterways

Source: *Save the Soil, A Study in Soil Conservation and Erosion Control*, H.M. Holm, Saskatchewan Agriculture, 1982.

### Cover Cropping

The practice of seeding a cover crop is also used to provide a measure of wind erosion control. Late summer seeding is done planting oats, barley or fall rye, usually seeded at half th rate of a crop for grain. Cover crops also help to trap additional snow throughout the winter. Maintaining a trash cover and a cloddy surface are also important to reduce water erosion and loss of soil.

### Barrier Strips

The establishment of annual barrier strips is another technique to reduce wind velocity at ground level and thereby reduce the potential for soil movement. Barrier strips also help to capture and maintain snow during winter months, increasing soil moisture reserves, resulting in greater soil protection and higher yields in the following crop year.

Various crops are used for annual barriers. Producers should experiment with different crops to see which ones meet their needs. Legumes such as field peas have ben used in barrier strips, also fixing nitrogen for the strip. Grasses have been successful. The greatest success on the prairies has been with Tall Wheat Grass (TWG), variety Orbit. It is recommended to seed TWG in single row barriers seeded 50-60 ft. apart. Recommended seeding rates are from 25-30 seeds per foot of row. Planting is best done in the early spring or in late fall as close to freeze up as possible to discourage germination until spring. With fall seeding some winter seed loss may occur and seeding rates should be increased. It is recommended that each barrier strip should consist of at least 2-3 rows of plants seeded 15-30cm (6-12") apart. Distance between barriers depends on the erodibility of the soil, implement size and type of crop. Strips should be seeded as close to right angles as possible to the prevailing wind direction. On sloping ground strips should be seeded on the contour across the slope to minimize water erosion.

Plans for the construction of a barrier strip seeder are available free of charge from the Agriculture Canada Swift Current Research Station, Box 1030, Swift Current, Saskatchewan S9H 3X2.

## STEWARDSHIP ON YOUR FARM

Farming successfully in an ecologically sound manner - A goal of the 90's. We need to conform to natural laws in farming so that we can grow food in ways that do not harm the environment. We need to be stewards of the farmland to ensure production is carried out in a manner that protects soil and water resources and habitats for fish and wildlife.

### Wildlife Habitat

Manage the farm for wildlife by:

1. Protecting habitat (soil,water and vegetation) from destruction by farm animals and machinery.
2. Choosing agricultural and land management practices which will benefit wildlife

Habitat is destroyed most often by the conversion of wetlands and woodlands to cropland and the improper timing in the use of fire, grazing, mowing and pesticides.

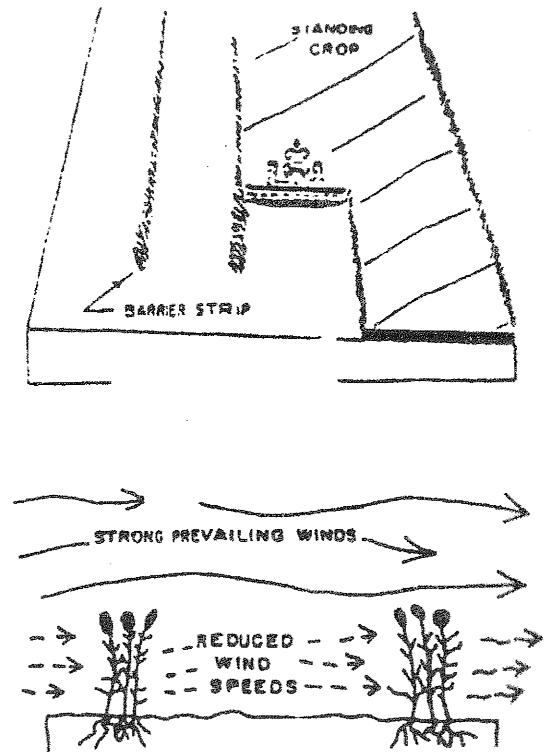



Figure 3.5 Barrier Strips

Source: *Topsoil*, Yukon Soil Conservation Newsletter, Winter 1991/1992, C.A.S. Smith, K. Bisset, Agriculture Canada, Yukon Soil Conservation Program, 1992.

### What Can I Do?

1. Develop the farmland with habitat management in mind.
   - Unsuitable lands for cultivation such as wetlands or difficult to cultivate areas, gullies and rock piles are valuable wildlife habitat and should be left to native vegetation.
   - Wetlands are probably the most productive areas for wildlife on rural land. Carefully consider preservation or management before thinking about draining and filling.
   - Reduce the need to develop marginal lands for cultivation or pasture as these areas provide nesting areas and cover for many species.
2. Maintain a mixture of vegetative types or plant communities.
   - Strip habitat including fence rows, hedgerows, shelterbelts, windbreaks, ditch banks and stream banks provide variety to the landscape and wildlife habitats.

> *"Wildlife is not a luxury, but a necessity. It enriches our spirit. It increases the value of our property. It is part of life that contributes to the wholeness of the land."*
>
> Ruth L. Hine

- Planting of new varieties of trees, shrubs and grasses also enhances habitat.
- Shrubs and grassy cover, for example, reduce soil erosion, moisture loss and increase soil formation and fertility.

3. Choose agricultural practices which will reduce soil erosion and reduce soil loss into surface waters and wetlands.
   - Plant highly erodable sites to a permanent ground cover.
   - Maintain crop residues and minimize fall tillage.
   - Plant crops at least 9 metres (30 ft) from the edge of vegetation along a stream or wetland.
   - Minimum and no-till cultivation, contour plowing, and crop rotations will reduce wind and water erosion.
   - Used at the right time and in the right place, fire, grazing and mowing are tools that you can use to restore wildlife habitat.

> *"A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise."*
>
> Aldo Leopold

> *"In order for farmers to be able to protect the environment, all of society must adjust itself to allow farming to be economic as well as ecological."*
>
> (Synergy, Spring 1990)

4. Protect Water Quality and Fish Habitat
   - Livestock should be kept out of streams and off banks.
   - Land clearing and uncontrolled access of cattle to watering areas can threaten aquatic resources. Poorly placed feed lots and the feeding of livestock on the ice in winter can affect water quality if during spring runoff animal wastes go directly into adjacent downstream waters.
   - Herbicides, pesticides or fertilizers can be harmful to the aquatic environment.
   - Minimize the use of pesticides and herbicides, by using spot applications and crop rotations.
   - Use a minimum of pesticides and herbicides, by spot application.
   - Time fertilizer and pesticide applications to reduce nutrient and herbicide runoff to waterways.
   - Fertilizers can add to the waterbody nutrients which can cause increased growth of algae and aquatic plants.
   - Pesticides can be toxic if not properly applied.
5. Plant a little extra crop, intentionally for wildlife:

*I've planted an extra plot of field peas for the Canada geese which flock to my farm every fall. Its amazing how they eat the crop completely to the ground, even doing this before they start on the grain.*

- Mayo Producer

## FENCING

"Open range" is now a part of Yukon history. Livestock control laws require containment of animals and penalties exist for livestock found on highways. Fencing is a large investment of money and labour and care should be taken to decide the most suitable type of fencing for the operation, determine what is affordable and priorize the construction. Fencing is usually a progressive operation, done as the farm develops to define farm boundaries, confine animals and keep animals from crops.

> *"Good Fences Make Good Neighbours"*
>
> - The Mending Wall
> Robert Frost

### *Fence Posts:*

Wood, metal and concrete are commonly used for fence posts. The selection of posts should be determined by the availability and cost, the length of service desired and the type and amount of livestock to be confined. Wood should be treated at the butt end 15-20cm (6-8") above the ground line with a good wood preservative. Wood corner, end and gate posts should be substantial, usually not less than 25-30cm (10-12") in diameter.

The corner, end and gateposts should be long enough so they can be set 1-1.2m (3.5-4 ft) deep, used at each corner or end and two posts used on each side of gates. These posts are the foundation of the fence and will take most of the strain of the fence as well as the whole strain of stretching. These are usually set in concrete to ensure stability. With wood posts a double span corner arrangement is preferable to a single span anchor. Double span assemblies have more than twice the strength of single span assemblies. Double span assemblies should be used on fence lengths of 100 to 400m and single span assemblies may be used on fence lengths up to 100m. Brace posts can be horizontal or diagonal as shown in Figure 3.6-b.

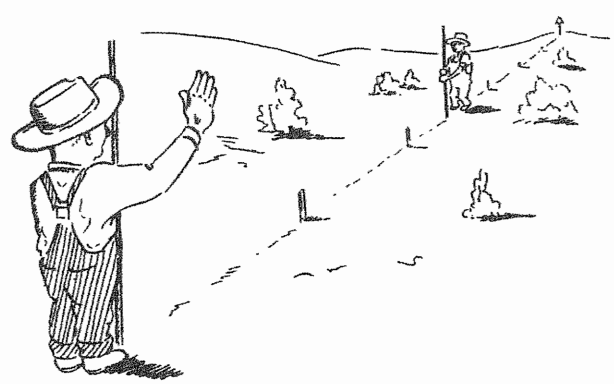
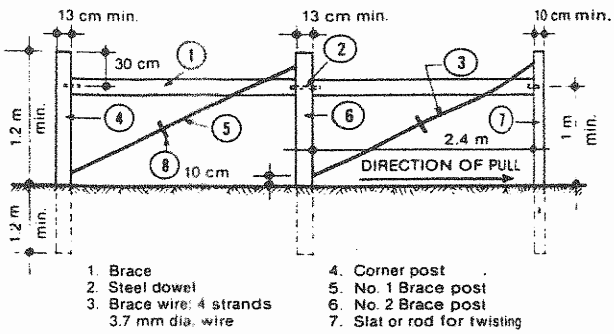


Figure 3.6 a) Line Posts and Corners
- *Lining up the Line Posts*

Similar heavy posts should be set at intervals of 30-40 rods or 150m-200m (495-660 ft)apart where there is a long straight stretch and at the top and bottom of each slope if the ground is hilly. The line posts, at least 10cm (4") in diameter and from 1.8-2.4m (6-8 ft) long can be spaced from 4-5 m (12-16 ft) apart up to longer spans of 5-6m (16-20 ft) apart. Posts should be driven into the ground at a depth of .6 -.8m (2-2.5 ft). Post spacings should be reduced to 4m (13ft) where the terrain is uneven or where a particularly strong fence is needed. Get a helper to assist with the lining up of the fence posts.



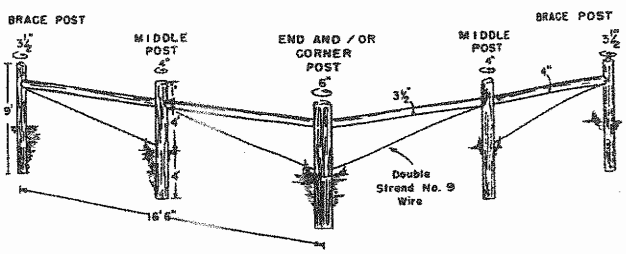
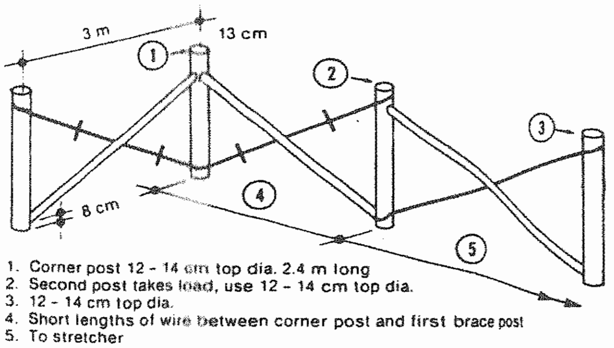




Figure 3.6 b) Line Posts and Corners

- Double Span Corner Arrangement: *Horizontal Wood Braces*




- Double Span Corner Arrangement: *Diagonal Wood Braces*

***Fencing:***

Except for corrals and horse fences, woven and or barbed wire fences are most used for most classes of livestock. The best way to determine how much fencing is required is to measure the area on all sides, add these measurements together and add additional fencing for wrapping around the corner, end and gate posts.

**Woven Wire Fencing:**

Woven wire fencing comes in Nos. 9, 11, 12 1/2 and 14 1/2 gauge wire. No. 9 wire is the strongest. Woven wire usually comes in 20 rod rolls (16.5 ft/rod). The mesh or stays are in 6 or 12" spacing. Generally, the closer 6" spacing will give better service than the 12" spacing. Heavier wire than normal is needed for fencing small areas, where a dense concentration of animals is involved and where animals have already learned to get out.

The use of woven wire in combination with barbed wire differs for different classes of farm animals as shown in Figure 3.7.

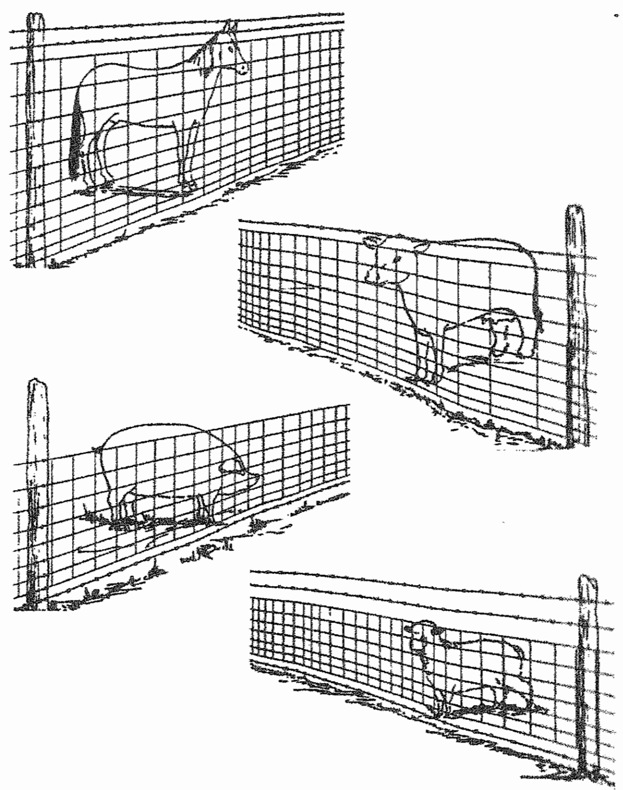
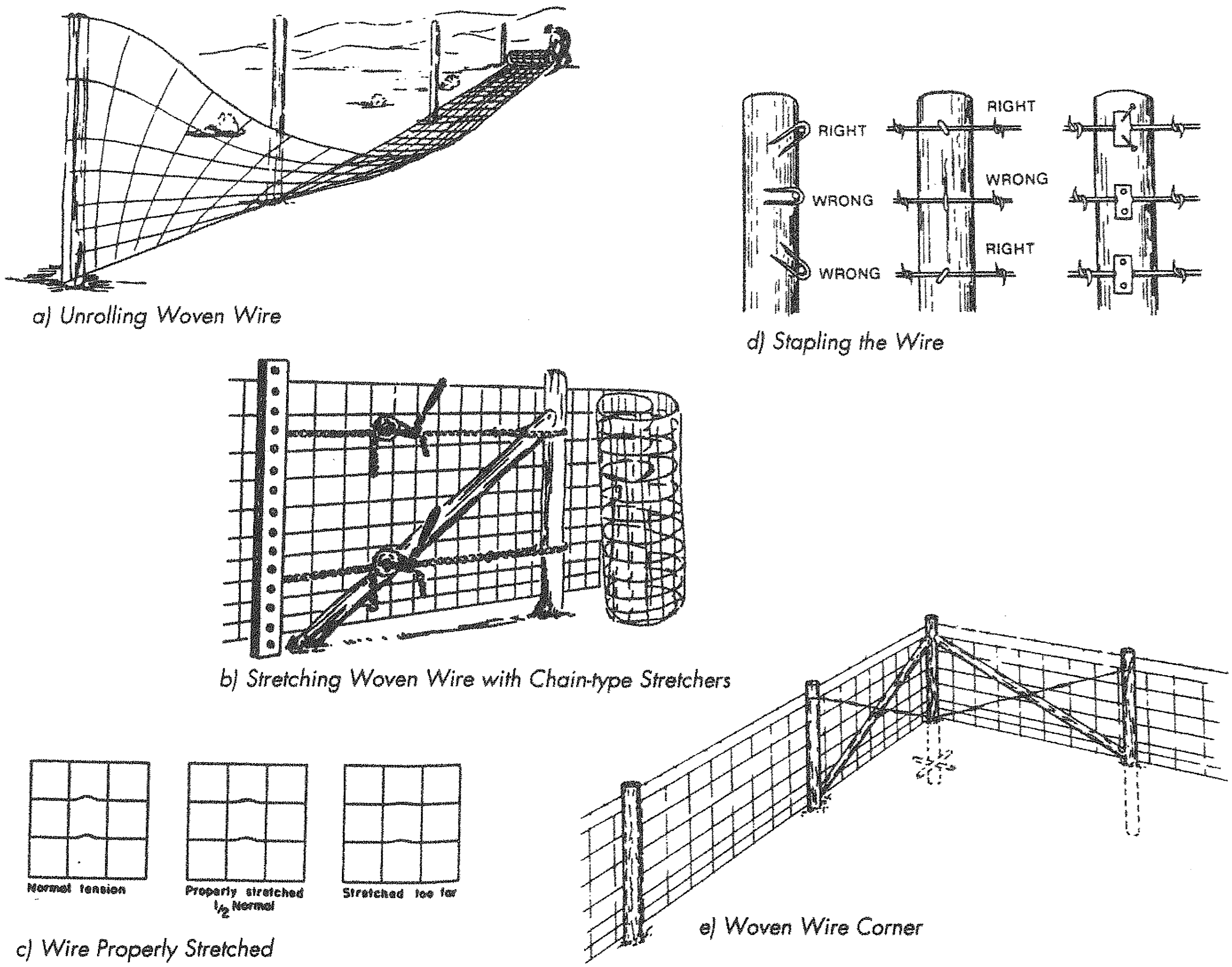


Figure 3.7 Woven Wire Fencing/Animal Type

Source: *Farm Pasture Fencing*, Agriculture Canada, Pub.1568/E

For hogs, 66cm (26") or 91cm (36") woven wire is used, placed 8-10cm (3-4") above the ground with a single strand of barbed wire stretched beneath the woven wire to prevent rooting under the fence. For horses, cattle and sheep, where a higher fence is required, add one or two strands of barbed wire above the woven wire.




a) Unrolling Woven Wire

b) Stretching Woven Wire with Chain-type Stretchers

c) Wire Properly Stretched

d) Stapling the Wire

e) Woven Wire Corner

Figure 3.8 Fastening Methods

Source: *Farm Pasture Fencing*, Agriculture Canada, Pub.1568/E

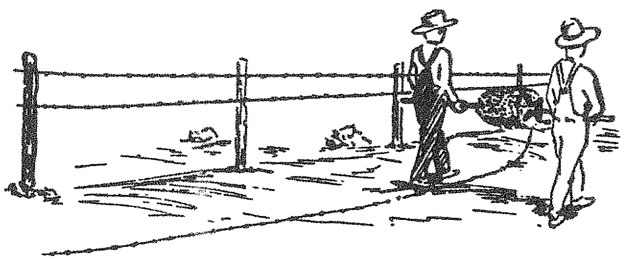
**Fastening Methods**

Attach the fencing properly to the end post making sure that the stay wire is straight up and down, parallel with the end post and straight in line with the fence line. Unroll the fence with its bottom edge close to the bottom of the line posts and extends beyond the next end or corner post. Attach the chaintype stretchers to the end post, making sure that the chains on the stretchers are straight. Set up the fence along the line posts by hand a few temporary fastenings made with wire at intervals to the line posts. Then stretch the fence until the tension curves are about 1/2-2/3 their normal size. Overstretching removes the tension curves and injures the fence. When the stretching is complete cut off the fence sufficiently beyond the fence post so that the line wires may be wrapped around it and take up the slack in each line wire and wrap each one around the post starting with the bottom wire first. Secure to the end post and release the fence stretchers. The fence should be fastened to the line posts with fence staples (1 1/2" for soft woods and 1 inch for hardwoods.) Less splitting will occur if the staples are driven in diagonally to the grain. Do not drive staples clear in so that it can slide a bit when the line wire expands or contracts with changes of temperature.

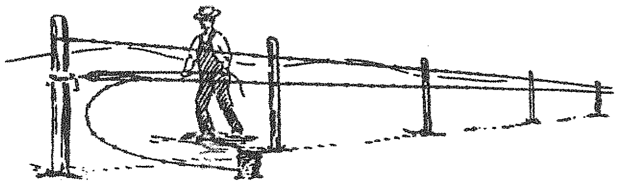
**Barbed Wire Fencing:**

Barbed wire is usually 12 1/2 gauge. Styles of barbed wire differ in shape and the number of points of the barb. The two point barbs are normally spaced 10cm (4") apart while the four point barb are generally spaced 12 cm (5") apart. Any style is satisfactory and selection is a matter of preference. Barbed wire usually comes in 80 rod spools (16.5 ft/rod).

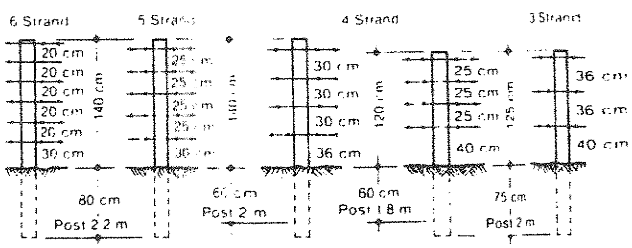
Put a crow bar or iron pipe through the spool of barbed wire and with two people walk along the fence line as the wire unrolls. A tractor may be practical for unrolling the wire with large fencing jobs. The barbed wire can be stretched by using a tackle block stretcher equipped with wire grips. Start with the top wire first. Staple the wire as shown in Figure 3.8 d. The spacing for 3-6 strand fences and post heights as well as a barbed wire splice are illustrated in Figure 3.9.



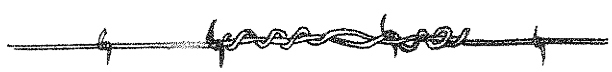
*a) Unrolling Barbed Wire*



*b) Stretching Barbed Wire with a Tackle Block Stretcher.*




*c) Wire Spacing and Line Post Sizes*



Barbs 10 - 12 cm apart

*d) Barbed Wire Splice*

Figure 3.9 Barbed Wire Fencing Methods

**Electric Fencing:**

Electric fencing can be installed at a minimum cost where temporary enclosure is desired. Wood or steel posts may be used. Corner posts should be firmly set and well braced as required for any non-electric fence so to stand the pull necessary to stretch the wire tight. Line posts may be spaced 12-15m (40-50 ft) apart for horses and cattle and 8-12m (25-40 ft) apart for sheep and swine. Barbed wire is recommended but smooth wire can be used satisfactorily. As a rule of thumb, the correct wire height for an electric fence is about three fourth the height of the animal, with two wires provided for sheep and swine. Different heights are shown in Figure 3.10 for different farm animals. For mixed livestock use 3 wires at 20cm (8"), 30cm (12"), and 81cm (32").

**Wire Spacing:**

A) Cattle – 76-101cm (30-40")
B) Calves – 30-46cm (12-18")
C) Sheep, two wires – Bottom wire 20-25cm (8-10")
– Top wire 41-46cm (16-18")
D) Swine, two wires – Bottom wire 15-20cm (6-8")
– Top wire 36-41cm (14-16")
E) Horses – 76-101 cm (30-40")

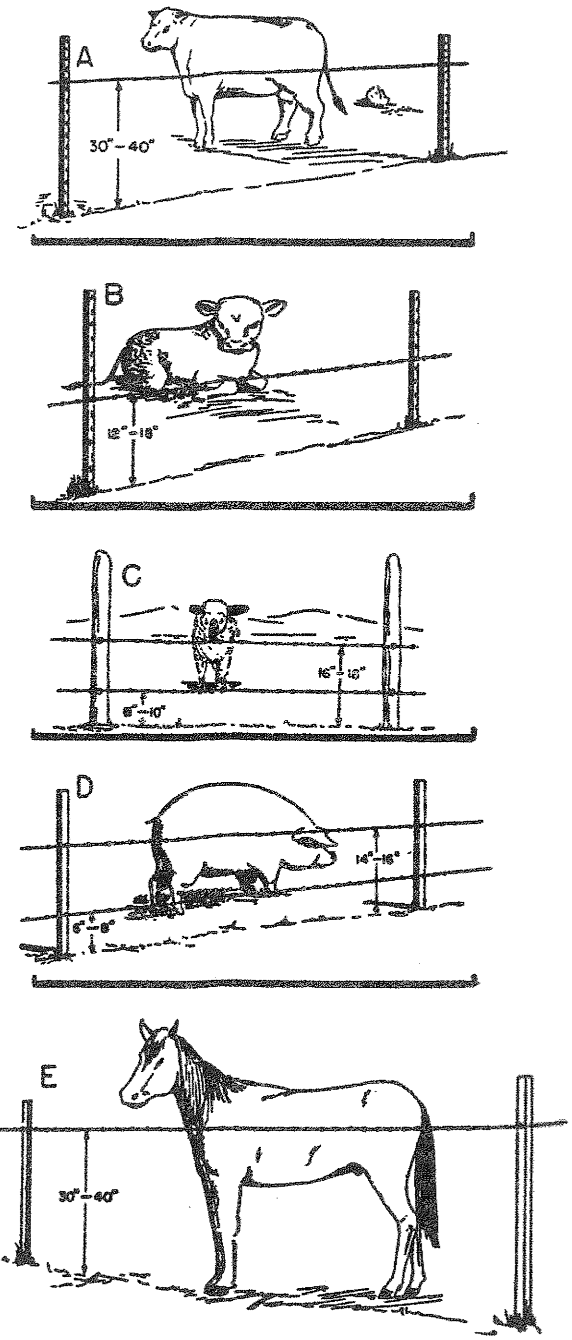



Figure 3.10 Electric Wire Spacing/Animal Type

Figures 3.7 to 3.10: *The Stockman's Handbook*, Fourth Edition, 1970. With the permission of Interstate Publishers Inc., Danville Illinois, and of the author, Dr. M. E. Ensminger, P.O. Box 429, Clovis, CA 93612.

Wires should be fastened to the posts by insulators and should not come into direct contact with the post, weeds, or the ground. Glass, porcelain or plastic insulators are available on the market. The snap on plastic insulators for steel posts work well for this type of fencing. The electric fence should be grounded by using grounding rods. In a 3 strand fence the middle wire should be grounded to one rod and the other two strands to another rod.

**Wooden "Russell Fence":**

These are built out of firekilled timber with sections (4.2-4.8m (14-16 ft) long. The benefit of this system is that posts are not dug into the ground. These have been used on grazing leases or large fenced areas in the Yukon. A few local contractors are available for this type of fence construction.

### *Gates*

The location of gates needs to be well planned to facilitate travel into and around the farm fields. Gates may be constructed of various materials. Steel and aluminum gates are available from metal building suppliers. Plans for wood gates, "Texas gates" and cattle guards are available from the Canada Plan Service. Gates should be of a width to accommodate machinery etc. and should be well braced and durable.

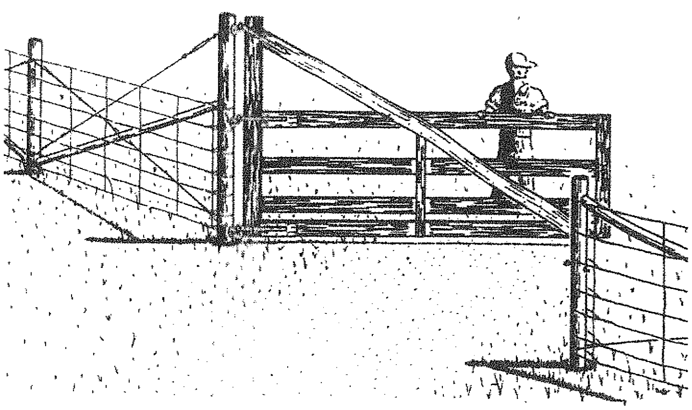


Figure 3.11 Farm Gate

Source: *Farm Gate*, Canada Plan Service, Plan M-8364.

# SOIL MANAGEMENT

The management of your soil is the basis of success for future crop production. The first step in soil management is to determine the soil quality and nutrient availability through soil tests.

## SOIL TESTING

Soil tests help you to maintain a more productive soil, to increase your crop yields or to establish plants more quickly - whether for a field, garden, greenhouse or lawn area. A complete soil test will help to determine your fertilization, soil improvement and irrigation practices to achieve maximum nutrient availability and plant growth. Soil testing can be divided into three major steps: 1) taking the sample, 2) completing the laboratory analysis, and 3) interpreting the results.

> **"Don't Guess – SOIL TEST"**

## TAKING THE SOIL SAMPLE

Taking the sample can be a major source of error in the process therefore it is very important to get a representative sample of the field or garden area you are sampling. Each soil sample should represent only one soil type, condition, or growing situation. Sample separately, the garden area, the flower bed, the lawn and one for each uniform land area within a field. Sample separately areas of different soil types and areas to be used for different crops, soil and crop management procedures including:

- low spots
- bottom lands and uplands
- different slopes
- organic soils
- coarse textured soils
- soils of different colour
- soils with different cropping history
- soil irrigated vs. non-irrigated
- soils with past fertilizing, liming or manuring histories

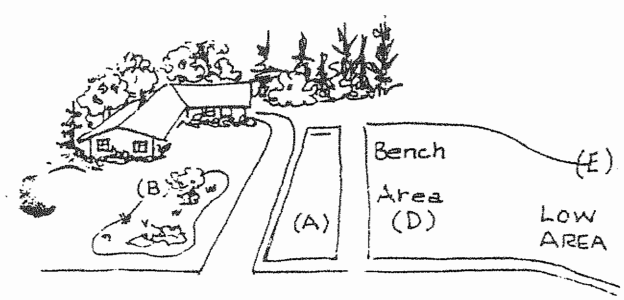
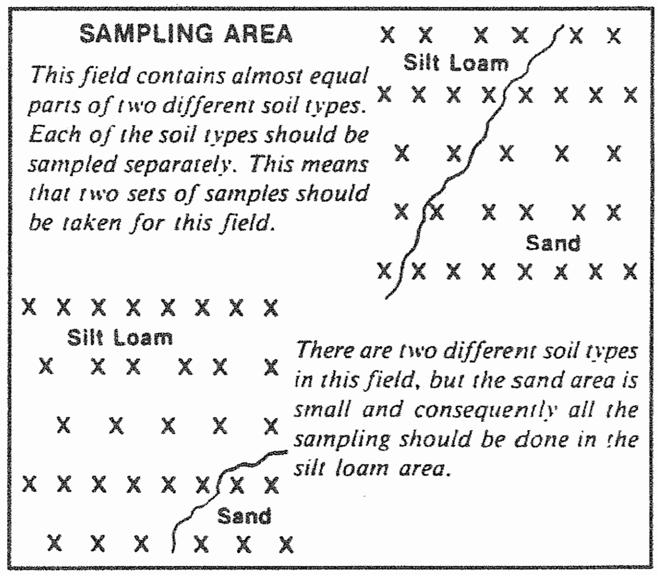



Figure 4.1 Sample Different Areas

Source: *Soil Sampling*, University of Alaska Extension Service, Fairbanks, Alaska, 100G-00044

Within the specific area chosen for the soil test a stratified random sampling should occur. Each sample should consist of at least 20 subsamples taken in a criss cross pattern, equidistant from one another, to make up the sample size. Approximately 1 kg (2.2 lbs) is sufficient for the soil testing procedures, but most importantly it must be representative. For smaller areas, samples will be closer together to make up the sample size. For larger areas, spaces between subsamples will be greater but ensure the entire field is represented.



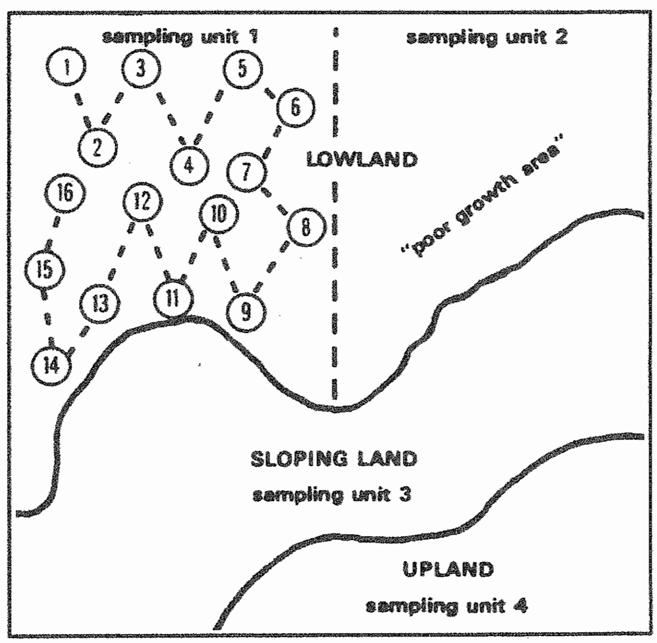




Figure 4.2 Sample in a Criss Cross Pattern

Source: *Soil Sampling*, University of Alaska Extension Service, Fairbanks, Alaska, 100G-00044

Two separate samples should be taken **at each point**, at the 0-6" depth and 6-12" depth. Each of these individual samples will make up the total sample to represent a given area. The separate depths are analyzed separately and then combined for an overall evaluation of the soil quality and fertility.

### *Time of Sampling*

The initial soil sample should be taken prior to the first planting and fertilizing so that a baseline test will be available to correlate future soil test results and guide soil management decisions. Thereafter, the fall is an excellent time to take your sample to have fertilizer recommendations available prior to planting in the spring.

### *Tools for the Job*

#### Soil Auger

A soil auger should be used to complete the sample for more accuracy whenever available, as shown in Figure 4.3. This tool provides a 1 inch wide core sample from the specific depth. Push the auger into the soil to a 1 ft depth which is usually the end of the core on most soil augers. Twist the auger out making sure the open side of the auger is up so as to not loose your sample. The 0-6" depth is clearly marked on the auger, take this portion (top end of core) for one sample and the 6-12" (bottom end of core) for the other sample. There are often differences in soil colour and texture within the 0-6" depth and 6-12" depth.

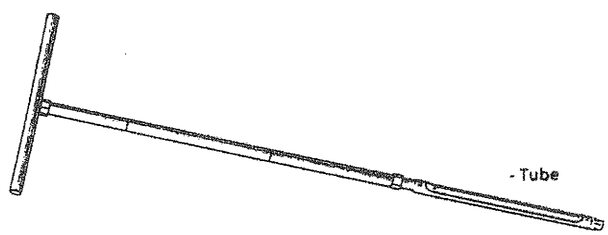



Figure 4.3 Soil Auger

Soil augers work well in drier soils but can get stuck if the soil is too wet. Compacted soils are also difficult to sample. However, the accuracy of the soil depth can be obtained more easily than with a shovel. Soil augers are available from suppliers for about $60.00. The Agriculture Branch has a few which are available on loan for growers to complete their soil sampling.

#### Shovel

If a shovel has to be used, this provides for a good sample:

1. Dig a V-shaped hole 1 ft deep or at plow depth.
2. Take a 1 inch slice from one side of the hole.
3. Trim the sides of the slice, leaving a one inch strip on the spade.
4. Divide the 1 inch strip into 0-6" and 6-12" samples.

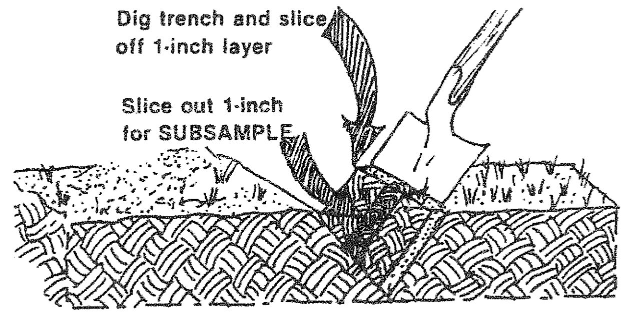



Figure 4.4 Taking a Subsample with a Shovel

Source: *Soil Sampling*, University of Alaska Extension Service, Fairbanks, Alaska, 100G-00044

#### Sample Bags

For sample bags use medium sized "Baggies" or plastic freezer bags which can be sealed easily. Sample bags, provided by a soil testing lab are also available at the Yukon Agriculture Branch.

### *Preparing the Samples for the Lab*

Label each sample with a description of the location (ie. Field A, the date of the sampling, and the soil depth (0-6" or 6-12"). This helps when you have to sort through the soil samples and properly label them for lab analysis.

Care should be taken to keep the sample cool until it is able to be dried. High temperatures may heat up the sample which may alter the nitrates and could affect a higher level of nitrogen in the soil test results.

As soon as possible, samples should be spread out on newspaper and dried for a couple of days at room temperature. Do not apply artificial heating. Then rebag your sample for the soil testing lab, using approximately 1 kg (2.2 lbs) of soil. Organic or coarse materials should be removed.

Label each sample, with your name, description of the location, (ie. Field A), the date of the sampling, and the soil depth (0-6" or 6-12"). Keep a record of the sample description so that you can correlate the Lab Number and soil testing results. Soil depths taken, (0-6" and 6-12") are separately entered but form one sample, ie. Sample 1A and 1B, Field A.

Additional information can also be provided to the Lab, regarding the past crop grown, if is newly broken ground, or what is the intended future crop. This will help to acquire more specific fertilizer recommendations.

## LABORATORY ANALYSIS

The Agriculture Branch and Yukon Crop Development Programs have primarily used Norwest Labs for soil testing: Address: 9938-67 Avenue, Edmonton, Alberta T6E OP5. There are many other soil testing labs in western Canada which can be used.

For the sake of illustration, a description of Norwest Labs analysis procedures and recommendations are described in this section. Using the same lab has provided a way for the Agriculture Branch, Agriculture Canada and local farmers to correlate results as they undergo similar laboratory procedures and recommendations.

For commercial growers, the Agriculture Branch will send off your soil samples to Norwest Labs for analysis. If you want to send a sample to Norwest Labs yourself, the best way is via bus, you can send it collect, and they will pick it up in Edmonton. Check for current fees for soil sampling. If money is short, Package D is the minimal one you should order.

At Norwest Labs a complete soil analysis includes:

- Package D: Nitrate, phosphate, potassium, sulphate, pH, E.C. texture, organic matter, calcium, magnesium, sodium
- Package E: Complete Micronutrients: Boron, Zinc, Copper, Iron Manganese
- Additional Packages: Lime Requirement

## INTERPRETING YOUR SOIL TEST

Norwest Labs presents the results of your soil test in three sections and this format has been used to explain the various components of soil test results. Relative information has been given to further explain each aspect of the soil test results.

1. Nutrient Analysis - (Macro/Micro Elements)
2. Soil Quality (pH, Electrical Conductivity (E.C.), Organic Matter %, Soil Texture)
3. Fertilizer Recommendations.

## NUTRIENT ANALYSIS

There are 16 essential elements required for plant growth. The plant cannot complete its life cycle in the absence of the element. These essential elements must be present in forms useable by plants and in concentrations optimum for plant growth.

The **macronutrients** are those elements required in relatively large quantities. They are nitrogen, phosphorous, potassium, calcium, magnesium and sulphur. Of these, nitrogen, phosphorous and potassium are called the **primary nutrients** which are used in considerable quantities by crops.

Calcium, magnesium and sulphur are considered **secondary nutrients**, used in moderate quantities and which influence pH. Calcium and magnesium are added to acid soils to increase soil pH in the form of limestone and are called lime elements. Suphur is used to decrease soil pH and is added as farm manure, superphosphate, sulfate of ammonia or as flowers of sulphur.

The **micronutrients** are elements needed in considerably smaller quantities, known as trace or minor elements. This includes iron, clorine, manganese, copper, zinc and molybdenum. The essential elements from air & water and soil solids are indicated in Table 4.1.

Table 4.1 Essential Elements

| MACRONUTRIENTS Used in Large Amounts | | MICRONUTRIENTS Used in Small Amounts |
|---|---|---|
| Mostly from Air & Water | From Soil Solids | From Soil Solids |
| Carbon (C) | Nitrogen (N) | Boron (B) |
| Hydrogen (H) | Phosphorous (P) | Zinc (Zn) |
| Oxygen (O) | Potassium (K) | Copper (Cu) |
| | Sulphur (S) | Iron (Fe) |
| | Calcium (Ca) | Manganese (Mn) |
| | Magnesium (Mg) | Clorine (Cl) |
| | | Molybdenum (Mo) |

Note:

* Other minor elements, such as sodium, fluorine, iodine, silicon, strontium and barium do not seem to be universally essential, as the 16 listed, although the soluble compounds of some may increase crop growth.
* Some sources say 17 elements are essential, to include Cobalt (Co), as a minor element.

Source: *The Nature and Properties of Soils*, N.C. Brady, 8th Ed., p21.

On the soil test report from Norwest Labs the concentration of essential nutrients is indicated in parts per million (ppm), which is one pound of nutrient in one million pounds of soil. (There are about two million pounds of soil per acre for each 6 inches of depth.)

Table 4.2 Critical Levels of Available Nutrients in Soil

| | MACRONUTRIENTS | | | | | | | | MICRONUTRIENTS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N/NH4 | N/NO3 | P | K | S/SO4 | Ca | Na | Mg | Fe | Cu | Zn | B | Mn | Mo | Cl |
| **Excess:** | 50 | 55 | 60 | 500 | 20 | 5000 | 50 | 1000 | 100000 | 5.0 | 20 | 3.5 | 100 | 1.3 | 20 |
| **Optimum:** | 5 | 35 | 25 | 125 | 8 | 250 | 2 | 60 | 10 | 0.8 | 1.0 | 0.5 | 2.0 | 0.2 | 8 |
| **Marginal:** | 1 | 20 | 15 | 80 | 2 | 50 | 1 | 30 | 5 | 0.3 | 0.5 | 0.3 | 1.0 | 0.1 | 4 |
| **Deficient:** | | | | | | | | | | | | | | | |

Source: *Norwest Labs Information Sheet*, 1990.

For the complete soil test (Package D & E), a total of 12 essential elements are analyzed for ppm at 0-6". Nitrates and sulphates are also indicated for the 6-12" depth. Sodium (Na), not an essential element, is tested for as part of Package D. Determining micronutrients, chlorine (Cl) or chloride and molybdenum (Mo) are not included in Package E, as these elements are not routinely tested for.

On the Norwest Lab soil test report, from left to right, ppm results are presented as: Ammonium Nitrogen ($NH_4$), Nitrate-Nitrogen ($NO_3$), Phosphate or Phosphorous (P), Potassium (K), Sulphate ($SO_4$) or Sulphur (S), Calcium (Ca), Sodium (Na), Magnesium (Mg), Iron (Fe), Copper (Cu), Zinc (Z), Boron (B) and Manganese (Mn).

In Table 4.2, threshold values are indicated for each macro and micronutrient in parts per million (ppm). Norwest Labs uses these values as critical levels of available nutrients in the soil to determine four levels of nutrient availability, indicated as Excess, Optimum, Marginal and Deficient. The nutrient level is considered to be deficient if below the marginal category critical levels. This forms part of Norwest Labs fertilizer recommendations.

As part of the nutrient analysis, the total lbs/acre and the estimated available lbs/acre are indicated for nitrate ($NO_3$), phosphate, potassium and sulphate. A graph illustrates the relative amounts of 12 elements (N, P, K, S, Ca, Na, Mg, Fe, Cu, Zn, B, Mn) as to whether they are deficient, marginal, optimum or in excess. This is a combination of the nutrients available in your soil at 0-6" and 6-12".

### *Available Forms of Nutrients*

The essential elements are rarely present in elemental form in nature but are nearly always combined with other elements into chemical compounds. Mineral nutrients elements from weathering rocks, fertilizers, and organic materials are dissolved in the soil solution or held by the solid phase of the soil. The accumulation of essential elements from the soil by growing plants is primarily a process of ions containing the essential elements moving from the soil water into the plant roots.

Table 4.3 Available forms of Essential Nutrients

| MACROELEMENTS | | | MICROELEMENTS | | |
|---|---|---|---|---|---|
| Element | Symbols | Available Form | Element | Symbols | Available Form |
| Carbon | C | $CO_2$ | Iron | Fe | $Fe^{+++}$,$Fe^{++}$ |
| Hydrogen | H | $H_2O$ | Chlorine | Cl | $Cl^-$ |
| Oxygen | O | $O_2$,$H_2O$ | Manganese | Mn | $Mn^{++}$ |
| Nitrogen | N | $NO_3^-$,$NH_4^+$ | Boron | B | $BO_3$,$B_4O_7$ |
| Phosphorous | P | $H_2PO_4^-$,$HPO_4$= | Zinc | Zn | $Zn^+$ |
| Potassium | K | $K^+$ | Copper | Cu | $Cu^{++}$,$Cu^+$ |
| Calcium | Ca | $Ca^{++}$ | Molybdenum | Mo | $MoO_4$= |
| Sulphur | S | $SO_4$= | | | |
| Magnesium | Mg | Mg++ | | | |

Source: *Hydroponic Food Production*, H.Resh, Third Edition, 1985.

The available forms of the essential elements in the soil, as indicated in Table 4.3, pass from the soil solution through selective membranes into the roots and move up to the top of the plant. In the green part of the plant, energy from the sun and carbon dioxide from the air are used to form many different organic compounds. Figure 4.5 illustrates this process:

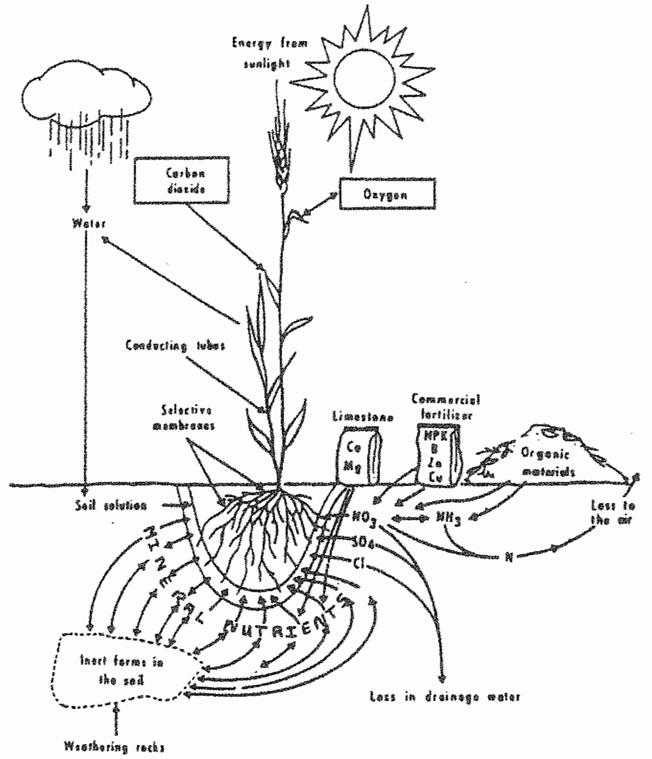



Figure 4.5 Available Nutrient

### *Yukon Nutrient Levels*

#### Agriculture Branch

Since 1986, the Yukon Agriculture Branch has tested soils throughout the Yukon, including uncropped lands and cultivated areas. In Table 4.4, a total of 357 samples were summarized for soil nutrient analysis for nitrogen, phosphorous and potassium. Soil test were completed by Norwest Labs and the nutrient levels are defined by four categories, as previously described.

Table 4.4 Nutrient Levels in Yukon Soils

| Category | Nitrogen | Phosphorous | Potassium |
|---|---|---|---|
| Deficient | 87% | 47% | 22% |
| Marginal | 7% | 17% | 17% |
| Optimum | 4% | 27% | 60% |
| Excess | 2% | 9% | 1% |

In newly developed farm soils, nitrogen is usually deficient, phosphorous is low and potassium usually optimum.

Yukon soils in their natural state are low in fertility, particularly those which are formed on coarse textured glaciofluvial or alluvial soils. They are characterized by cold temperature regimes, affecting soil activity and the availability of nutrients. Nitrogen deficiency (87%) is explained by the fact that most of the samples come from newly cleared land. Nitrogen is commonly deficient, except in well developed organic soils. Phoshorous is deficient on less than 1/2 of the samples and is usually within the optimum amounts in the Whitehorse area. Potassium availability varies with soil types and regions. It is usually more available in the soils near Whitehorse than in Watson Lake, Mayo or Dawson.

### YCDP Soil Tests

Soil tests were taken in the fall of 1988 and 1989 for every site involved in the YCDP research project.

Table 4.5 YCDP Nutrient Levels - Fall 1988 & 1989

| Nutrient Analysis: | Deficient | Marginal | Optimum | Excess |
|---|---|---|---|---|
| **Fall 1988** | | | | |
| WATSON LAKE | N, P, K, B | S | Cu, Zn | |
| WHITEHORSE | N, B | S, Cu, Zn | K | P |
| CARMACKS | N | | K, S, Cu, Zn, B | P |
| PELLY | N, P, B | K | Cu, Zn | S |
| MAYO | N, P, K, Zn, B | S, Cu | | |
| DAWSON | N, P, K, B | | Cu, Zn | S |
| **Fall 1989** | | | | |
| WHITEHORSE | B | K, Zn | N, P | S, Na |
| CARMACKS | | N | K, Na, Zn, B | P, S |
| PELLY | P,B | K | N,Zn | S,Na |
| MAYO | N, P, K, S, Zn, B | | Na | |
| DAWSON | N, K, B | P | Na, Zn | S |

Note:

* In regions with more than one site the most limiting category was used for each element.
* In 1988, Na was optimum at all sites and in 1989, Cu was optimum at all sites.

The fertility of sites varied between region and between those areas which had been cultivated for years, or newly developed. Some areas had been fertilized during the 1985-1987 NCDP program and fertility levels had been improved. The site in Carmacks had been used as a garden for many years and was fairly well balanced for nutrients. The Mayo forage site was a newly developed field and required the most nutrients.

In the fall 1988, soil tests revealed deficiencies of nitrogen at all sites. Phosphorous was deficient at most sites, except those in Whitehorse and Carmacks. Potassium was also deficient, except in Whitehorse or Carmacks (optimum) and Pelly Farm (marginal).

Sulphur was deficient only at the Mayo site. For the micronutrients, boron was deficient in five of the six regions and zinc was deficient only at the Mayo site.

In the fall 1989, after two seasons of fertilizing according to recommendations, deficiencies of some nutrients were reduced. Boron continued to be deficient at the same sites, as in 1988. Sodium and sulphur were in excess at some sites.

## SOIL QUALITY

Soil quality refers to the soils' ability to support and promote plant growth. This portion of the soil test includes soil pH, Electrical Conductivity (E.C.), Organic Matter %, and Texture.

### *Soil Reaction*

The hydrogen ion concentration ($H^+$) in a solution (such as soil solution) determines the acidity. This concentration is expressed in terms of pH values which lie between 1 and 14. In Figure 4.6 shows the pH scale with corresponding items for different values.

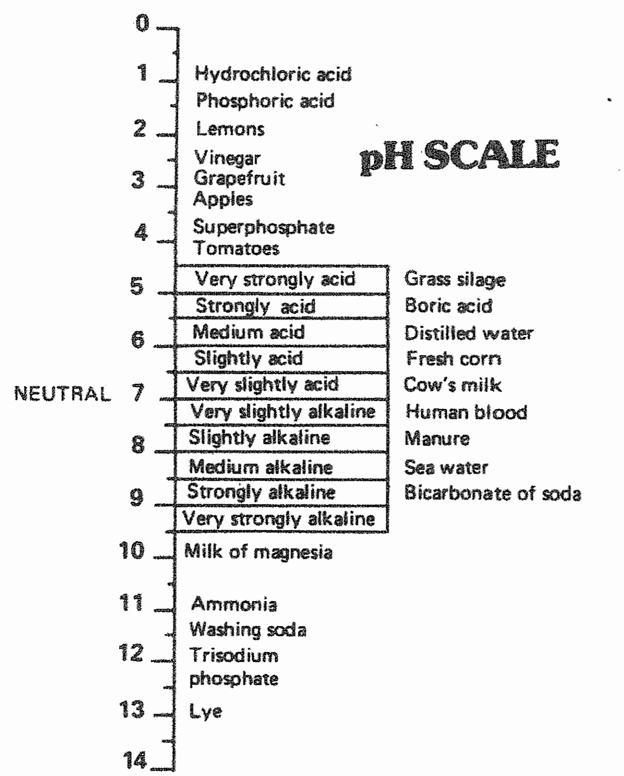



Figure 4.6 pH Scale

Source: *Down to Earth Vegetable Gardening Know-How*, D.Raymond, Garden Way Publishing, 1975.

Soil solution values are mostly between 4 and 8. A pH of 7 represents a neutral reaction. The pH value of a solution is the logarithm of the reciprocal of the hydrogen ion concentration, stated as $pH = \log 1/[H^+]$. Acidity increases as the pH lowers from 7, the solution increasing in hydrogen ions ($H^+$). Acidity decreases and alkalinity increases as hydoxyl ions ($OH^-$) increase, as values rise above 7. A neutral reaction has an equal concentration of both ions. Because pH numbers are logarithmic a soil solution with a pH of 5 is ten times as acid as one having a pH of 6 and one hundred times more acid than a soil solution of 7.

Figure 4.7 shows the range of pH values for soils of humid and arid regions, from acid peat soils to alkali mineral soils. Soils are either in the acid, neutral or alkaline category.

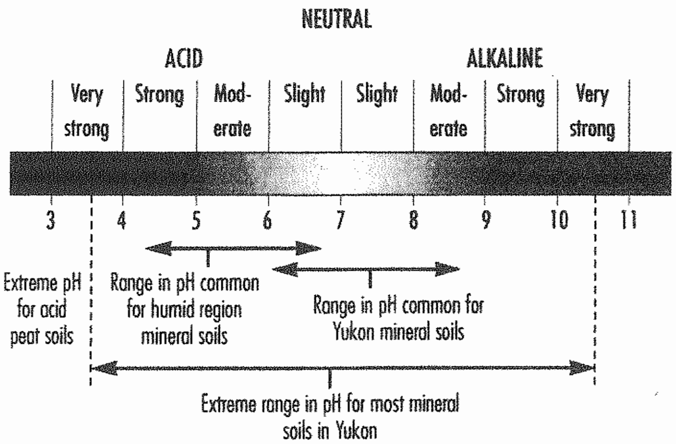



Figure 4.7 Ranges in Soil pH

The pH value of soil has a corresponding reaction class as defined in Table 4.6.

Table 4.6 Soil Reaction Classes

| REACTION CLASSES | pH VALUE |
|---|---|
| Extremely Acid | <4.5 |
| Very Strongly Acid | 4.6 - 5.0 |
| Strongly Acid | 5.1 - 5.5 |
| Moderately Acid | 5.6 - 6.0 |
| Slightly Acid | 6.1 - 6.5 |
| Neutral | 6.6 - 7.3 |
| Mildly Alkaline | 7.4 - 7.8 |
| Moderately Alkaline | 7.9 - 8.4 |
| Strongly Alkaline | >8.5 |

Source: *Manual for Describing Soils in the Field*, The Canada Soil Information System (Cansis), 1982.

In general soils in the southern part of the territory are neutral to alkaline and in the northern part are slightly acid to neutral soil. The range of pH of Yukon soils, determined by Agriculture Branch and YCDP soil tests is from pH 5.1-8.9. (See Yukon Soil Quality Levels.)

### *pH Affects Nutrient Availability*

The soil pH can influence nutrient absorption and plant growth through the direct effect of the hydrogen ion, or indirectly by its influence on nutrient availability, soil microbial activity and the presence of toxic ions. The availability of several of the essential nutrients is drastically affected by soil pH, including the solubility of certain elements that are toxic to plant growth.

In Figure 4.8, the availability of nutrients and activity of microorganisms for pH levels 4-9 are indicated. The wide portions of the bands indicate the zones of the greatest microbial activity and the most readily available nutrients. A pH range of approximately 6 to 7 is the zone with the most readily available plant nutrients and activity of soil microorganisms. It is microbial activity that converts organic forms of nutrients into forms that plant nutrients can absorb.

With a pH of less than 6.0, nitrogen, phosphorous, potassium, sulphur, calcium and magnesium, become less available. If the soil pH is suitably adjusted for phosphorous, other plant nutrients, if present in adequate amounts, will be satisfactorily available in most cases. The kind of phosphate ion present varies with the pH of the soil solution. At higher acidities the $H_2PO_4$ ions tend to dominate and on alkaline soils $HPO_4$ ions prevail. A soil reaction which yields a mixture of these ions is preferred and between a pH of 6-7 phosphorous availability is at a maximum as far as most plants are concerned.

When the pH of a mineral soil is low, aluminum, iron and manganese are soluble, so much that they may become extremely toxic to plants. Several essential minor elements including iron, manganese, zinc, copper, and cobalt tend to become less available as the pH is raised from 5.0 to 8.0. As the pH is increased, the amounts of these ions in solution become less until at neutrality or somewhat above certain plants may suffer from a lack of availability of these elements.

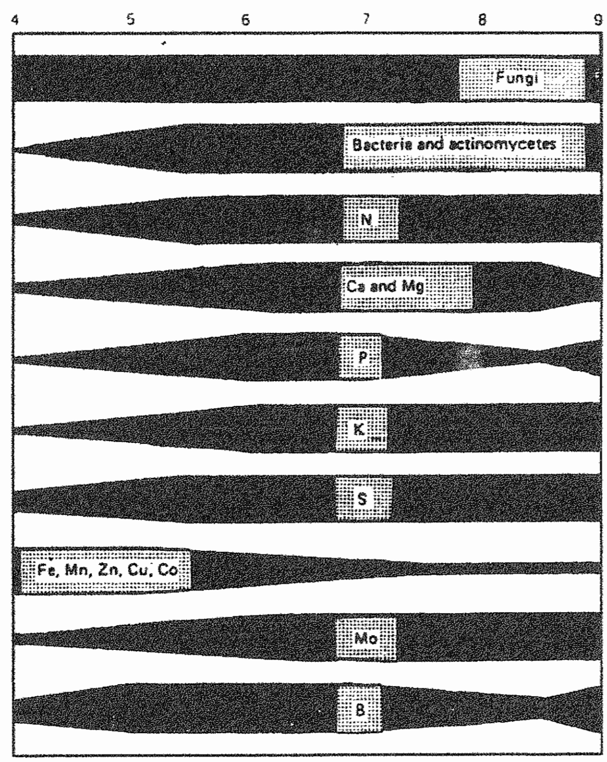



Figure 4.8 Availability Of Nutrients and Activity of Microorganisms related to Soil pH

For manganese and iron, this is especially true on overlimed sandy soils or alkaline arid region soils. Copper and zinc are affected by the raise in pH, the critical point being near pH 7, above which their availability declines. Boron is most available between pH 5-7, below and above which availability declines. If lime is added to the soil this may further affect the availability of boron to plants. The excess of calcium may also hinder the movement of boron into the plant and interfere with boron metabolism.

The activity of microorganisms (bacteria, actinomycetes and fungi) are also related to pH. Bacteria becoming less active when soil pH is less than 5.5. Fungi are versatile and flourish satisfactorily at all soil reactions. Nitrification and nitrogen fixation (microbial processes) take place vigorously in mineral soils only at pH values well above 5.5.

Pasture grasses, many legumes, small grains, field crops and a large amount of vegetables are most productive within the pH range from 5.8-6.0 to slightly above 7.0.

### Electrical Conductivity (E.C.)

The salinity of soils is indicated by their electrical conductivity (E.C.) level which is a measure of total concentrated soluble salts. Salinity is measured in mS/cm (microsiemens per cm), mmhos/cm (millimhos/cm) or dS/cm (decisiemens per centimeter). One mmho/cm is equivalent to 1 dS/cm and on the average to 640 ppm of salt.

Toxicity to some plants may occur if the E.C. is above 2 mS/cm and to most plants above 5 mS/cm. (See Tolerance of Plants to Salinity – Crop Management). High soil salinity may result in toxic concentrations of ions in plants. These soils are formed when the drainage is impeded and the surface evaporation becomes excessive and soluble salts are formed in the surface horizon. Such soils are sometimes called white alkali soils because a surface crustation is present, white or light in colour. The soluble salts are mostly chlorides and sulfates of sodium, calcium and magnesium. The pH is usually above 8.5. and the electrical conductivity of a saturated extract is greater than 4 (m S/cm).

Table 4.7 E.C. Levels and Crop Responses

| EC mmhos/cm, EC mS/cm | Crop Responses |
|---|---|
| 0-2 | Salinity effects mostly negligible |
| 2-4 | Yields of sensitive crops may be restricted 4-8 Yields of many crops restricted |
| 8-16 | Only tolerant crops yield satisfactorily |
| >16 | Only a few very tolerant crops yield satisfactorily |

Source: *Knott's Handbook for Vegetable Growers*, O. Lorenz & D. Maynard, 1988, J. Wiley and Sons, pg 115

#### Salinity Classes

Salinity is evaluated on the basis of three classes:

**Weakly Saline** - Soils are slightly affected by salt or alkali. The growth of sensitive crops is inhibited, but that of salt tolerant crops may not be. The salt content is 0.15-0.35 % and the conductivity is 4-8 m S/cm.

**Moderately Saline** - Soils are are affected by salt or alkali causing crop growth to be affected and crops do not perform well. The salt content is 0.35-0.65 % and the conductivity is 8-15 m S/cm.

**Strongly Saline** - Soils are strongly affected by salt or alkali and only a few kinds of plants survive. The salt content is greater than 0.65 % and the conductivity is greater than 15 mS/cm.

### Organic Matter

The percentage of organic matter is indicated as part of soil quality. Organic matter influences the physical and chemical properties of soils. It commonly accounts for at least half the cation exchange capacity (C.E.C.) of soils. The C.E.C. is the sum total of exchangeable ions (positively charged) that a soil can absorb. Organic matter is responsible perhaps more than any single factor for the stability of soil aggregates. It also supplies energy and body building constituents for soil microorganisms. It improves soil structure by providing for more air spaces. The result is a soil which is easier to till and can hold more moisture.

In general, soils which had been built up over the years from cropping practices have a higher organic content than newly broken mineral soils. Poorly drained soils, in low lying peat or boggy areas usually have a higher organic content, but are limited by poor aeration due to high moisture levels.

#### Yukon Levels - % Organic Matter

The Yukon Agriculture Branch has also tested soils throughout the Yukon for percent organic matter. For Table 4.8, 94 soil samples were reviewed. The majority of soils (42%) had over 5 % organic matter. In the Yukon, soils with less than 2% organic matter are considered deficient, soils with 2-5% are marginal, and soils with more than 5% are good for organic matter. Soils with less than 5% would require special management practices to improve organic matter content, ie. with crop residues or animal wastes, and thereby improve tilth and water storage capacities.

Table 4.8 Yukon % Organic Matter Levels

| Category | % of Records | % Organic Matter |
|---|---|---|
| Deficient | 27% | <=2% |
| Marginal | 31% | >2<=5% |
| Good | 42% | >5% |

### Yukon Soil Quality Levels

The Agriculture Branch has tested soils on natural and uncropped land as well as on land used for pasture and forage crops. In Table 4.9, the pH electrical conductivity (E.C.) and organic matter % are summarized into 3 regions:

Southeast: Watson Lake

Southwest: Kluane east to Whitehorse

Central: Carmacks north to Dawson

(See Figure 2.1 for boundaries of regions)

## Table 4.9 Regional Soil Quality Levels - Yukon

| Region | Range of pH | Mean pH | Range of E.C. | Mean E.C. | Range of %Org Matter | Mean %Org Matter |
|---|---|---|---|---|---|---|
| Southeast | 5.3 - 7.6 | 6.2 | .10 - .60 | .30 | NA | NA |
| Southwest | 5.3 - 8.9 | 7.5 | .0 - 11.2 | 1.1 | 1.0 - 67.2 | 7.1 |
| Central | 5.2 - 8.2 | 6.9 | .10 - 10.5 | .70 | 1.1 - 27.7 | 8.3 |

There is a range of pH from 5.2 (strongly acid) to 8.9 (strongly alkaline). The southwest region, including the Whitehorse area has the highest pH levels, with a mean of pH 7.5 (moderately alkaline). The E.C. levels are also the highest in the southwest region, with some soils above 4 mmhos where the yields of may crops may be restricted, as in the alkali areas in the Takhini valley. Mean E.C. values are usually below 2 mmhos, where plant growth is not restricted. There is a wide range of organic % levels from 1-67.2. The higher figures are probably peat soils. Organic matter % is generally higher in the central region than in the southwest.

The soil quality results of the YCDP soil tests, taken in the fall 1988 and 1989, are indicated in Table 4.10.

## Table 4.10 YCDP Soil Quality Levels - Fall 1988 & 1989

| Region | Range of pH | Range of E.C. | Range of %Organic Matter |
|---|---|---|---|
| **Fall 1988** | | | |
| Watson Lake | 5.2 - 6.3 | .30 - .80 | 10 - 57 |
| Whitehorse | 7.4 - 8.1 | .50 - 5.2 | 1 - 5 |
| Carmacks | 7.8 | .40 | 2 |
| Pelly | 8.2 | 2.1 | 9 |
| Mayo | 5.3 - 7.3 | .20 - .40 | 3 - 4 |
| Dawson | 6.1 - 6.6 | .40 - 1.60 | 4 - 13 |
| **Fall 1989** | | | |
| Whitehorse | 7.5 - 8.0 | .40 - 3.2 | 2.4 - 4 |
| Carmacks | 7.3 | .40 | 2.4 |
| Pelly | 8.3 | 2.2 | 10 |
| Mayo | 5.1 - 5.5 | .20 - .40 | 3.1 - 4 |
| Dawson | 6.0 - 6.2 | .50 - 1.5 | 4.8 - 12.6 |

* No soil test was taken in Watson Lake in 1989.

There was a range in pH at the trial sites between 5.1 - 8.1. At the Mayo forage site with a pH of 5.3, lime was recommended at the rate of 3.6 tons/acre. A lime trial was conducted at this site. (See Cereal Production). The Electrical Conductivity (E.C.) levels were not restrictive to plant growth, except for one site in the Whitehorse area. A field north of Whitehorse on the Mayo Road had been planted to an oat crop and irrigated in 1987. In 1988 a forage crop was established here without irrigation. By the fall 1988, E.C. levels were in the toxic range (5.2 mmhos), where the yields of many crops could be reduced. During 1989, the forage crop was not irrigated and the E.C. level had dropped to 3.2 mmhos. Forages, without irrigation appeared to improve salinity levels. Soils ranged from 1-57 % Organic Matter. Usually soils in newly developed fields were between 2-5%.

In the older developed fields and gardens, the average was 10% Organic Matter. The Watson Lake forage site was a peaty soil with a pH of 5.2 (Very Acid) with 57% organic matter.

### *Soil Texture*

The particles of a soil are classified by size into sand, silt and clay. Classes according to soil particle size (mm) are indicated in Table 4.11.

## Table 4.11 Soil Particle Size Classes

*Soil-Particle Size Classes (diameter, mm)*

| | 2.0 | 0.02 | 0.002 | 0 |
|---|---|---|---|---|
| Gravel | Sand | Silt | Clay | |
| Particles visible with the naked eye | | Particles visible under microscope | Particles visible under electron microscope | |

Source: *Knott's Handbook for Vegetable Growers*, O. Lorenz & D. Maynard, 1988, pg 105.

### Soil Textural Classes

In most cases, the quantities of sand, silt and clay present require a modified textural class name, ie. a loam in which sand is dominant is classified as a sandy loam or if silt is dominant then as a silt loam. Coarseness of soil particles are included in the textural modifier. Classes of soil textures most commonly found on agricultural soils are indicated in Table 4.12.

## Table 4.12 General Terms Used to Describe Soil Texture

| Common Name | Texture | Soil Textural Class |
|---|---|---|
| Sandy Soils | Coarse | Sands |
| | | Loamy sands |
| Loamy Soils | Moderately | Sandy Loam |
| | Coarse | Fine Sandy Loam |
| | Medium | Very Fine Sandy Loam |
| | | Loam |
| | | Silt Loam |
| | | Silt |
| | Moderately | Clay loam |
| | Fine | Sandy Clay Loam |
| | | Silty Clay Loam |
| Clayey Soils | Fine | Sandy Clay |
| | | Silty Clay |
| | | Clay |
| Organic Soils | | Organic |

Source: *The Nature and Properties of Soils*, N.C. Brady, 8th Edition, 1974, pg 47.

The percentage of sand, silt, and clay may be plotted on the soil textural triangle, shown in Figure 4.9, to determine the textural class of a soil. In using the diagram, the points corresponding to the percentages of clay and sand in the soil are located on the sand and clay lines, respectively. Lines are then projected inward. The name of the compartment in which the two lines intersect is the textural class of the soil. Most soils of agricultural importance are a type of loam, defined as a mixture of 7-27% clay, 28-50% silt and less than 52% clay. A soil containing 13% clay, 41% silt and 46% sand would have a loam texture.

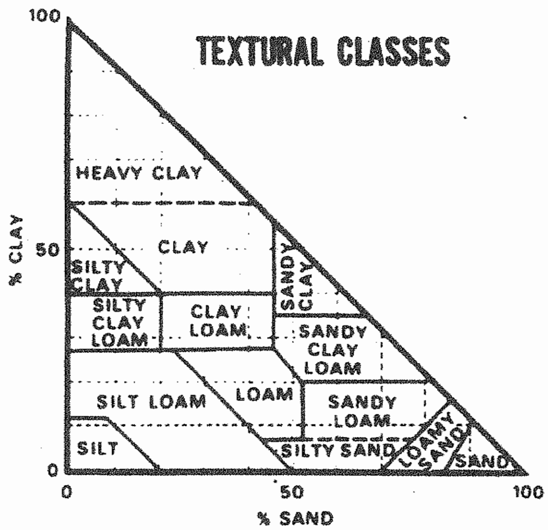



Figure 4.9 Soil Textural Triangle

Source: *Manual for Describing Soils in the Field*, The Canada Soil Information System (Cansis), 1982, pg 68.

While management practices can alter the other soil quality parameters, pH, E.C. and organic matter %, soil texture (at least on a field scale) is not readily altered or changed. It is an inherent property that does not change.

### Determining Your Soil Texture in the Field

There are five ways to test for soil texture in the field:

**Moist Cast Test:** Compress some moist soil by clenching it in your hand. If the soil holds together (ie. forms a cast) then test the strength of their cast by tossing it from hand to hand. The more durable it is the more clay is present.

**Ribbon Test:** Moist soil is rolled into a cigarette shape and then squeezed out between the thumb and forefinger to form the longest and thinnest ribbon possible.

**Feel Tests:** *Graininess Test* - Soil is rubbed between thumb and fingers to assess the % sand. Sand feels grainy.
*Dry Feel Test* - Soils with > 50% sand. Soil is rubbed in the palm of the hand to dry it and to separate and estimate the size of the individual sand particles. The sand particles are allowed to fall out of the hand and the amount of finer material (silt & clay) remaining is noted.
*Stickiness Test* - Soil is wetted and compressed between the thumb and forefinger. Degree of stickiness is determined by noting how strongly it adheres to the thumb and forefinger upon release of pressure and how much it stretches.

**Taste Test:** A small amount of soil is worked between the front teeth. Sand is distinguished as individual grains which grit sharply against the teeth. Silt particles are identified as a general grittiness, but individual grains cannot be identified. Clay particles have no grittiness.

**Shine Test:** A small amount of moderately dry soil is rolled into a ball and rubbed once or twice against a hard, smooth object such as a knife blade or thumb nail. A shine on the ball indicates clay in the soil.

Table 4.13 Field Test Characteristics of Soil Texture Classes

| | | | | | |
|---|---|---|---|---|---|
| **SAND** | grainy with little floury material | no cast | none | unnecessary | unnecessary |
| **LOAMY SAND** | grainy with slight amount of floury material | very weak cast, no handling | none | unnecessary | unnecessary |
| **SILTY SAND** | grainy with moderate amount of floury material | weak cast, no handling | none | unnecessary | unnecessary |
| **SANDY LOAM** | grainy with considerable amount of floury material | weak cast, allows careful handling | none | unnecessary | unnecessary |
| **LOAM** | fairly soft and smooth with evident graininess | good cast, readily handled | barely begins to ribbon | unnecessary | unnecessary |
| **SILT LOAM** | floury with slight graininess | weak cast, allows careful handling | flakes, rather than ribbons | silt grittiness, some sand graininess | unnecessary |
| **SILT** | very floury | weak cast, allows careful handling | flakes, rather than ribbons | silt grittiness | unnecessary |
| **SANDY CLAY LOAM** | very substantial graininess | moderate cast | short and thick (< 3cm) | sand graininess clearly evident | slightly shiny |
| **CLAY LOAM** | moderate graininess | strong cast | fairly thin, breaks readily, barely supports own weight | sand graininess clearly evident | slightly shiny |
| **SILTY CLAY LOAM** | smooth and floury | strong cast | fairly thin, breaks readily, barely supports own weight | silt grittiness | slightly shiny |
| **SANDY CLAY** | substantial graininess | strong cast | thin, fairly long (5-7.5 cm), holds own weight | sand graininess clearly evident | moderately shiny |
| **SILTY CLAY** | smooth | very strong cast | thin, fairly long (5-7.5cm), holds own weight | silt grittiness | moderately shiny |
| **CLAY** | smooth | very strong cast | very thin, long (7.5 cm) | smooth | very shiny |

Source: *Manual for Describing Soils in the Field*, The Canada Soil Information System (Cansis), 1982, pg 68.

### Fertilizer Recommendations

Fertilizer recommendations are made for your crop you plan to grow. Norwest Labs gives three levels of recommendations for fertilizer based on three potential target levels for yields; High, Moderate and Your Goal (lowest yield). Fertilizer required is indicated in lbs/acre for nitrogen, phosphorous ($P_2O_5$), potassium ($K_2O$) and Sulphur (S).

Phosphorous recommendations are indicated for placed or broadcast applications. Levels of micronutrients are indicated as to adequate, marginal or deficient. If levels are deficient, fertilizer is recommended and if marginal, these should be monitored yearly. (See Plant Nutrition – Crop Management).

Soil nutrient levels require a build up and maintenance to first acquire proper yields, then continued for maintenance of optimum levels. Once nutrient levels fall in the excess category no fertilizer is recommended.

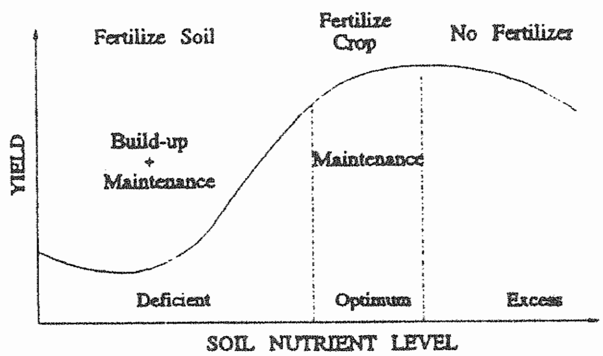



Figure 4.10 General Relationship Between Soil Nutrient Level and Yield.

Source: *Forage Information Series*, Factsheet, B.C. Ministry of Agriculture and Fisheries, 1990.

## FERTILIZER COMPOSITION AND APPLICATION

### *Commercial Fertilizers*

Commercial fertilizers are available in a variety of forms and composition. Commercial fertilizers may be blended to any required ratio recommended in the soil test. Fertilizers are available in granular,liquid or gaseous form.

The rule of thumb for fertilizer is to place as much of the material with the seed as possible and broadcast or band the balance. Methods of fertilizing include:

1. Placement with the seed in the seed drill or broadcast spreader;
2. Sideband placement near the seed;
3. Banded into the soil prior to seeding;
4. Broadcast and incorporate into the soil;
5. Broadcast without incorporation.

Fertilizer drilled with the seed is the most effective application method while broadcasting and no incorporation are the least effective. With surface placement, yield increases are more dependent upon rainfall than when fertilizers are placed or incorporated in the soil.

### Chemical Composition

The chemical composition of fertilizers for N, P, K and S nutrients are indicated on the label according to their guaranteed analysis as percent by weight. Nitrogen (N) is the first component of the nutrient analysis label, then Phosphorous ($P_2 0_5$), then Potash or potassium ($K_2O$),and Sulphur (S). Sulphur is always indicated in parentheses in mixed fertilizer compositions. For example: 34-0-0(11) (Ammonium sulfate) contains 34% nitrogen by weight, 0% phosphorous and potassium by weight, and 11% sulphur by weight; A 100 lbs of 34-0-0 (11) contains 34 lbs of nitrogen (N), 0 lbs of phosphate ($P_2O_5$) and 0 lbs of potash ($K_2 0$) and 11 lbs of sulphur.

### Percentage of Macronutrients in Selected Fertilizers

In the Yukon, granular fertilizers are most commonly used and are available in the following percentages:

Table 4.14 Commercial Fertilizers – Composition

| Name | Nutrient Analysis |
|---|---|
| **Nitrogen Fertilizers** | |
| Urea | 46-0-0 |
| Ammonium Nitrate | 34-0-0 |
| Ammonium Sulfate-Urea | 19-3-0 (22), 21-0-0 (21), 21-0-0 (24) 20-0-0 (24), 43-0-0 (1), 34-0-0 (11) |
| Sulfur coated Urea | 40-0-0 (6), 30-0-0 (4) |
| **Phosphate Fertilizers** | |
| Mono-Ammonium Phosphate | 11-48-0, 11-51-0, 11-54-0, 11-55-0, 12-51-0 |
| Diammonium Phosphate | 18-46-0 |
| Monocalcium Phosphate | 0-45-0 |
| **Nitrogen Phosphate Fertilizers** | |
| Ammonium Phosphate Sulphate | 16-20-0 (14) |
| Ammonium Nitrate Phosphate | 23-23-0, 23-24-0, 27-14-0, 17-34-0 25-25-0, 28-14-0 |
| Ammonium Nitrate Phosphate Sulphate | 26-13-0 (13) |
| Urea Ammonium Phosphate | 28-28-0, 27-27-0, 34-18-0, 34-17-0, 19-39-0 |
| **Potash Fertilizers** | |
| Potassium Chloride (Muriate of Potash) | 0-0-60, 0-0-62 |
| Blends | 0-30-10 (5), 8-24-24 (1) |
| **Sulphur Fertilizers** | |
| Elemental Sulphur | 0-0-0-90 S to 0-0-0-99 S |
| Gypsum (Calcium Sulphate) | 0-0-0-(13-19) |
| **Complete Fertilizers** | |
| 10-30-10 (5), 13-13-13, 8-24-24 (1), 12-16-10 (1), 14-14-10 (11), 16-16-16 (3), 8-24-24 (3), 8-25-25, 17-17-17 | |

### Macronutrients

**Nitrogen Fertilizer:** Of all the nutrients we apply to the soil, nitrogen is in the greatest demand, in the greatest concentration in the crop, and has the greatest impact on crop growth and quality.

The efficiency of nitrogen increasing yield and or protein content is significantly affected by the time of application and method of placement. Nitrogen fertilizers are very soluble and move readily in moist soil. The expected yield increase from applying nitrogen is directly related to the moisture conditions during the growing season. With application after emergence of the crop, precipitation is required to move the nitrogen into the rooting zone. Phosphorous nutrition must also be considered when applying nitrogen. A deficiency in either of these elements limits yield and therefore reduces the effect of the other. (See Plant Nutrition – Crop Management).

Ammonium nitrate (34-0-0) is the most commonly used commercial fertilizer in the Yukon. Urea (46-0-0) is the highest analysis of dry nitrogen fertilizer. This is more subject to volitization than (34-0-0) when not incorporated into the soil. It is not recommended to mix urea (46-0-0) and ammonium nitrate (34-0-0) fertilizers. The time of application can be late fall or in the spring. Late fall applications can be an opportune time to apply fertilizers depending on the particular field conditions. However, excessively wet conditions in the spring on poorly drained soils can cause significant losses of fall applied nitrogen. Most Yukon farmers apply nitrogen in the spring time.

**Phosphorous Fertilizer:** Fertilizer phosphorous is rapidly absorbed by soil colloids and does not readily move in the soil. Placement of phosphorous with the seed or close to the seed is best. Placement below the depth of seeding may improve availability under dry conditions because the fertilizer is in the moist part of the root zone. Broadcast-incorporated applications are less effective. The amount broadcast must be 2-6 times more than the amount placed near the seed to obtain equal yield increases in the year of application. On Norwst Lab recommendations the amount of phosphorous ($P_2O_5$) required is indicated for placed or broadcast.

**Potassium Fertilizer:** Potassium fertilizer can be seed placed, sidebanded, broadcast and incorporated in the spring or fall. Potassium will move in the soil more readily than phosphorous. For annual crops, potassium fertilizers are more efficient when drilled with the seed or banded. Broadcast applications can be used at about twice the rate used for drill-in application.

**Sulphur Fertilizer:** Fertilizers containing sulphur are available in two sulphur forms as sulphate ($SO_4$) salts and fertilizers containing elemental sulphur. Ammonium sulphate, (21-0-0(21) etc., is the most commonly used source (See Table 4.14). Sulphur fertilizer is usually applied in combination with phosphorous and nitrogen. In the sulphate form it moves readily in moist soils. Soluble sulphate fertilizers provide an available sulphur source either as broadcast, drill-in or band applications and can be broadcast in fall or spring. Elemental sulphur (S) should be broadcast 1 year before it is required for crop growth because of its slow release characteristics. It is converted to the available sulphate form by bacteria. This is a slower process and because of this elemental sulphur is more suitable for application on perennial forage than annual crops. If used on annual crops it should be applied in the fallow year or in the fall to allow conversion to the sulphate form. Another sulphur bearing mineral is gypsum ($CaSO_4$), though this is not as widely used.

## Sustainable Inputs

Inputs of nutrients beyond crop requirements will affect both the environment and the net income of the producer. Target levels of fertilizer recommended by Norwest Labs to provide for a sustainable agricultural system in the Canadian Prairies are:

1. Nitrate should be:
   20-35 lbs/acre on 0-6 inch depth
   30-45 lbs/acre on 0-12 inch depth
   40-65 lbs/acre on 0-24 inch depth
2. Phosphate should not be below 45 lbs/acre or above 80 lbs/acre.
3. Potassium should not be below 350 lbs/acre.
4. All micronutrients should be 50 - 100 % above their deficiency levels.
5. Organic matter, pH and salts should be monitored to avoid loss of soil quality.

Source: Norwest Labs Fact Sheet

### Micronutrients

Micronutrients are available as specific fertilizers. In the Yukon, this may include boron, copper or zinc. As these are needed in small quantities, care must be taken to thoroughly mix these with the other fertilizers you are applying, ie, N, P, or K. It is best to use a granular form if available and if possible have these commercially blended with your other fertilizers according to your specific soil test recommendations.

**Boron:** Boron (B) is available in granular, powder or liquid forms. Sodium tetraborate ($Na_2B_4O_7.5H_2O$) is the most common boron fertilizer material. Borax ($Na_2B_4O_7.10H_2O$) and sodium pentaborate ($Na_2B_{10}O_{16}.10H_2O$) are other common boron fertilizer materials.

- *Borate-68* (20.2%B) is sold in two mesh sizes; Coarse and Granular.
- *Borate-48* (14.3%B)is a very fine granular material. It does not dry blend well with other fertilizers and is used by fertilizer companies to make special blends involving other processes than dry mixing.
- *Borate-40* (12.5%B) is produced in granular form and is intended to mix with other dry fertilizers, this allows for less segregation in field spreaders.
- *Borax* (11%B) is very fine granular material, usually found in cleaning agents.

It is best to completely mix boron with other fertilizers prior to application to reduce the risk of over fertilizing certain areas and causing toxicities. Boron can be applied in spring or fall to perennial and annual crops, except on coarse textured sands or gravelly soils which should have only a spring application. Residual boron persists in some soils up to three to four years. This is dependent on the boron rate, soil type, amount of irrigation or rainfall. Most recommended boron fertilizer rates have a life expectancy of three years on all but sandy soils under irrigation. Norwest Labs recommends boron at the rate of 10 lbs/acre for vegetables, grasses and cereals,and 20 lbs/acre for alfalfa and legumes. (See YCDP Boron Trial – Forage Production).

*I order Borate-40 in a 25 kg bag. Its a larger sized round pellet which mixes better than the powder form with the other granular N,P,K,S fertilizers. As it takes very little to meet the requirements, I weigh out the exact amount I need for each given area and crop type.*

-Whitehorse Producer

## Leave a Check Strip

The only way to assess the effect of a fertilizer is to leave an unfertilized check strip in the field. The check strip must be harvested separately to gauge the difference in yields between an equivalent area in the fertilized portion in the same field. This is also true for lime and gypsum or sulfur applications to alter pH or for organic fertilizer applications. This will help determine the best fertilizing practices for your area.

**Zinc:** Zinc is applied as zinc sulphate ($ZnSO_4$). Norwest Labs recommends a rate of 20 lbs/acre for deficient soils. Zinc Sulphate Monohydrate is a commercial zinc fertilizer. This is in a fine powdery form. It is a very caustic, the label indicating to avoid breathing vapour and contact with eyes, skin and clothing. This has been necessary at only a few farms, in the Mayo and Whitehorse areas.

**Copper:** This is usually not deficient on Yukon soils but has been found to be marginal at a few farms in Whitehorse and Mayo. Apply as Copper Sulphate ($CuSO_4$), available in a granular form.

Table 4.15 Plant Nutrients in One Ton of Different Manures

| Animal | Percent Moisture | Tons of Manure Produced/Year Per 1,000# Wt. (Fresh: normal bedding) | Approximate Composition Pounds per Ton | | | Percent Organic Matter |
|---|---|---|---|---|---|---|
| | | | N | $P_2O_5$ | $K_2O$ | |
| Cow | 86 | 15.0 | 11 | 3 | 10 | 30 |
| Goat | 65 | — | 16 | 10 | 17 | 60 |
| Duck | 61 | — | 22 | 29 | 10 | 50 |
| Goose | 67 | 4.5 | 22 | 11 | 10 | 50 |
| Hen | 73 | — | 22 | 18 | 10 | 50 |
| Hog | 87 | 18.0 | 11 | 6 | 9 | 60 |
| Horse | 80 | 10.0 | 13 | 5 | 10 | 60 |
| Sheep | 68 | 7.5 | 20 | 15 | 8 | 60 |
| Steer | 75 | 8.5 | 12 | 7 | 11 | 60 |
| Turkey | 74 | — | 26 | 14 | 10 | 50 |
| Rabbit (dried) | 6 | 6.0 | 45 | 27 | 16 | — |

Source: *Animal Manure as Fertilizer,* Alaska Extension Service, Fairbanks Alaska, J. Perser, 100G-00340

## *Organic Fertilizers*

Organic fertilizers, for natural sources of macro and micronutrients include animal manures, plant residues and natural minerals such as phosphate or granite rock.

### Manure

Animal manure is a useful source of plant nutrients as well as an excellent soil amendment. When applied to soils, manure of all types will supply plant nutrients over extended periods of time. The rates of application depend on soil texture as well as the crops to be grown. The nutrient content of all types of manure will decrease during open storage due to volitization and leaching processes. Losses of nitrogen due to volitization are very high during the first 2-4 days after application. Therefore it is important that manure be incorporated into the soil soon after application.

**Typical Composition of Manures**

Manures vary greatly in their nutrient content. The kind of feed used, the percentage and type of litter or bedding, the moisture content and the age and degree of rotting or drying all modify the composition. The value of livestock manure is based on:

1. Type of Animal
2. Feed Consumed
3. Bedding Used
4. Method of Handling
5. Rate and Method of Application
6. Soil type and Crops to be Grown

**Plant Nutrients in One Ton of Manure**

Plant nutrients in pounds per ton from different animal manures, based on tons produced per year are presented in Table 4.15. A 1,000 lb cow will produce about 15 tons of manure, containing approximately 171 pounds of Nitrogen, 46 lbs of phosphorous ($P_2O_5$) and 148 lbs of potassium ($K_2O$).

In Table 4.16, the micronutrients in pounds/ton in different animal manures are indicated.

Table 4.17 Typical Compositions of Animal Manures

| Source | Dry Matter (%) | Approx. Composition (%) Dry Weight N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|---|
| Dairy | 15-25 | 0.6-2.1 | 0.7-1.1 | 2.4-3.6 |
| Feedlot | 20-40 | 1.0-2.5 | 0.9-1.6 | 2.4-3.6 |
| Horse | 15-25 | 1.7-3.0 | 0.7-1.2 | 1.2-2.2 |
| Poultry | 20-30 | 2.0-4.5 | 4.5-6.0 | 1.2-2.4 |
| Sheep | 25-35 | 3.0-4.0 | 1.2-1.6 | 3.0-4.0 |
| Swine | 20-30 | 3.0-4.0 | 0.4-0.6 | 0.5-1.0 |

Source: *Knott's Handbook for Vegetable Growers*, O. Lorenz & D. Maynard, John Wiley & Sons, 1988, p 99

### Manure Application

Research has shown that manure will loose approximately 1/3 of its fertilizer and organic matter value in 3 months ,1/2 in 6 months and even more over a longer period. When manure is exposed to the weather, ammonia gas washes away with the rain, phosphorous is washed or drained away with the liquid portion , potassium is either washed away or carried off in the urine and organic matter is rotted away. To reduce manure losses:

1. Use ample bedding to absorb liquid manure.
2. Store manure in straight sided well packed piles and provide overhead protection from weather.
3. Avoid spreading manure on frozen ground and within 100' of streams, lakes or ponds.
4. Incorporate manure by disking or plowing when practical.

*" Commercial fertilizers do not have the same soil building properties or generally contain as much micronutrients as manure. However manures and composts are generally too low in phosphorous for many vegetable crops. A combination of manure and commercial fertilizer can be used to produce the balanced fertility level required."*

- *Yukon Garden Handbook*, D.Filteau, Agriculture Branch, Renewable Resources, Government of Yukon, 1987.

Table 4.16 Micronutrients in Animal Manure (lbs/ton)

| Animal | Boron | Calcium | Copper | Iron | Magnesium | Manganese | Molyb. | Sulfur | Zinc |
|---|---|---|---|---|---|---|---|---|---|
| Horses | .03 | 15.7 | .01 | .27 | 2.8 | .02 | .002 | 1.4 | .03 |
| Cattle | .03 | 5.6 | .01 | .08 | 2.2 | .02 | .002 | 1.0 | .03 |
| Sheep | .02 | 11.7 | .01 | .32 | 3.7 | .02 | .002 | 1.0 | .05 |
| Hogs | .08 | 11.4 | .01 | .56 | 1.6 | .04 | .002 | 2.7 | .12 |
| Laying Hens | .12 | 74.0 | .03 | .93 | 5.8 | .18 | .011 | 6.2 | .18 |
| Broilers | .08 | 29.0 | .06 | 2.00 | 8.4 | .46 | .007 | — | .25 |

Source: *Animal Manure as Fertilizer*, Alaska Extension Service, Fairbanks Alaska, J. Purser, 100G-00340.

### Percentage Composition of Various Materials

In Tables 4.18 - 4.20, the composition of various organic materials are listed as to their nitrogen, phosphorous/ phosphoric acid ($P_2O_5$) and potassium (potash) content. From these figures one can determine, roughly, the N, P, K ratio of the compost.

Table 4.18 Typical Composition of Some Organic Materials

| Organic materials | Percentage on a Dry Weight Basis | | |
|---|---|---|---|
| | N | $P_2O_5$ | $K_2O$ |
| Blood | 13.0 | 2.0 | 1.0 |
| Bone meal,raw | 3.0 | 22.0 | – |
| Bone meal,steamed | 1.0 | 15.0 | – |
| Fish meal | 10.0 | 6.0 | – |
| Sewage sludge | 1.5 | 1.3 | 0.4 |

Table 4.19 Composition of Organic Materials

| Materials | Moisture % | Approx. Pounds per Ton of Dry Material | | |
|---|---|---|---|---|
| | | N | $P_2O_5$ | $K_2O$ |
| Alfalfa hay | 10 | 50 | 11 | 50 |
| Alfalfa straw | 7 | 28 | 7 | 36 |
| Barley hay | 9 | 23 | 11 | 33 |
| Barley straw | 10 | 12 | 5 | 32 |
| Sweet Clover hay | 8 | 60 | 12 | 38 |
| Field pea hay | 11 | 28 | 11 | 30 |
| Field pea straw | 10 | 20 | 5 | 26 |
| Oat hay | 12 | 26 | 9 | 20 |
| Oat straw | 10 | 13 | 5 | 33 |
| Ryegrass hay | 11 | 26 | 11 | 25 |
| Rye hay | 9 | 21 | 8 | 25 |
| Rye straw | 7 | 11 | 4 | 22 |
| Common Vetch hay | 11 | 43 | 15 | 53 |
| Wheat hay | 10 | 20 | 8 | 35 |
| Wheat straw | 8 | 12 | 3 | 19 |

Table 4.20 Percentage Composition Of Various Materials

| Material | Nitrogen | Phosphoric Acid | Potash | Material | Nitrogen | Phosphoric Acid | Potash | Material | Nitrogen | Phosphoric Acid | Potash |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Alfalfa hay | 2.45 | 0.50 | 2.10 | Pigweed, rough | .60 | .16 | – | Hair | 12 - 16 | – | – |
| Apple, fruit | .05 | .02 | .10 | Pine needles | .46 | .12 | .03 | Harbor mud | .99 | .77 | .05 |
| Barley (grain) | 1.75 | .75 | .50 | Potatoes, tubers | .35 | .15 | .50 | Hoof meal and horn dust | 10 - 15 | 1.5 - 2 | – |
| Beet roots | .25 | .10 | .50 | Potatoes, leaves, stalks | .60 | .15 | .45 | Incinerator ash | .24 | 5.15 | 2.33 |
| Brewer's grains (wet) | .90 | .50 | .05 | Potato skins, raw (ash) | – | 5.18 | 27.50 | Kentucky bluegrass (green) | .66 | .19 | .71 |
| Ground bone, burned | – | 34.70 | – | Powder-works waste | 2 - 3 | – | 16 - 18 | Kentucky bluegrass (hay) | 1.20 | .40 | 1.55 |
| Coal ash (anthracite) | – | .1 - .15 | .1 - .15 | Pumpkins, flesh | .16 | .07 | .26 | Soot from chimney flues | .5 - 11 | 1.05 | .35 |
| Coal ash (bituminous) | – | .4 - .5 | .4 - .5 | Pumpkin seeds | .87 | .50 | .45 | String bean strings | – | 4.99 | 18.03 |
| Coffee grounds | 2.08 | .32 | .28 | Ragweed, great | .76 | .26 | – | Sunflower seed | 2.25 | 1.25 | .79 |
| Coffee grounds (dried) | 1.99 | .36 | .67 | Red clover, hay | 2.10 | .50 | 2.00 | Sweetpotato skins | – | 3.29 | 13.89 |
| Corncobs (ground, charred) | – | – | 2.01 | Redtop hay | 1.20 | .35 | 1.00 | Sweetpotatoes | .25 | .10 | .50 |
| Corncob ash | – | – | 50.00 | Residuum from raw sugar | 1.14 | 8.30 | – | Tea grounds | 4.15 | .62 | .40 |
| Cowpeas, green forage | .45 | .12 | .45 | Rhubarb, stems | .10 | .04 | .35 | Tea-leaf ash | – | 1.60 | .44 |
| Cowpeas, seed | 3.10 | 1.00 | 1.20 | Sewage sludge | .74 | .33 | .24 | Timothy hay | 1.25 | .55 | 1.00 |
| Crabgrass (green) | .66 | .19 | .71 | Eggshells | 1.19 | .38 | .14 | Tomatoes, fruit | .20 | .07 | .35 |
| Cucumber skins (ash) | – | 11.28 | 27.20 | Feathers | 15.30 | – | – | Tomatoes, leaves | .35 | .10 | .40 |
| Dog manure | 1.97 | 9.95 | .30 | Field bean (seed) | 4.00 | 1.20 | 1.30 | Tomatoes, stalks | .35 | .10 | .50 |
| Duck manure (fresh) | 1.12 | 1.4 | .49 | Field bean (shells) | 1.70 | .30 | .35 | Waste from hares | 7.00 | 1.7 - 3.1 | .60 |
| Eggs | 2.25 | .40 | .15 | Fire-pit ashes | – | – | 4.96 | Wheat, bran | 2.65 | 2.90 | 1.60 |
| Eggshells (burned) | – | .43 | .29 | Fish scrap | 7.76 | 13.00 | .38 | Wheat, grain | 2.00 | .85 | .50 |
| Milk | .50 | .30 | .18 | Fish scrap (fresh) | 2 - 7.5 | 1.5 - 6 | – | Wheat, straw | .50 | .15 | .60 |
| Molasses residue | .70 | – | 5.32 | Fresh-water mud | 1.37 | .26 | .22 | White clover (green) | .50 | .20 | .30 |
| Orange skins (ash) | – | 2.90 | 27.00 | Garbage rubbish | 3.4 - 3.7 | .1 - 1.47 | 2.25-4.25 | White sage (ashes) | – | – | 13.77 |
| Pea pods (ash) | – | 1.79 | 9.00 | Garbage tankage | 1 - 2 | .5-1 | .5-1 | Wood ashes (leached) | – | 1 - 1.5 | 1 - 3 |
| Pigeon manure (fresh) | 4.19 | 2.24 | 1.41 | Garden beans, and pods | .25 | .08 | .30 | Wood ashes (unleached) | – | 1 - 2 | 4 - 10 |

Table 4.21 Nitrogen Content of Organic Substances

| Material | % Nitrogen | Material | % Nitrogen | Material | % Nitrogen |
|---|---|---|---|---|---|
| **Plant Wastes** | | Peanut Shells | 3.6 | Sugar Wastes | 2.0 |
| Beet Wastes | .4 | Peanut Shell Ashes | .8 | Tea Grounds | 4.1 |
| Coffee Wastes | 2.0 | Pine Needles | .5 | Tobacco Stems | 2.5 - 3.7 |
| Green Cowpeas | .4 | Potato Skins | .6 | | |

Table 4.21 Cont.

| Material | % Nitrogen | Material | % Nitrogen | Material | % Nitrogen |
|---|---|---|---|---|---|
| **Meal** | | Human Urine | 0.60 | **Grasses** | |
| Bone Black Bone Meal | 1.5 | Night Soil | 0.80 | Clover | 2.0 |
| Raw Bone Meal | 3.3 - 4.1 | Sheep Manure (solid fresh excrement) | 0.55 | Red Clover | .55 |
| Steamed Bone Meal | 1.6 - 2.5 | Sheep (fresh urine) | 1.95 | Vetch Hay | 2.8 |
| Oats, Green Fodder | .49 | Stable Manure, mixed | 0.50 | Corn Stalks | .75 |
| Wheat Bran | 2.36 | Swine Manure (solid fresh excrement) | 0.60 | Alfalfa | 2.4 |
| Wheat Middlings | 2.75 | Swine (fresh urine) | 0.43 | Immature Grass | 1.0 |
| Meat Meal | 9 - 11 | Sewage Sludge | 1.7 - 2.26 | Blue Grass Hay | 1.2 |
| Bone Tankage | 3 - 10 | **Leaves** | | Cowpea Hay | 3.0 |
| Cattle Manure (fresh excrement) | 0.29 | Aspen Leaves | .8 | Pea Hay | 1.5 - 2.5 |
| Cattle Manure (fresh urine) | 0.58 | Pear Leaves | .7 | Soybean Hay | 1.5 - 3.0 |
| Hen Manure (fresh) | 1.63 | Apple Leaves | 1.0 | Timothy Hay | 1.19 |
| Dog Manure | 2.0 | Cherry Leaves | .6 | Salt Hay | 1.06 |
| Horse Manure (solid fresh excrement) | 0.44 | Raspberry Leaves | 1.35 | Millet Hay | 1.22 |
| Horse Manure (fresh urine) | 1.55 | Garden Pea Vines | .25 | | |
| Human Excrement (solid) | 1.00 | | | | |

### Natural Nitrogen Sources

The level of nitrogen for many organic materials is indicated in Table 4.21.

Organic forms of nitrogen are more stable than chemical or commercial forms and become available for plant growth more gradually. Organic matter holds nitrogen in the form of protein compounds which give it up more slowly under the pressure of microbial dissolution. The protein first decomposes into its amino acids and then ammonium compounds are formed. Bacteria then break these down into nitrites ($NO_2$) and then nitrates ($NO_3$) which is a form of nitrogen that plant roots can take in. (See Figure 4.11 – Nitrogen Cycle).

### Natural Phosporous Sources

Phosphorous may be added to the compost or to the soil in the form of raw pulverized phosphate rock or as bone meal. Phosphate rock varies somewhat with the composition dependent upon the source of the rock, about 30% phosphoric acid. Raw bone meal generally contains between 2-4% nitrogen, 22-25% phosphoric acid ($P_2O_5$). Steamed bone meal is the most common of the bone meal fertilizers sold. This usually contains 1-2% nitrogen, up to 30% phosphorous. Table 4.18 indicates steamed bone meal as 15% $P_2O_5$. Best results of bone meal are obtained when it is applied in conjunction with other organic materials. Other natural phosphate sources are indicated in Table 4.22.

### Natural Potassium Sources

The natural forms of potash include potash rock granite dust and greensand. Granite dust, granite rock or granite stone meal is the most widely used potash mineral. This has varying amounts of potassium ($K_2O$), but the average is between 3-5.5%. Greensand marl or glauconite greensand, is an iron-potassium-silicate which imparts a green colour to the minerals in which it occurs. This is from undersea deposits which contain from 6-7% potash. Other natural sources of potassium are listed in Table 4.23.

Table 4.22 Other Natural Phosphate Sources

| Material | Phosphoric Acid % |
|---|---|
| Dried ground Fish | 7 |
| Dried Blood | 1-5 |
| Hoof & Horn Meal | 2 |
| Raw Sugar Wastes | 8 |
| Manure: Poultry, fresh | 1 - 1.5 |
| dried | 1.5 - 2.0 |
| Goat/Sheep, fresh | 0.6 |
| dried | 1.0 - 1.9 |
| Hog, fresh | .45 |
| dried | 1.0 |
| Cow, fresh | .25 |
| dried | 1.0 |
| Wood Ashes | 1 - 2 |
| Pea Pod Wastes | 3 |
| Citrus Wastes (orange skins) | 3 |

### *How to Determine Your Commercial Fertilizer Needs*

Fertilizer materials can be blended to the the exact ratio recommended by your soil test to acquire the exact nutrients needed and thereby reduce fertilizer wastage. A Whitehorse fertilizer outlet will send your soil test to the fertilizer company in Alberta who will create a fertilizer formula specific for your needs.

### YCDP Trials

During the YCDP trials, soil tests were taken every fall to acquire fertilizer recommendations to prepare for fertilizing at planting time the following spring. Blends were prepared according to the fertilizer requirements for each trial site. Ammonium nitrate (34-0-0) was used for nitrogen, monoammonium phosphate (11-51-0 or 11-55-0) was used for phosphorous and potassium chloride or muriate of potash (0-0-60) for potassium requirements.

Fertilizer requirements were determined for each area and different crop types. In Table 4.24, calculations are shown, from determining your area to quantities needed for each fertilizer type for the imperial system and for conversion to the metric system.

You can convert lbs/acre recommendations to kg/ha by using a conversion figure (1.12). (See the conversion figures in the Appendix C for converting from imperial to metric or metric to imperial).

> **Research in North America and Europe has shown that nitrate and phosphate are the main nutrients which can pollute surface and ground water. These nutrients may or may not be directly related to fertilizer inputs. The key to management of of plant nutrients is to limit losses within the nutrient cycle.**

Determine the weight and number of bags of each fertilizer to use on each area and mix thoroughly together in the broadcast spreader or on a tarp etc prior to application. For smaller areas weigh out the amounts with a scale and mix thoroughly in a bucket. This way you will maximize the use of fertilizer for what your field or garden area needs, ie. there is no overuse of fertilizer and dollars are saved.

### *Lime Requirements*

If your soil test indicates an acid soil or low pH then Package F: can be acquired from Norwest Labs which will indicate the amount of lime required to neutralize your soil. In the Yukon, this may be required on peat soils or in areas recently cleared of a spruce forest. Yukon soils are usually in the neutral or alkaline range and the addition of lime is not recommended. A YCDP trial was conducted on a field in Mayo with a pH of 5.3 (Strongly Acid), lime was applied at different rates to see the effects on an oat crop. (See YCDP Lime Trial – Cereal Production).

> *"Straw is full of valuable nutrients: A 60 bushel per acre barley crop produces straw containing about 30 lbs of nitrogen, 8 lbs of phosphate, 67 lbs of potassium and 6 lbs of sulphur."*
>
> - Conservation Matters, Sept 1990

Limestone or calcium carbonate ($CaCO_3$)is used to raise pH. The amount required depends on the soil type, as soils have differing capacities to absorb the calcium and thereby affect a rise in pH. Table 4.25 shows the different amounts of limestone needed to change pH for different soil types.

Table 4.25 Limestone Needed to Change the Soil Reaction

| Change in pH Desired in Plow-Depth Layer | Limestone (lb/acre) | | | | | |
|---|---|---|---|---|---|---|
| | Sand | Sandy Loam | Loam | Silt Loam | Clay Loam | Muck |
| 4.0–6.5 | 2600 | 5000 | 7000 | 8400 | 10,000 | 19,000 |
| 4.5–6.5 | 2200 | 4200 | 5800 | 7000 | 8,400 | 16,200 |
| 5.0–6.5 | 1800 | 3400 | 4600 | 5600 | 6,600 | 12,600 |
| 5.5–6.5 | 1200 | 2600 | 3400 | 4000 | 4,600 | 8,600 |
| 6.0–6.5 | 600 | 1400 | 1800 | 2200 | 2,400 | 4,400 |

Source: *Knott's Handbook for Vegetable Growers*, Third Edition, O. Lorenz & D. Manynard, John Willey & Sons, 1988, pg 111.

Table 4.23 Natural Sources of Potash

| MATERIAL | % Potash Content ($K_2O$) |
|---|---|
| Wood ashes (broad leaf) | 10.0% |
| Wood ashes (coniferous) | 6.0 |
| Molasses wastes (curbay) | 3.0 - 4.0 |
| Flyash | 12.0 |
| Potato tubers | 2.5 |
| Dry potato vines | 1.6 |
| Vegetable wastes | 1.4 |
| Rapeseed meal | 1.0 - 3.0 |
| Beet wastes | 0.7 - 4.1 |
| Wool wastes | 1.0 - 3.5 |
| **Straw** | |
| Millet | 3.2 |
| Buckwheat | 2.0 |
| Oats | 1.5 |
| Barley | 1.0 |
| Rye | 1.0 |
| Wheat | 0.8 |
| **Manure** | |
| Cow (fresh excrement) | 0.1 |
| (dried excrement) | 1.5 |
| Cow (fresh urine) | 0.5 |
| Horse (fresh excrement) | 0.3 |
| (dried excrement) | 1.6 |
| (fresh urine) | 1.5 |
| Hog (fresh excrement) | 0.5 |
| (fresh urine) | 0.8 |
| Goat and Sheep (fresh excrement) | 0.3 |
| (dried excrement) | 3.0 |
| (fresh urine) | 2.3 |
| Chicken (fresh) | 0.6 - 1.0 |
| (dried) | 1.2 |
| Pigeon (fresh) | 1.0 |
| Duck (fresh) | 0.6 |
| Goose (fresh) | 0.6 |
| Dog (fresh) | 0.3 |
| **Leaves** | |
| Apple leaves | 0.4 |
| Peach leaves | 0.6 |
| Pear leaves | 0.4 |
| Cherry leaves | 0.7 |
| Raspberry leaves | 0.6 |
| Grape leaves | 0.4 |
| Oak leaves | 0.2 |
| **Hay Materials** | |
| Vetch hay | 2.3 |
| Alfalfa hay | 2.1 |
| Kentucky blue grass hay | 2.0 |
| Red clover hay | 2.1 |
| Cowpea hay | 2.3 |
| Timothy hay | 1.4 |
| Pea forage | 1.4 |
| Winter rye | 1.0 |
| Immature grass | 1.2 |
| Garden Pea Vines | 0.7 |
| Weeds | 0.7 |
| **Natural Minerals** | |
| Granite dust | 3.0 - 5.5 |
| Greensand marl | 7.0 |
| Basalt rock | 1.5 |

Table 4.24 Fertilizer Calculations

## IMPERIAL:

### 1. Determine Area to be fertilized in acres:

**Example:**

Area Measured = 350′ x 50′ = 17,500 square ft / 43,560 square ft/acre = .40 acre

### 2. Determine Recommended Rate for Each Crop Type and Quantities for each Fertilizer Type to Make a Blend

A. Nitrogen Recommendation = 100 lbs/acre, 34-0-0 Ammonium Nitrate used

100 lbs/acre x .40 acre / divided by active % = 40 lbs actual N needed / .34 = 117.6 lbs 34-0-0

B. Phosphorous Recommendation = 50 lbs/acre, 11-55-0 Ammonium Phosphate used

.40 acre x 50 lbs/acre / divided by active % = 20 lbs actual P needed / .55 = 36.3 lbs 11-55-0

(Also Added: 11 % Nitrogen = .11 x 36.3 lbs = 4 lbs Actual N)

C. Potassium Recommendation = 35 lbs/acre, 0-0-60 Potassium Chloride used

.40 acre x 35 lbs/acre / divided by active % = 14 lbs actual K needed / .60 = 23.3 lbs 0-0-60

D. Boron Recommendation = 10 lbs/acre

.40 Acre x 10 lbs/acre = 4 lbs Boron needed

## METRIC:

### 1. Determine your area in hectares:

**Example:**

Area Measured = 106.7m x 15.2m = 1622 square meters / 10,000 square meters/ha = .16 hectares

A. Nitrogen Recommendation = 100 lbs/acre x 1.12 = 112 kg/ha

.16ha x 112 kg/ha / divided by active % = 17.92 kg Actual N needed / .34 = 52.7 kg 34-0-0

The highest amount of limestone is required on peat and muck soils where organic matter is highly decomposed. At a YCDP trial site in Watson Lake, the forage field had a very peaty soil, with a pH of 5.2. The lime requirement, from Norwest Labs, required 14.5 tons/acre. Due to limited funds this was not applied.

There are different grades of limestone from fine powder to granular. A pulverized, finely graded limestone is normally the desired form of lime as it is more rapidly effective in its reaction with the soil and thus benefits plant growth more quickly than the coarser grades. Coarser grades of lime, although less rapid in reaction, remain in the soil longer with the influence possible for a longer period of time. Common liming materials are indicated in Table 4.26.

Table 4.26 Common Liming Materials

| Materials | Chemical Formula | Pure $CaCO_3$ Equivalent (%) | Liming Material (lb) Necessary to Equal 100 lb of Limestone |
|---|---|---|---|
| Burned lime | $CaO$ | 150 | 64 |
| Hydrated lime | $Ca(OH)_2$ | 120 | 82 |
| Dolomitic limestone | $CaCO_3$, $MgCO_3$ | 104 | 86 |
| Limestone | $CaCO_3$ | 95 | 100 |
| Marl | $CaCO_3$ | 95 | 100 |
| Shell, oyster, etc. | $CaCO_3$ | 95 | 100 |

Source: *Knott's Handbook for Vegetable Growers*, Third Edition, O. Lorenz, D.Manynard, John Willey & Sons, 1988, pg 111.

### Common Acidifying Materials

Sulphur can be used to reduce the pH of your soil. In Table 4.27, the amount of sulphur needed to change the desired pH for sands, loams and clays is indicated. The forms of sulphur which are used to acidify soil are indicated in Table 4.28. Gypsum ($CaSO_4$)or calcium sulphate, which contains 13-19% sulphur (sulphate form), can also be used. This is not as soluble as ammonium sulphate. (See Table 4.14). Certain fertilizer materials also increase soil acidity when used in large quantities. Urea, ammonium nitrate, ammonium sulfate and ammonium phosphate are fertilizers which are acidic in reaction. Generally, reducing pH is a very expensive process and results are short lived. This is not usually practical on a large scale.

### Alberta Sustainable Agriculture Association

This organization is for organic growers in Alberta. A field can be certified organic if there has been no use of chemical fertilizers, insecticides, herbicides or fungicides, or use of unacceptable methods during three years (36 months) before harvest. For certification management practices required include: a soil building program, rotation of non-perennial crops, use of resistant varieties, intercropping, and careful management of soil health to prevent weeds pests and diseases.

## Table 4.27 Quantity of Sulphur Needed to Change Soil pH

| | Sulfur (lb/acre) | | |
|---|---|---|---|
| Change in pH Desired | Sands | Loams | Clays |
| 8.5–6.5 | 2000 | 2500 | 3000 |
| 8.0–6.5 | 1200 | 1500 | 2000 |
| 7.5–6.5 | 500 | 800 | 1000 |
| 7.0–6.5 | 100 | 150 | 300 |

Source: *Knott's Handbook for Vegetable Growers*, O. Lorenz, D. Maynard, J. Wiley & Sons, 1988, p 112.

## Table 4.28 Common Acidyfying Materials

| Material | Chemical Formula | Sulfur (%) | Acidifying Material (lb) Necessary to Equal 100 lb of Soil Sulfur |
|---|---|---|---|
| Soil sulfur | S | 99.0 | 100 |
| Sulfuric acid (98%) | $H_2SO_4$ | 32.0 | 306 |
| Sulfur dioxide | $SO_2$ | 50.0 | 198 |
| Lime–sulfur solution (32° Baumé) | $CaS_x$ + water | 24.0 | 417 |
| Iron sulfate | $FeSO_4 \cdot 7H_2O$ | 11.5 | 896 |
| Aluminum sulfate | $Al_2(SO_4)_3$ | 14.4 | 694 |

[1] Certain fertilizer materials also markedly increase soil acidity when used in large quantities.

Source: *Knot's Handbook for Vegetable Growers*, O. Lorenz, D. Maynard, J. Wiley & Sons, 1988, p 112.

## SOIL IMPROVEMENT PRACTICES

Soil management practices must focus on maintaining and improving the nutrient profile of our agricultural soils. The increasing cost of applying commercial soil nutrients, the high cost of intensive soil cultivation practices and the evidence of soil degradation are of primary concern to producers when they evaluate their soil management practices.

### *Basic Concepts to Improve Your Soil:*

1. Always have the soil protected by a crop.
2. Mix what is growing into the soil by any tillage method you find convenient or practical.
3. Replace the organic matter which is taken off by cropping. Only by doing so can the permanent fertility and productivity of the soil be maintained.

### *Improve Soil Nitrogen*

There are three major forms of nitrogen in soils, organic nitrogen associated with soil humus, ammonium nitrogen fixed by certain clay minerals and soluble, inorganic ammonium and nitrate compounds. The supply of soil nitrogen depends on the amount and type of organic matter, activity of soil micro-organisms, yield of previous crop (crop removal), amount of crop residue worked into the soil, past cultural and cropping practices and climatic conditions.

Nitrogen can be added to soils by commercial fertilizers, crop residues, green manure crops, farm manure and ammonium and nitrate salts brought down by precipitation. Sources of nitrogen are from:

1. rainwater
2. breakdown of soil organic matter
3. breakdown of manure
4. fertilizer (usually urea or ammonium nitrate)
5. nitrogen fixation by legumes.

### The Nitrogen Cycle

The nitrogen cycle, illustrated in Figure 4.11, is controlled by the biochemical reactions within soils. The process of tying up nitrogen in organic forms is called immobilization and its slow release is called mineralization, affected by soil organisms and soil organic matter. Nitrification, a process of oxidation is brought about by bacteria. Nitrites ($NO_2$) are converted to nitrates ($NO_3^-$), a form available to plants. Nitrogen in the air ($N_2$) is fixed by leguminous crops (See Nitrogen Fixation By Legumes). Nitrogen from rainfall is also converted to nitrates. Depletion of nitrogen is due to crop removal, drainage, erosion and to loss in a gaseous condition. Gaseous losses of nitrogen are increased by poor drainage and lack of aeration. The maintenance of a soil in a bare condition may also increase gaseous losses.

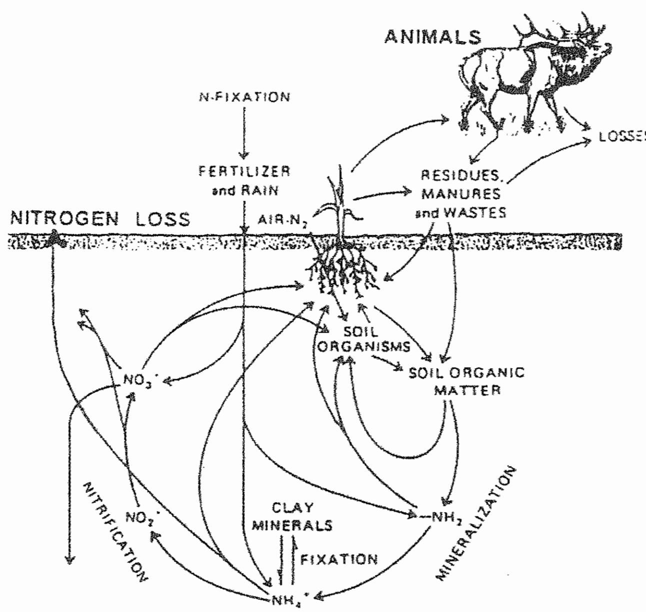



Figure: 4.11. Nitrogen Cycle

### *Soil Activity*

The activity of soil organisms and bacteria is directly related to soil temperature and moisture conditions. Soil temperatures reach higher temperatures in Dawson than Whitehorse. In Whitehorse, soils are thawed slightly longer. Soil temperatures of cultivated soils in the Yukon tend to be cooler than in Alaska and much lower than regions of southern Canada.

### *Improve Organic Matter Content*

Rapid decomposition of fresh organic matter contributes most effectively to the physical condition of the soil. Plenty of moisture, nitrogen, and a warm temperature speed up the rate of decomposition. The function of organic matter in the soil includes:

- Organic matter serves as a source of energy for soil microorganisms and as a source of plant nutrients.
- Organic matter holds the minerals absorbed from the soil against loss by leaching until they are released by the action of microorganisms.
- Bacteria thriving on the organic matter produce complex carbohydrates that cement soil particles together into aggregates.
- The waterholding capacity of sands and sandy soils may be increased by the incorporation of organic matter. Aggregation in heavy soils may improve drainage.
- Penetration of roots through the soil is improved by good structure brought about by the decomposition of organic matter.
- The entrance and percolation of water into and through the soil are facilitated and this reduces losses of soil by erosion.
- It is seldom possible to make a large permanent increase in the organic matter content of a soil of a large area but adding organic matter to garden and greenhouse soils will improve their productivity.

> **Haines Junction Mile 1019 1945-1952 Progress Report**
>
> *"The activity of soil micro-organisms is probably confined to the period between the end of May and mid-September, tapering off more or less abruptly in the latter month."*

Soils with low organic matter, characteristic of many soils in the Yukon, can develop strong surface crusts affecting the emergence of crops. Soils with higher organic matter usually do not have this problem.

### *Carbon-Nitrogen Ratio*

Most organic residues entering the soil have a high carbon and comparatively small amounts of total nitrogen and thus have a wide carbon-nitrogen ratio. When materials having a high carbon content are added to soils the available nitrogen is used to break down the residues, providing competition to plants for this nitrogen. The microbes or soil organisms break down plant residues and incorporate into their bodies all the inorganic nitrogen. Unless the plant residue contains at least 1.5% nitrogen, the decomposing organisms will utilize soil nitrogen. Soil organisms will tie up about 25lbs of nitrogen per acre from the soil in the process of decomposition of carbon rich organic matter. The rate of decay will lengthen or shorten this period before nitrification can occur.

The carbon-nitrogen ratio in plant materials is variable, ranging from 20:1 to 30:1, for legumes and farm manure, up to as high as 100:1 in certain strawy residues. C/N values for soils range from 8:1 to 15:1, the average is between 10:1-12:1. Bodies of microorganisms usually fall between 4:1-9:1. Alfalfa and clover have a narrower C/N ratio, and yield their nitrogen more quickly than if oats or wheat straw are plowed under. Sawdust has a very high C/N ratio (300:1) and requires additional nitrogen to aid decomposition. Mature residues whether legume or non-legume have a higher C/N ratio than do younger succulent materials.

Table 4.29 Carbon Nitrogen Ratios of Common Organic Materials

| Material | C:N Ratio |
|---|---|
| Alfalfa | 12:1 |
| Sweet Clover,young | 12:1 |
| Sweet Clover,mature | 24:1 |
| Rotted Manure | 20:1 |
| Oat straw | 75:1 |
| Timothy grass | 80:1 |
| Sawdust | 300:1 |

Source: *Knot's Handbook for Vegetable Growers*, O.Lorenz, D. Haynard, 1988, J. Wiley & Sons, p104.

### *Summer Fallow*

Summerfallow has been a useful practice to acquire weed control and improve crop production. Summerfallow is frequently challenged today, both from an agronomic and an economic point of view. Disadvantages of summerfallow include:

- It generally decreases the organic matter content of the soil.
- It leaves the topsoil unprotected and susceptible to wind and water erosion.
- It increases salinity by allowing the topsoil to dry up. The salts are brought up from the subsoil by capillary action to the soil surface where further evaporation leaves these salts concentrated in the upper layers.

The use of legumes, incorporated in the soil as a green manure crop, will help to reduce some of the problems from summerfallow.

### *"Plowdown" – Green Manure Crops*

"Plowdown" refers to the cultural practice of growing a legume crop such as clover or alfalfa to grow to the blossom stage and then incorporating the entire crop growth into the soil with a plow or rototiller. Higher available nitrogen and improved soil structure are the main benefits.

"Plowdown" offers the opportunity for "summerfallow" to earn its keep so to speak, from the improved soil condition and nutrient levels. The added inputs of seed and seeding will be offset by the savings in the number of cultivations which are not required until mid-season of the plowdown year.

A legume plowdown is most beneficial in land areas that are low lying, susceptible to flooding and erosion, or salinity. The greatest improvement will be noted on the heavy textured or clay soils which require large quantities of organic matter for the maintenance of proper tilth. Almost all soils will improve when "plowdown" is practiced.

- Soil structure and tilth are greatly improved with the addition of organic matter.
- Soil will be easier to handle under varying moisture conditions
- Water infiltration, water holding capacity and capillary action will improve.
- Alkali and saline soils will be improved.
- Clay or heavier soils will be less sticky and all soils less susceptible to pulverization.

The main effect of turning under forage legumes is to add nitrogen rich readily decomposable plant material. The addition of organic matter from plant residues and the deep rooted nature of these crops will improve water infiltration. The better internal and subsoil drainage will in fact reverse the salinization process and permit the salts accumulated at the surface to be carried down to lower levels.

Legumes, used as a "break-up" crop, can be effective in controlling diseases and insects that can build up under continuous crop production. Good development of legume crops before cultivation also results in effective competition for weeds. (See Green Manure Crops – Crop Management)

### Nitrogen Fixation By Legumes

Legume plants, when properly inoculated with rhizobia bacteria, have the ability to take nitrogen from the atmosphere ($N_2$) and fix it on their roots in a form that can be utilized by subsequent crops. Legume plants enter into a symbiotic or mutually beneficial partnership with the rhizobia bacteria. Soon after legume seeds germinate, rhizobia, present in the soil or added as seed innoculum, invade the root hairs and move through an infection thread toward the root. There the bacteria multiply, causing the swelling of root cells to form nodule clusters that become miniature nitrogen factories. Atmospheric nitrogen from soil air spaces around the nodules is fixed by binding it to other elements and thus changing it to a plant available form. (See Figure 4.11). The bacteria obtain carbohydrates from the plant and the growing legumes secures nitrogen in the ammonium form ($NH_4$) from the bacteria. The appropriate strain of Rhizobium must be used for specific legume crops. (See Green Manure Crops – Crop Management).

The sun provides the energy as the plant manufactures carbohydrates in the green leaves and translocates a portion to the nodules. The carbohydrates serve as a source of hydrogen to form ammonia ($NH_3$) from atmospheric nitrogen ($N_2$)and they supply the rhizobia with the energy required to grow and continue the process. Since $N_2$-fixation in root nodules is directly dependent on the translocation of carbohydrates from the leaves, the rate of fixation is fully synchronized with the rate of plant growth. Thus the fixed nitrogen is readily available in the form required for combination with carbohydrates to produce the amino acids used for the manufacture of protein.

The potential for nitrogen fixation is directly related to rhizobia survival, the extent of effective nodulation and plant growth factors. Any adverse soil condition or environmental stress that effects plant growth is likely to slow down the nitrogen fixation process. Rhizobia do not survive well in dry and very warm soil. Nodulation will be reduced in acid soils with a pH below 5.5. If soil deficiencies are present adequate fertilizer should be applied to promote vigorous growth, high yields of dry matter and good $N_2$-fixation. Calcium and magnesium are also very important in the nodulation and $N_2$ fixation processes. The amount of nitrogen fixed also differs for different legume species and varieties. (See Green Manure Crops-Crop Management). The use of legumes for soil improvement is essential on many soils, such as salt-effected, sandy and highly erosive soils.

To determine if nitrogen fixation is occurring dig up several plants at different spots in th field and examine the crown region for clusters of nodules. Slice the nodules open. If they are pink to beefsteak-red on the inside then they are effectively fixing nodules. The red colour is due to leghemoglobin , an iron containing pigment associated with active $N_2$-fixation. The number of nodules and the rate of $N_2$-fixation will increase with time after emergence and normally reaches a maximum just before the legume blooms.

### Plowdown Techniques

A soil improving crop should be fertilized adequately with nitrogen. This fertilization will increase the nitrogen content somewhat and improve later decomposition. Nitrogen may also have to be applied as the soil improving crop is incorporated into the soil to speed decomposition. As a general rule about 20 lbs of nitrogen should be added for each ton of dry matter for a non legume green manure crop.

> ***Swede Creek (Dawson) Experimental Station - 1926***
>
> *" On account of early frost the ploughing under of green crops does not materially improve the condition of the soil until the second year."*
>
> *The Yukon Territory 1926*, Dept. of Interior, Ottawa, 1926.

The best time to plowdown is shortly after full bloom, when the legume will decompose more quickly and is easier to incorporate with equipment.

Traditionally the moldboard plow has been the equipment used for a plowdown. However, plant residues are not incorporated into the soil as well as with other equipment. When the soil is dry and the crop is heavy, residues are deposited in a thick mat, insulating the topsoil from the subsoil, preventing water movement, and substantially slowing down the process of decomposition, humus formation and release of plant foods. Disk implements, single and double disk furrows, one way discers, offset discs, Rome-type and serrated discs, followed or preceded by heavy duty cultivators provides good incorporation of materials with the soils, especially if conditions are not the most favorable. Generally the most effective are the plow (not on erosive soil), the tandem or offset disk and the disk harrow. The deep tillage cultivator is the least effective. When choosing tillage implements for working under the legume stand, select one or a combination that will incorporate the top growth and roots and still leave a substantial trash cover on the soil surface. The timing of the first operation before the crop gets too thick for the selected equipment is often more important than the choice of the machine.

Good incorporation of organic matter near the surface of the soil will encourage bacterial fermentation and conservation of plant nutrients. The turning under of fresh legumes greatly stimulates the activity of soil microbes which in turn speeds up the cycling of nutrient elements and increases the release of plant available nutrients from soil organic reserves. Soil structure is also improved by binding more soil particles together into aggregates and forming more pore spaces. As a result the soil becomes more friable and less erosive, is easier to till and can hold more water.

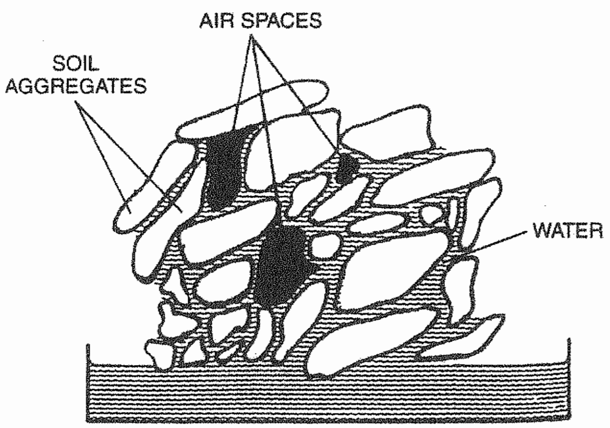



Figure 4.12 Soil Air Spaces

Forage legumes can help with salinity problems. Alfalfa with its deep roots and high water consumption can effectively use excess water in saline seeps, however too high a salt content can limit the growth of alfalfa. (See Salinity Research Project – Crop Management). The ability of crops to tolerate salt is enhanced on soils high in organic matter.

The amount of organic matter and nitrogen added will depend on the total dry matter produced, age or stage of the crop, and type of legume. With maximum above-ground growth the maximum amount of nitrogen and organic matter will be incorporated.

### *Composting Methods*

The original Idore compositing method was invented by the father of organic gardening Sir Albert Howard. He found that by layering different organic materials, decomposition took place more quickly and more completely. He first placed down a five or six inch layer of green matter, then a two inch layer of manure (bloodmeal, bone meal, or other high protein material may be substituted) and a layer of rich earth, ground limestone and phosphate rock. Sir Howard found that a heap 5-10 feet wide and five feet high was ideal (the length is optional). He found that decomposition was facilitated by aeration and so he placed pipes or stakes through the pile as it was being built, then he pulled them out when the pile was 5 feet high. He lightly pressed the outside of the pile to prevent blowing, formed a shallow basin on the top to catch rainwater, covered the entire surface with a layer of earth and left it to decay.

#### Requirements for Good Compost

1. Nitrogen is essential to fast composting. Adding manure and supplying nitrogen will perform the service of heating up the compost quickly. Satisfactory compost can be made without manure but it will take longer to rot up. Dried manure, cottonseed meal, dried blood, bone meal will work well as a heating up agent.
2. Shredding of material is essential. A compost shredder is the ideal tool, otherwise a rotary mower can also be used.
3. Sufficient moisture is needed. Composting will take place faster with moisture and should be watered liberally when it is first made. During long dry spells the heap should be watered to keep moist. However, don't let it get soggy.
4. Shred the basic raw materials to be used. Use grass clipping, leaves, straw, house and garden vegetable waste, weeds and manure, fresh or dried. Shred each type of material and place in the pile together. If they are not shredded it is necessary to layer the materials.

In most areas the decomposition will take a minimum of one to two years and often three depending largely on how favorable a site has been chosen for the heap and what practices are employed to hasten the decomposition of organic materials. A protected well drained area receiving maximum heat from the sun should be selected.

*Following clearing and discing my land, I planted field peas at 300 lbs/acre as a soil improvement crop for 2 years. Plant residues were incorporated into the soil each spring. There was a definite improvement in soil tilth."*

-Whitehorse Producer

**Layered Compost**

Organic materials such as sod, grass and hedge clippings, leaves weeds, manures, sawdust, shredded newspapers, and garden/plant residues all can be used for composting. Coarse materials are used in the first layer and should be approximately six inches deep for a good foundation. Finer materials should be used in the second layer which should be three inches deep. Manure is recommended but leaves or grass clippings are satisfactory. At this point start to build up the sides and ends of the pile slightly higher than in the centre, continuing this practice throughout the construction. The third layer should have a sprinkling of commercial or organic fertilizers to improve nutrient content, about one pound to 10 square feet of a mixed blend fertilizer (8-24-24, 10-20-10). The fourth layer should be an inch of good garden loam. This layer arrangement is repeated until the desired height (usually about 3 feet).

The top of the pile should be dish-shaped and then the pile wetted thoroughly. Some people drench the pile with warm water to increase initial bacterial action. To hasten the breakdown of organic matter and maintain optimum moisture levels in the heap the use of clear plastic is recommended. The plastic helps to retain the heat of decomposition and helps to maintain moisture levels more constant. Use a large enough sheet to completely cover the heap and cover the edge of plastic to completely seal the edge around the pile.

Wood ashes can also be used and layers of ashes should not be more than 3 inches thick to facilitate overall decomposition of the pile. As ashes can raise the pH of the soil this must be considered. Our soils tend to be above neutral in pH so raising the pH is not necessary. Wood ashes contain about 5-7% potash, 1.5-2% phosphoric acid, and 25-30% calcium.

"Building the pile within a tight wooden or cement box or utilizing a pit (methods often used in warmer climates) should be avoided in Alaska. The boxed method retains so much liquid that the bottom of the pile may become a solid block of ice and may not completely thaw during the summer. The pit method is impractical as our cold soils actually inhibit decomposition. Start a pile with layers of uniform thickness with a width of four feet and the usual height about three feet. The length is not important."

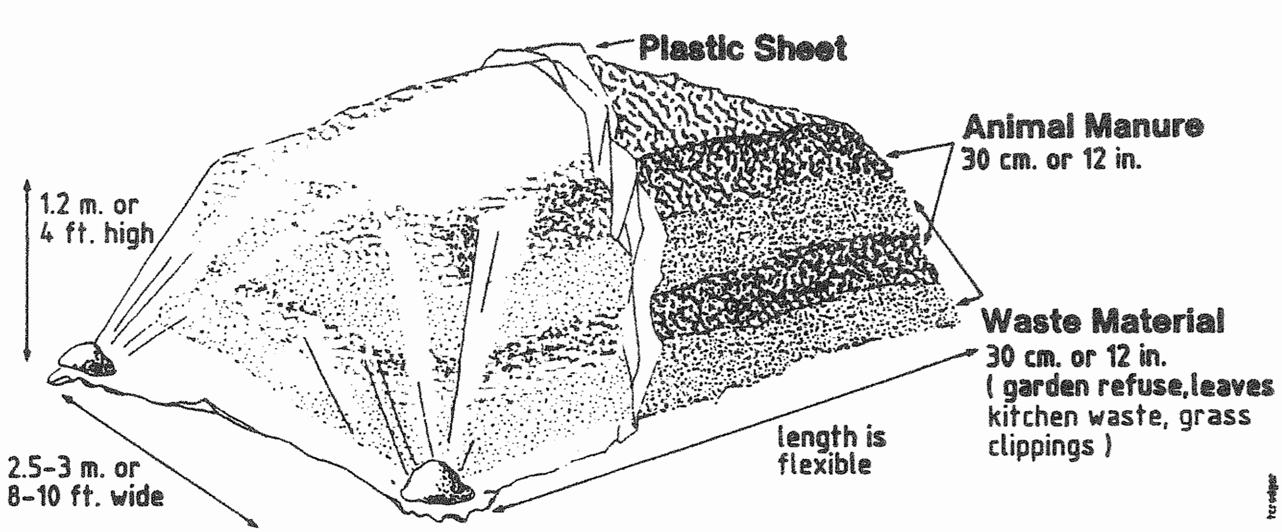
- *The Compost Heap in Alaska*, Cooperative Extension Service, University of Alaska, 1982, P-1-022.

The calcium in wood ashes facilitates decomposition. Diseased or pest laden plants should not be used as pests may survive in incompletely composted material. Kitchen wastes should be used but don't add meat or dairy products as this will attract animals and develop an odour during decomposition. In addition, the fats are slow to break down.

Turn the pile periodically to assist with decomposition. To help make a uniform compost, the pile should be forked over after 10 or 12 weeks. Mark an area about the same size as the original. In repiling the material, place the edge and end material in the centre of the new heap. Repile with squared up sides and dished top as before. It is common practice to sprinkle a little additional fertilizer through the heap when repiling.

If your heap doesn't heat up add more manure or organic

Figure 4.13 Compost Pile




Source: *Composting for Yukon Gardens*, Renewable Resources Bulletin, Vol. 3, No. 4, 1985.

nitrogen fertilizer. Otherwise, it will take longer for decay to take place. As you make it add rock phosphate, colloidal phosphate, granite dust, greensand or ground limestone. The bacterial activity in the heap will help break down the nutrients in the rock and making them available faster.

Deficient elements can be added to the compost in many ways. Autumn leaves are a teeming source of trace minerals which are not found in the upper layers of the soil: they should constitute a major part of every compost heap. Shred and mix leaves with weeds, lawn clippings, and plant residues. If you can get hay or alfalfa in the first year of growth it will break down faster in the compost heap. Its

## Table 4.30 The Relative Worth of Compost Materials

| MATERIAL | FERTILIZER CONTENT (per cent) Nitrogen (N) | Phosphorus (P) | Potassium (K) | HUMUS POTENTIAL | BREAKDOWN SPEED | COMMENTS |
|---|---|---|---|---|---|---|
| **Manures, Natural** | | | | | | |
| Cattle | 0.4 | 0.3 | 0.44 | high | moderate | Often expensive. Can be weedy. Best on loams and light soils. Composts well. |
| Steer | 0.7 | 0.3 | 0.4 | " | " | As above. Good supplies at feedlots. |
| Horse | 0.65-0.76 | 0.3-0.6 | 0.5-0.65 | " | " | Hot when fresh, compost until cool. Best on clay soils. |
| Pig | 0.3 | 0.3-0.4 | 0.45 | medium low | " | Should have high litter content. |
| Sheep and Goats | 0.65 | 0.46 | 0.23 | medium high | " | Hot when fresh, compost until cool. |
| Duck | 1.10 | 1.45 | 0.5 | medium low | " | All poultry manure is hot when fresh. Compost with litter. |
| Goose | 1.10 | 0.55 | 0.5 | " " | " | |
| Chicken | 1.1-1.8 | 1.0 | 0.5 | " " | " | |
| Turkey | 1.3 | 0.7 | 0.5 | " " | " | |
| Rabbit | | | | | | |
| Commercially grown | 5.0 | 3.3 | 2.0 | medium high | " | Hot, compost until cool. |
| Home grown | 2.0 | 1.0 | 0.5 | " " | " | " " " |
| (All manures vary widely, depending on the kind and amount of litter they contain.) | | | | | | |
| **Manures, Dried and Shredded** | | | | | | |
| Cattle | 1.3 | 0.9 | 0.8 | medium | moderate | Uniform, odorless, weed free. No microflora. |
| Sheep or Goat | 1.5-2.5 | 1.0-1.5 | 1.0-3.0 | " | " | " " " |
| Poultry | 4.5 | 3.2 | 1.3 | low | " | |
| **Manures, Green (cover crops)** | | | | | | |
| Alfalfa | 3.0-4.0 | not available | | medium high | rapid | Expensive nitrogen. Good source of humus, but needs lime for growth. |
| Austrian winter peas | 2.3-3.8 | 0.22 | 1.03 | " " | " | Faster growing than alfalfa, but needs lime for growth. |
| Clover, red | 2.0-3.2 | 0.25 | 1.28 | " " | " | |
| Clover, crimson | 2.26-3.3 | 0.20 | 1.86 | " " | " | A legume, adds nitrogen to soil. |
| Cowpeas | 2.5-3.0 | 0.25 | 1.45 | " " | " | Quick crop, legume. |
| Lespedeza, common | 2.0-2.5 | 0.19 | 0.8 | " " | " | Not hardy in North. |
| Lespedeza, sericea | 2.1-2.4 | 1.24 | 0.91 | " " | slow | Not hardy in North. High nitrogen in soil, but plow under when still soft to hasten breakdown. |
| Lupine, blue | 2.0-2.5 | not available | | " " | moderate | Found mainly in western U.S. |
| Vetch, hairy | 3.0-4.0 | 0.45 | 2.18 | " " | rapid | Good legume and quick crop. |
| Oats | 1.3-1.4 | 0.17 | 1.09 | " " | " | Quick crop. Less nitrogen. |
| Rye, annual | 1.2-1.47 | 0.24 | 1.25 | " " | " | Not the best. |
| Rye, winter | 1.7-2.3 | 0.18 | 1.05 | " " | " | Can be grown at almost any season. |
| **Litter** | | | | | | |
| Bean straw | 1.2 | 0.2 | 1.2 | " " | moderate | |
| Oat straw | 0.6 | 0.2 | 1.3 | " " | " | All straws apt to be weedy. Compost thoroughly. |
| Rye straw | 0.6 | 0.3 | 0.8 | " " | " | |
| Wheat straw | 0.5 | 0.2 | 1.0 | " " | " | |
| Sawdust | 0.2 | 0.1 | 0.2 | medium | moderate-fast | Hardwood best. Add nitrogen if fresh. |
| Wood shavings | 0.2 | 0.1 | 0.2 | " | moderate-slow | Unsightly and blows around. Add nitrogen. |
| Oak leaves | 0.8 | 0.35 | 0.2-0.3 | " | " " | Avoid softwoods, maple, and birch. Oak leaves are acid. |
| Pine needles | 0.45 | 0.12 | 0.3 | low | | |
| Bagasse | 1.02 | 0.14 | 1.30 | high | " " | Sugarcane residue, often used as commercial henhouse litter. |

Table 4.30 Cont.

| MATERIAL | FERTILIZER CONTENT (per cent) Nitrogen (N) | Phosphorus (P) | Potassium (K) | HUMUS POTENTIAL | BREAKDOWN SPEED | COMMENTS |
|---|---|---|---|---|---|---|
| Peat moss (sphagnum) | 0.8-1.5 | trace | trace | " | " " | Acidity varies. Chicken-litter grade costs less, lasts longer. |
| Sedge peat | 1.0-3.5 | " | " | low | rapid | Acid. |
| **Other Vegetable Sources** | | | | | | |
| Alfalfa meal | 2.5 | 0.5 | 2.0 | high | moderate-rapid | Spoiled meal good for gardens, cheap if found. |
| Alfalfa straw | 1.5 | 0.3 | 1.5 | " | moderate | As above. |
| Castorbean pomace | 5.0-6.0 | 2.0 | 1.0 | moderate-high | rapid | If coarse, compost. Acid. |
| Cocoa shell meal | 2.5 | 1.0 | 2.5-3.4 | medium | moderate | Fragrant. Potash may build up if used regularly. |
| Cottonseed meal | 6.5-8.0 | 2.0-3.0 | 1.5-2.0 | high | moderate-rapid | Acid. Fine for azaleas, etc. |
| Garbage tankage | 2.5 | 1.5 | 1.5 | medium | " " | Becoming more common. Varies widely in quality. |
| Linseed meal | 5.5 | 1.7 | 1.3 | high | " " | |
| Mustardseed meal | 5.0 | 1.0 | 1.0 | " | " " | |
| Olive pomace | 1.2 | 0.8 | 0.5 | medium | moderate | |
| Rapeseed meal | 5.7 | 1.7 | 1.2 | high | rapid | |
| Ravison meal | 5.5-6.0 | 2.0-2.25 | 0.75-1.25 | " | " | |
| Soybean meal | 7.0 | 2.0 | 2.0 | " | " | |
| Tung oil pomace | 5.5-6.0 | 2.0 | 1.3 | medium | moderate | In South, if not replaced by synthetics. |
| Winery pomace | 1.0-2.0 | 1.5 | 0.5-1.0 | " | moderate-rapid | |
| Coffee grounds | 2.1 | 0.3 | 0.3 | moderate-low | moderate | |
| Tea leaves | 4.2 | 0.6 | 0.4 | moderate-high | moderate-rapid | Acid, fine-textured. |
| Brewers grains | 0.9 | 0.5 | 0.05 | moderate-low | moderate | Bad odor. |
| Shredded cornstalks | 0.5 | 0.2-0.4 | 0.4-1.6 | moderate | very slow | Compost. Better than cobs. Shredding hastens breakdown. |
| Corncob ash | 0 | 0 | 50.0 | none | rapid | |
| Peanut shells | 0.8-2.0 | 0.2 | 0.5-1.0 | medium | moderate | Crush. |
| Seaweed, average | 0.5 | 0.1 | 1.0-5.0 | moderate-low | " | Compost in water except fall. |
| Seaweed, kelp | 1.6-3.3 | 1.0-2.0 | 15.0-20.0 | low | " | " " |
| Spanish moss | 0.6 | 0.1 | 0.6 | moderate-high | " | Compost well. |
| Sugar beet leaves | 0.3 | 0.4 | 0.07 | medium | moderate-rapid | |
| Tobacco stems and waste | 1.5-3.3 | 0.5 | 4.0-9.0 | moderate-high | moderate-slow | |
| **Hays** | | | | | | |
| Bean vine | 0 | 0.4 | 1.3 | " " | moderate-rapid | Chop, compost. |
| Kentucky blue grass | 1.2 | 0.4 | 1.6 | high | " " | Cut before seeds form, chop, compost. |
| Pea vine | 1.0 | 0.3 | 1.0 | moderate-high | " " | Chop, compost. |
| Salt-marsh | 1.1 | 0.25 | 0.75 | low | very slow | Better as a mulch. |
| Timothy | 1.3 | 0.6 | 2.0 | moderate-high | moderate-rapid | Chop, compost. |
| **Non-vegetative** | | | | | | |
| Ashes, unleached hardwood | 0 | 1.0-2.0 | 4.0-10.0 | none | ready | Alkaline, 35 per cent calcium. |
| Dried blood | 9.0-14.0 | 1.0 | 1.0 | " | " | Mix 1 ounce per gallon water before using. |
| Bone, burned | 1.5 | 30.0-33.5 | 0 | " | moderate | |
| Bonemeal, raw | 3.0-4.0 | 20.0-24.0 | 0 | " | very slow | Much overrated. Use finest grade. |
| Bonemeal, steamed | 1.0-2.5 | 20.0-30.9 | 0 | " | slow | Faster-acting than raw. |
| Egg shells | 1.2 | 0.38 | 0.14 | " | " | Crush finely. |
| Feathers | 10.0-15.0 | 0 | 0 | low | moderate | Compost. |
| Fish emulsion | 5.0 | 2.4 | 1.2 | trace | ready | Traces or more of about every element needed for growth. |
| Fish scrap | 5.0 | 2.6-3.2 | 0 | very low | moderate | |
| Fish meal | 8.0-10.0 | 4.0-9.0 | 2.0-3.0 | " | " | |
| Hair | 8.2-10.7 | 0 | 0 | low | slow | Compost. |
| Hair, hog | 14.0 | 0 | 0 | " | " | " |
| Hoof and horn meal | 7.0-15.0 | 0 | 0 | " | " | |
| Leather waste | 5.0-13.0 | 0 | 0 | " | " | Shred, compost. |
| Sewage sludge | 2.0-6.0 | 2.5-4.0 | trace | moderate-low | moderate-fast | Processed, no odor, good. Can vary in quality with source. |
| Tankage | 5.0-10.0 | trace | trace | " " | moderate | Alkaline. |
| Tankage with bone | 5.0-10.0 | 8.0-20.0 | 0 | " " | " | " |
| Wool waste | 2.0-8.0 | 0.25-0.55 | 3.0 | low | moderate-slow | Compost. |

Source: *Country Journal*, July 1979, p54-55.

worthwhile using all the hay you can get, young or old, which should be shredded if possible. Sawdust can be used but should be in fine sprinklings and it should not be packed too heavily or it could prevent aeration of the heap. Weeds, used in green form are a valuable addition as they extract different elements in the soil. It may not be desirable to include seed-laden weeds as these usually do not completely decompose. If the compost is made properly the bacterial action and heat can destroy live seeds. The more weed seeds the more manure or other organic nitrogen should be used for proper heating.

Although compost contains nutrients its greatest benefit is improving the soil physical characteristics. Therefore it should not be considered a complete fertilizer. In most cases, additional fertilization will be necessary to achieve maximum plant growth and production. An excellent review of compost materials is presented in Table 4.30.

### Sheet Composting

Instead of composting in heaps, organic farmers spread compost material directly on the soil, in raw form, then turn them under to compost. This method works for large scale gardens and fields.

Green manure cover crops, spoiled hay, cannery wastes, seaweed, spent hops, woodchips or sludge have been used. Left over the winter, the material will be greatly decayed by spring. The addition of natural mineral fertilizers will facilitate the release of nutrients. The sheet composting idea has been used successfully for many years in many variations. It is still the most efficient, most practical way to improve tilth and productivity of a large acreage.

### Mulches

Plant residues applied to the soil surface or left on the surface from the preceding crop are used to reduce soil loss and weed growth and to conserve moisture. However, mulches in the garden area can prevent warm up of soils early in the spring. Mulches can be added later in the season when soils have been warmed.

## SOIL COMPACTION

Soil compaction refers to the disruption and reduction of large pores within the soil. Penetration into the soil by tillage implements and crop roots is restricted. The continuity of the pores from the surface of the soil to deeper depths is disrupted, and thus, the transmission of water through the soil and gases between the crop's roots and atmosphere is reduced.

Soil compaction, as illustrated in Figure 4.14, can be determined by visual observation. Cloddy seedbeds, increased surface water ponding, loss of granular soil structure and reduced pore spaces through the soil are good visual indicators of compaction. Probing soil layers with a knife can indicate compacted zones and help determine where rooting or water flow is curtailed. Depressed crops, stunted or contorted root systems, a tendency to show yellow colouring especially during or after large rainfalls indicate poor aeration and compacted soils. In addition root rot diseases may increase with surface compaction. A reduction in yield is the most significant effect of soil compaction. With less root penetration into the soil, root mass is reduced and a plant's ability to take up nutrients is reduced. Plant roots remain closer to the surface and are therefore more susceptible to drought.

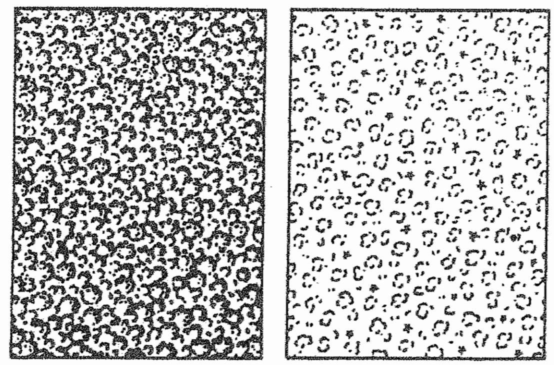
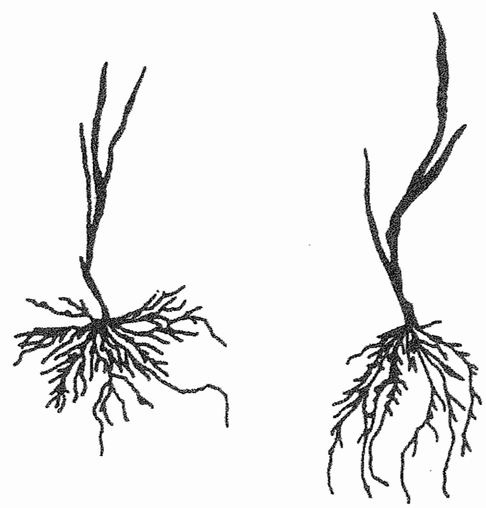



Figure 4.14 Compacted/Uncompacted Soil Conditions
*a) Pore Spaces*




*b) Root Growth*

Source: *Soil Compaction, A Review of its Origin and Characteristics*, Factsheet, B.C. Ministry of Agriculture and Fisheries, Agdex 518, 1990.

As a result of a reduction in the size and macropores in the soil, the reduction in aeration, microbial activity is reduced. Thus the breakdown of organic matter and fertilizer into useable plant nutrients is reduced affecting soil fertility.

Compacted soils also tend to warm more slowly, resulting in slower crop growth and higher moisture contents. The potential for surface erosion is increased. From a soil moisture stand point, all soils should be considered as capable of being compacted. In general, soils with fine textures (silt and clay), low organic matter content, high porosity and weakly aggregated structure are more susceptible to serious compaction.

### *Tillage*

Tillage breaks apart soil aggregates, permitting soil particles to move apart or be forced closer together. However, in wet soils, tillage does not break apart soil particles but rather smears the particles together to form clods. A greater amount of compaction occurs when the soil is wet. Tillage exerts downward pressure on the soil layers below the surface leading to deep compaction and the formation of "plow pans". Thin layer smearing by implements, such as moldboard plows or rotovators, plus compaction from the contact pressure of the tractor wheel can cause deep tillage related compaction. The greater the contact pressure and/or the more frequently the vehicle passes over a particular area in the field, the greater and deeper will be the resulting compaction. The effects of wheel traffic on soil is shown in Figure 4.15. The dotted and dashed lines indicate zones of compaction.

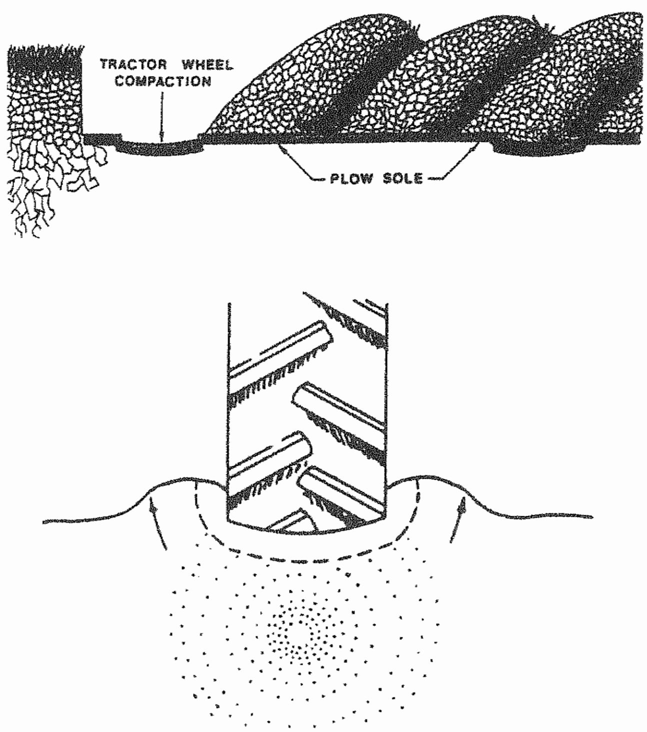



Figure 4.15: Wheel Compaction

Source: *Soil Compaction, A Review of its Origin and Characteristics*, Factsheet, B.C. Ministry of Agriculture and Fisheries, Agdex 518, 1990.

### *Minimum Tillage*

When a layer of soil is loosened by tillage, it expands or fluffs up. For example, if a soil is plowed 9 in. deep, the layer of soil fluffs up to 11 or more in. With this increased amount of pore space the soil can hold more rainwater than it could before plowing. Repeated tillage reduces this temporary water storage capacity. Growers who formerly cultivated a row crop three times now do so once or not at all. On soils that do not crack, one cultivation may be helpful to increase water penetration. Care has to be taken to keep tillage to a minimum and to continue to build up the organic matter and humus content of the soil.

Other cultural practices that lead to compaction are leaving soil surfaces exposed, organic matter depletion and the use of excessive fertilizers or pesticides. The exposure of soils due to lack of vegetative or trash cover allows raindrop impact to disperse soil particles leading to "puddling" of the soil and ultimately compaction. In reduced tillage and forage production systems soil structure is improved by microbial decomposition of organic residues. Excessive use of fertilizers or pesticides could be harmful to those organisms. This can lead to a decline in the breakdown of organic matter into products that bind soil aggregates.

## SOIL CHARACTERISTICS AND IRRIGATION

### *Soil Moisture Deficits*

The moisture stored in the soil at any given time may be computed from climatological records where the evapotranspiration demand is subtracted from precipitation. Evapotranspiration is the loss of water from the soil, both by evaporation and by transpiration of the plants growing thereon. Temperature is a broad integrator of the balance of radiation exchanges, air movement, humidity and other meteorological factors affecting evapotranspiration.

Soil Moisture deficits have been determined for each farming community in the Yukon, as shown in Table 4.31.

Table 4.31 Soil Moisture Deficits (mm)

| Station | (mm) |
|---|---|
| Watson Lake | 121 |
| Whitehorse | 218 |
| Haines Junction | 31 |
| Mayo | 167 |
| Dawson | 167 |

* Soil Moisture deficit = precipitation – potential evaporation.

Source: *Agriculture Potential and Climate Change in the Yukon*, *C. Tarnocai, C. Smith, D. Beckman, Agriculture Canada, 1988.*

This means that Whitehorse has the greatest soil moisture deficit for the areas where agricultural production occurs. Dawson and Mayo have similar deficit levels. Haines Junction has the least soil moisture deficit.

Soil moisture deficits may be improved with the addition of organic matter to coarse textured mineral soils to increase moisture storage capacity.

### Soil Depth

The depth of soil is important not only because of the amount of available water it stores but also for determining the rooting depth of plants. Shallow soils have low available water capacities and require more frequent irrigations than moderately deep or deep soils. Water and plant nutrients losses due to leaching are more likely to occur as a result of applying more water than the soils are capable of holding. The amount of water stored by a soil increases with silt and clay content. Soil depth classes are indicated in Table 4.32.

Table 4.32 Soil Depth Classes

| Depth (cm) | Class |
|---|---|
| 0-25 | Very shallow |
| 25-50 | Shallow |
| 50-100 | Moderately deep |
| 100-150 | Deep |

### Soil Water Movement

Water movement in soils is by saturated flow or unsaturated flow. Saturated flow takes place when the soil pores in the wettest portion of the soil are completely filled or saturated with water. Unsaturated flow occurs when the pores in even the wettest soil zones are only partially filled with water.

The flow under saturated conditions is determined by two major factors, the hydraulic force driving the water through the soil and the ease with which the soil pores permit water movement.

This is expressed mathematically as $V = kf$ where V is the total volume of water moved per unit of time, "f" is the water moving force and "k" is the hydraulic conductivity of the soil. The hydraulic conductivity of a saturated soil is essentially constant being dependent on the size and configuration of the soil pores. The volume of water moving down the soil profile will depend upon this force as well as the hydraulic conductivity of the soil.

The liquid flow of water takes place from one soil zone to another. The direction of flow is from a zone of higher to one of lower moisture potential. During and immediately following a heavy rain or irrigation application, pores in the upper soil zones are often entirely filled with water.

After rainfall ceases or irrigation ceases there will be a continued downward movement of the water, responding to the downward hydraulic gradient. After a day or so this rapid downward movement will become negligible. The soil is then to be said is at **field capacity**. Water has moved out of the larger pores and its place has been taken by air.

In unsaturated field conditions, most of the soil pores are filled with air and pockets of water are not in touch with each other. Water movement is very slow compared to that in saturated conditions.

In Figure 4.16, the comparative rates of irrigation water movement into a sandy loam soil (left)and a clay loam soil (right) are shown. Most of the water movement was likely by saturated flow. The water moved much more rapidly in a downward direction in the sandy loam than in the clay loam. soil movement in sand, in a downward direction. Thus sandy layers as well as compact silt and clay influence downward moisture movement in soils.

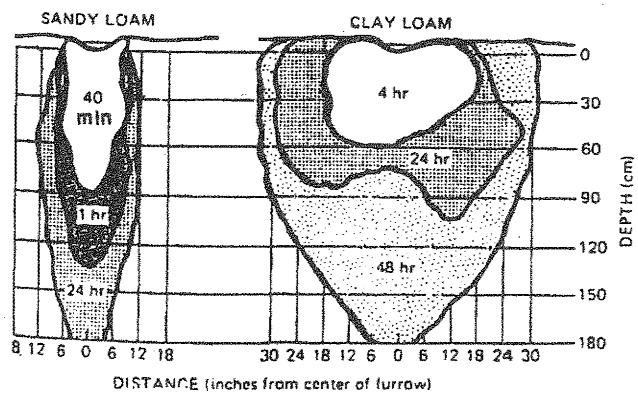



Figure 4.16 Rates of Irrigation Movement

In soils, capillary action causes water movement which brings moisture from the water table upward to the soil surface. This upward movement is different in soils of different textures and structures. As shown in Figure 4.17, there is a rapid rise in sand, but height obtained is moderate. The pores of a loam soil are more favorable for movement than those in compact clay.

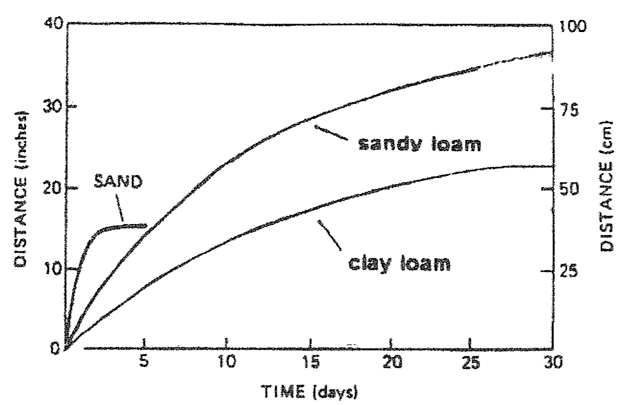



Figure 4.17 Upward Movement of Moisture in Different Soils

Highwater tables favor upward capillary flow of water promoting surface evaporation and salt accumulation. This means that the salts will not move downward, but will build up in the upper root zone, where salinity is most detrimental to growth.

### Availability of Water

Knowing the capacity of your soil to retain available water is essential for efficient irrigation. Excess irrigation can lead to saturated soils while not enough irrigation can lead to unsaturated soils and plants may wilt from lack of water. The texture, structure and organic matter content all influence the quantity of water a given soil can supply to growing plants. However, texture is the over riding factor in determining the moisture holding capacity of a mineral soil. The amount of water plants absorb is determined by a number of plant, climatic and soil variables. Rooting habits, basic drought tolerance, and stage and rate of growth are all important factors.

All other factors being equal, deep soils will have greater available moisture than will shallow ones because of greater volume of soil material. Soil stratification or layering will influence markedly the available water and its movement in the soil. Hardpans or impervious layers slow down drastically the rate of movement of water and also influence unfavorably the penetration of plant roots. Sandy layers also act as barriers to soil moisture movement from the finer textured layers above. Movement through a sandy layer is very slow at intermediate and high tensions. The overlying layers must be less than saturated before movement in the sand will take place.

The classes of soil-water availability to plants and drainage characteristics are illustrated in Figure 4.18.

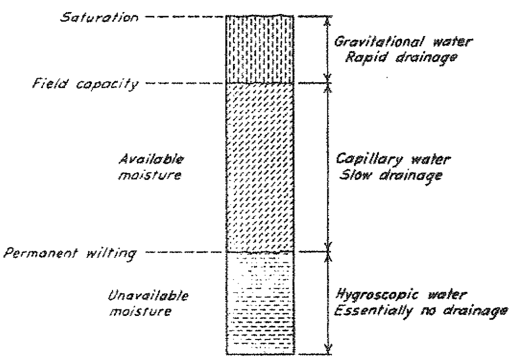



Figure 4.18 Availability of Soil Water

Source: *Irrigation Principles and Practices*, 4th edition, V.E. Hansen, J. Wiley & Sons, p 47.

> *"The moisture deficit in Yukon is particularly evident in May, June and July in most communities. The driest areas generally are the Carcross valley and the Whitehorse and Takhini valley areas."*
>
> - *Yukon Garden Handbook*, D. Filteau, Agriculture Branch, Renewable Resources, 1987.
>
> *"The average amount of available moisture in the soils in the Takhini and Dezadeash Valleys is about 3 inches in the upper two feet of soil; each 6 inch layer of soil contains about 0.75 inch of available moisture. A 0.75 inch application of water wets the soil to a depth of 6 inches, 1.5 inches of water wets soil to 12 inches, 2.2 inches to 18 inches, 2.9 inches to 24 inches, 4.4 inches to 36" and 6.0 inches of water wets soil to 48 inches."*
>
> *"It is therefore recommended that, in the Yukon, irrigation begin in the first week of June for grass crops, in mid June for cereal crops and in the last week in June for hoed or vegetable crops.*
>
> *"The need for irrigation in the area is shown by a 341 per cent increase in the yield of marketable potatoes from an application of 3.5 inches of water at planting time at the Experimental Farm, Mile 1019."*
>
> - *Reconnaissance Soil Survey of the Takhini and Dezadeash Valleys in the Yukon Territory*, J.H. Day, Canadian Dept. of Agriculture, 1962.

## Field Capacity

When gravitational water has been removed, the moisture content of the soil is called field capacity. The concept of field capacity is extremely useful in arriving at the amount of water available in the soil for plant use. Most of the gravitational water drains through the soil before it can be used consumptively by plants. In practice, field capacity is determined 2 days after irrigation, and thereby defines a specific point on the moisture-content time curve. A soil will come to field capacity more quickly when an active crop is growing than when no roots are removing water from the soil.

Soil moisture tension is normally between 1/10 (sandy soils) and 1/3 atmospheres (clay soils) when the soil is at field capacity.

Special precaution should be taken not to overlook the water consumptively used by the crop between the time of irrigation and the time at which field capacity is determined. Observing the decrease in moisture by making moisture determinations at different times after irrigation is valuable in understanding and properly interpreting the field capacities of the soil.

## Wilting Coefficient

A considerable amount of water in soils is not available to higher plants. As the soil drys out plants will show the effects of reduced soil moisture, by wilting. The soil moisture content when the plants permanently wilt is called the permanent wilting point or the wilting coefficient. The permanent wilting point is at the lower end of the available moisture range. The water remaining in the soil is found in the smallest of micropores and around individual soil particles. A plant will wilt when it is no longer able to extract sufficient moisture from the soil to meet its water needs. Temporary wilting will occur in many crops on a hot windy day, but the plants will recover in the cooler portion of the day. The soil moisture must be maintained considerably above the wilting coefficient if plants are to grow and function normally.

Soil water suction is measured in "bars". Available water is defined as the moisture retained in the soil between the field capacity (0.1 to 0.2 bar) and the permanent wilting coefficient (15 bars). This is said to be useable by plants. Water held at tensions greater than 15 bars is said to be unavailable to plants. In most soils, optimal growth of plants takes place when the soil moisture content is kept near the field capacity or at least does not approach the wilting point. (See Irrigation Practices – Crop Management)

In Figure 4.19, the general relationship between soil moisture and soil texture is indicated. The wilting coefficient increases as the texture becomes heavier. The field capacity increases until we reach the silt loams, then levels off. The available moisture holding capacity of a soil increases with heavier textures.

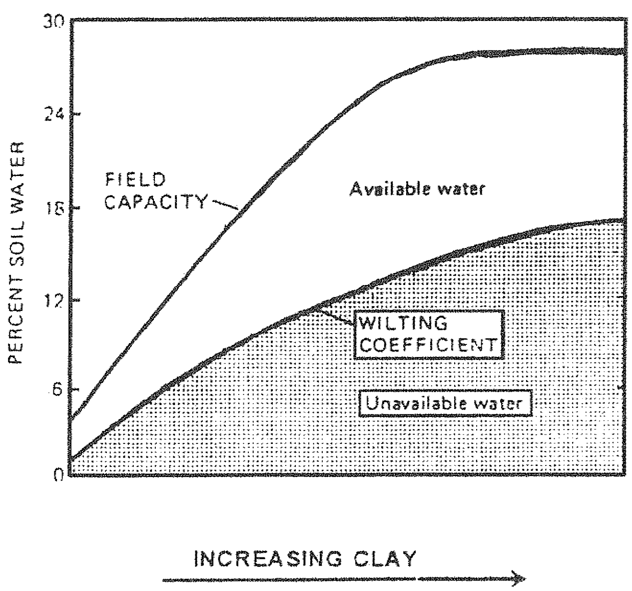



Figure 4.19 Relationship Between Soil Moisture and Soil Texture

The presence of salts in soils, either from applied fertilizers or as naturally occurring compounds can influence soil water uptake thereby increasing the wilting coefficient.

### *Soil Permeability*

Soil permeability is the rate at which the soil transmits water and air. It is determined by the size and shape of the pore spaces and the density of the soil which is in turn dependent on soil structure and texture. Soil permeability classes are based on the percolation rate of water through a soil profile measured in cm/hour.

Table 4.33 Soil Permeability Classes

| Percolation Rate cm/hour | Class |
|---|---|
| Less than 0.15 | Very slow |
| 0.15 - 0.51 | Slow |
| 0.51 - 1.50 | Moderately Slow |
| 1.50 - 5.10 | Moderate |
| 5.10 - 16.0 | Moderately rapid |
| 16.0 - 50.8 | Rapid |
| Greater than 50.8 | Very Rapid |

Very rapid or rapid permeability are characteristic of coarse textured soils. Excessive irrigation of a soil having rapid or very rapid permeability can result in excessive leaching of plant nutrients with possible contamination of the ground water. At the other extreme a soil having slow or very slow permeability has restricted downward movement of water which results in a waterlogged condition, in which the pore spaces are filled with water. Some soils have a dense layer beneath the surface which restricts free drainage of water and creates a perched water table. A soil with a slow or very slow permeability rate of less than 0.2 inches/hour is considered a poor risk for irrigation.

### *Soil Moisture Evaluation by the "Feel" Method*

Generally, to estimate soil moisture by the feel method:

- loose or hard soil means dry
- pliable soils means soil is not adequately irrigated
- soil forms a ball when squeezing a handful very firmly means it needs irrigation very soon
- sticky, slick or plastic soil means good for now check again in a few days.

A shovel will serve to obtain a soil sample from a shallow soil or when a shallow rooted crop is grown. A soil auger if available can be used and is necessary for obtaining samples from greater depths in the root zone. (See Taking the Soil Sample). Squeeze the soil sample in the hand and compare its behavior with the soils listed in Table 4.34 or 4.35.

Table 4.34 indicates how to determine percent available moisture in your soil by the "feel" method. Available moisture is the amount of moisture the soil holds for plant use between field capacity and wilting point. Soil moisture should be maintained above 50 field capacity for optimum growth. Moisture levels are indicated in millimeters per metre (mm/m).

Table 4.34 Soil Moisture Evaluation by "Feel" Method

| Percent of AM* in Soil | Sandy Loam | Loam | Clay Loam |
|---|---|---|---|
| 0 –24 | Dry, loose, flows through fingers. 0–35 mm/m** | Powdery, sometimes slightly crusted, but easily broken down into powdery condition. 0–45 mm/m | Hard, baked, cracked, difficult to break down into powdery condition. 0–50 mm/m |
| 25–49 | Appears to be dry, will not form a ball with pressure. 35–70 mm/m | Somewhat crumbly but will hold together from pressure. 45–90 mm/m | Somewhat pliable, will ball under pressure. 50–100 mm/m |
| 50–74 | Tends to ball under pressure but seldom holds together when bounced in the hand. 70–100 mm/m. | Forms a ball somewhat plastic, will slick slightly with pressure. 90–135 mm/m. | Forms a ball, will ribbon out between thumb and forefinger, has a slick feeling. 100–150 mm/m |
| 75–99 | Forms a weak ball, breaks easily when bounced in the hand, will not slick. 100–140 mm/m | Forms a ball, very pliable, slicks readily. 135–180 mm/m | Easily ribbons out between thumb and forefinger, has a slick feeling. 150–200 mm/m |
| 100 (field capacity) | Upon squeezing no free water appears on soil, but wet outline of ball is left on hand, soil will stick to thumb when rolled between thumb and forefinger. 140 mm/m | Same as sandy loam. 180 mm/m | Same as sandy loam. 200 mm/m |

Take a sample from each 0.25 m (1 ft) depth soil; squeeze handful of soil firmly.

- If the soil is too dry to form a ball, it contains less than one-quarter of the available moisture.* Reduced yield can be expected.
- If the soil is moist enough to form a ball but is somewhat crumbly when squeezed between thumb and palm, it contains about one-half of the available moisture. *Time to irrigate.*
- Note the durable ball when the soil has three-quarters of the available moisture. It is somewhat plastic and will stick with pressure when squeezed between forefinger and thumb. *Check again in a few days.*
- If the soil will ribbon out or if it sticks to the thumb when rolled between forefinger and thumb, it has between 75 and 100 percent available moisture.*

* Available moisture is the amount of moisture the soil holds for plant use between field capacity and wilting point.

** To change mm/m to in./ft, put a decimal point two places to the left, e.g., 35 mm/m approximates 0.35 in./ft.

**Note:** To change mm/m to in./ft, put a decimal point two places to the left, eg. 35 mm/m approximates 0.35 in./ft.

Source: *Commercial Raspberry Production in the Prairies*, A Grower's *Guide*, Second Edition, S. Williams, University of Saskatchewan, 1991, 1994.

Table 4.35 is another helpful chart to determine amount of readily available moisture remaining for the plant.

## Table 4.35 Practical Soil Moisture Interpretation Chart

Source: *Knott's Handbook for Vegetable Growers*, Third Edition, O. Lorenz & D. Maynard, J.Wiley & Sons, 1988, pg 170-171.

**PRACTICAL SOIL-MOISTURE INTERPRETATION CHART**

| Amount of Readily Available Moisture Remaining for the Plant | Sand (gritty when moist, almost like beach sand) | Sandy Loam (gritty when moist; dirties fingers; contains some silt and clay) | Clay Loam (sticky and plastic when moist) | Clay (very sticky when moist; behaves like modeling clay) |
|---|---|---|---|---|
| *Close to 0%.* Little or no moisture available | Dry, loose, single-grained; flows through fingers | Dry, loose, flows through fingers | Dry clods that break down into powdery condition | Hard, baked, cracked surface. Hard clods difficult to break, sometimes has loose crumbs on surface |
| *50% or less.* Approaching time to irrigate | Still appears to be dry; will not form a ball with pressure | Still appears to be dry; will not form a ball | Somewhat crumbly, but will hold together with pressure | Somewhat pliable; will ball under pressure |
| *50%–75%.* Enough available moisture | Same as sand under 50% | Tends to ball under pressure but seldom will hold together | Forms a ball, somewhat plastic; will sometimes stick slightly with pressure | Forms a ball; will ribbon out between thumb and forefinger |
| *75% to field capacity.* Plenty of available moisture | Tends to stick together slightly, sometimes forms a very weak ball under pressure | Forms weak ball, breaks easily, will not become slick | Forms a ball and is very pliable; becomes slick readily if high in clay | Easily ribbons out between fingers; feels slick |
| *At field capacity.* Soil will not hold any more water (after draining) | Upon squeezing, no free water appears; but moisture is left on hand | Same as sand | Same as sand | Same as sand |
| *Above field capacity.* Unless water drains out, soil will be water-logged | Free water appears when soil is bounced in hand | Free water will be released with kneading | Can squeeze out free water | Puddles and free water form on surface |

# CROP MANAGEMENT

In this section, the various management practices which affect all crop types are discussed. This includes field preparation to planting and maintenance. Plant nutrition, green manure crops, crop rotations, irrigation practices, pest and weed control are all important aspects in the proper management of crops.

## FIELD PREPARATION

After the stages of land clearing are completed the final preparation prior to planting should include:

1. Clean up the remaining sticks and tree debris to leave the field as clear of debris as possible. This includes pulling roots, and removing sticks, to the side of the field.

   It is best to burn wood debris in strips near shelterbelts or areas not to be planted to sensitive crops. Wood ashes contain between 1-10% Potash or Potassium ($K_2O$). Conifers have about 6% and broadleaf trees about 10% $K_2O$.

*Keep burn piles off of the growing area, especially if it is used for vegetables. I found that my vegetables did not do well in the spot that was used as a burn area for wood debris etc. High potassium levels causing toxicity were suspected for poor growth of vegetables crops (cauliflower,cabbages).*

-Whitehorse Producer

2. Take soil samples and send for analysis (See Taking the Soil Sample – Soil Management)
3. Determine which areas will be used for specific crops.The best locations within the field, for air drainage and minimum frost potential, should be used for sensitive crops. Vegetable crops need the best seedbed and the land should be worked more carefully. Cereals and forages can be planted on a rougher seedbed.
4. Use equipment to produce a loose or friable seedbed for each crop.

   Land should be tilled as close to planting date as possible. Many producers till one to two days before planting to conserve soil moisture. The field should be properly prepared to the depth of tuber or root development of the future crop. Soil should be thoroughly worked, particularly for root and tuber crops.

*After clearing, my field was disced and wood debris removed. I then rototilled several times in a criss cross pattern with a tractor drawn rototiller to 6-8" depth. This provided a good seedbed.*

-Whitehorse Producer

*I try not to over-till my soil as it will loose its structure. It seems to turn into flour if you rototill too much. Minimum tillage seems to be a good idea for our soils.*

-Whitehorse Producer

*I plant as soon as possible after field preparation to conserve soil moisture and keep soils from blowing away in the wind. Soils are usually dry at spring planting time in Whitehorse and moisture loss and wind erosion can be a problem.*

-Whitehorse Producer

## SEED QUALITY

Use good quality seed of adapted varieties. Classes of seeds includes Breeder seed, Select Seed, Foundation Seed, Registered Seed and Certified Seed. Breeder and Select seed are produced by plant breeders. Foundation, Registered and Certified Seeds are graded by a person authorized by Agriculture Canada.

Use Canada Certified No.1 seed as an assurance, of both varietal adaption and quality, as well as weed content. In most cases, seed available from local suppliers is certified seed. Stapled on the bag is usually a blue tag that tells you the crop type, the variety, and the Seed Sealing Lot No., including the date. Some weed seeds may be in certified seed as it is allowed in certain percentages. Seed companies will indicate this percentage when asked.

Common 1. seed is usually ordered when it is a crop type that is not available in a certified variety. For example in the YCDP trials meadow foxtail and red clover were Common No 1. Seed. Common No. 1. seed is available from specific producers, usually at a cheaper price than certified seed but can contain additional weed seed and seeds of other crops. Do not skimp on seed quality!

Certified grass, legume and cereal seed can be purchased from a number of seed companies. Local suppliers usually acquire their seed from Alberta seed companies. A number of Yukon producers have acquired seed from producers in the Peace river area, including Peace alfalfa and Carlton bromegrass. Varieties developed in Alaska are more difficult to obtain but can be purchased from seed producers in the

Palmer, Alaska area. The Plant Material Centre in Palmer can be contacted for information. A plant certificate is required, indicating that it is weed and disease free, for access across the border. In ordering seed from Alaska from the Plant Material Centre for the YCDP trials, there were no problems with ordering grass seed, ie. Polar brome but for the cereal seeds, (Weal barley, Toral oats, Ingal and Nogal wheat) a duty and special certificate from the Canada Customs Office was required.

### Germination Test

Certified seed for forages and cereals will usually have a good germination percentage. This is not always indicated on the seed bag however, but can be assumed to be in the range of 85% and above. Usually on vegetable packages, ie. from Stokes Seed Co. the germination percentage is indicated. Seed with germination of less than 85-90% should have increased seeding rates. If you have any old or otherwise suspect seed a germination test should be given to determine viability.

Count out a representative amount of seeds, in lots of 10 to determine their viability. If you have less seeds, take 10, or if more, use lots of 10, and if you have a 25 kg bag take 100 seeds. Set them between wet pieces of paper towel and keep this wet until germination takes place. Keep them at an air temperature of 20°C (70°F) to 26.6°C (80°F). Some gardeners recommend rolling the up the seeds in a wet paper towel, and then rolling the rolled paper towel in a water soaked terry-cloth towel, placing this in a plastic bag and sealing it. In four to ten days, when the seeds have had time to sprout, carefully unwrap the paper towels and count the number of seeds sprouted per total number and thus determine germination %. Darkness, moisture, air and heat are all required for proper seed sprouting.

> *" No matter how well we fertilize, irrigate and control pests, we will never produce a 100 percent crop if we don't do a 100 percent job of planting."*
>
> - Alberta Horticulturalist

## PLANTING METHODS

Prior to planting there are many considerations including:

1. Determine the crops you plan to grow: for sale and for "on farm consumption", including crops used for farm animals and family needs.
2. Order all seed, preferably certified, to ensure less weeds and good germination. Determine seeding rates for each crop and amounts required.
3. Order all fertilizer, to meet soil test recommendations. Determine the different fertilizer application rates and amounts for each area and crop type.

   Fertilizer can be ordered from local suppliers that is specifically mixed for your requirements or as separate bags of N, P and K fertilizer. For large amounts, order prior to spring before road weight bans go into effect.
4. Have a good plan of your various plantings and the approximate planting schedule.

Planting techniques are indicated for specific crop types in the forage, cereal and vegetable production sections.

### Soil Temperatures for Germination

Soil temperatures should be determined before planting to get the best germination. These can be determined using special soil thermometers available from garden supply centers or a standard thermometer. Place the bulb or sensing part of the thermometer at the intended seeding depth and when it ceases to rise take a reading. It is recommended to take a reading twice daily, once in the morning and afternoon; the average daily soil temperature usually lies between the two readings. Spring seeding should not begin until soil temperature at seeding depth reaches or exceeds the required minimum indicated in Table 5.1.

Table 5.1 Germination Temperatures for Field Crops

| | Minimum (°C) | Preferred (°C) |
|---|---|---|
| **Cereals** | | |
| wheat | 4 | 20 |
| barley | 3-5 | 20 |
| oats | 5 | 20-24 |
| **Forages** | | |
| alfalfa | 1 | 26 |
| red clover | 3 | 25 |
| sweet clover | 1 | 18-25 |
| fescues | 3 | 13-18 |
| timothy | 4 | 18-22 |
| **Vegetables** | | |
| bean | 8-10 | 16-30 |
| beet | 4 | 10-30 |
| cabbage | 4 | 7-35 |
| carrot | 4 | 7-30 |
| cauliflower | 4 | 7-30 |
| celery | 4 | 15-21 |
| swiss chard | 4 | 10-30 |
| corn | 10 | 16-32 |
| cucumber | 16 | 16-35 |
| eggplant | 16 | 24-32 |
| lettuce | 2 | 4-27 |
| onion | 2 | 10-35 |
| parsley | 4 | 10-30 |
| parsnip | 2 | 10-21 |
| peas | 4 | 4-24 |
| pepper | 16 | 18-35 |
| pumpkin | 16 | 21-32 |
| rutabaga | 4 | 16-30 |
| radish | 4 | 7-32 |
| spinach | 2 | 7-24 |

Table 5.1 Cont.

| | Minimum (°C) | Preferred (°C) |
|---|---|---|
| squash | 16 | 21-35 |
| tomato | 10 | 16-30 |

Source: *Soil Temperature for Germination*, Alberta Agriculture, Agdex 590-1, 1980.

## PLANT NUTRITION

### *Functions of Essential Elements for Plant Growth*

16 elements are generally considered essential for growth of higher plants. These are divided into the macronutrients or macroelements, those required in relatively large quantities and the micronutrients or minor elements needed in considerably smaller quantities. (See Fertilizer Composition and Application in the Soil Management section). The functions of these essential elements in the plant are listed below:

MACRONUTRIENTS

1. **Carbon (C):** Constituent of all organic compounds found in plants.
2. **Hydrogen (H):** Constituent of all organic compounds of which carbon is a constituent. Important in cation exchange in plant-soil relations.
3. **Oxygen (O):** Constituent of many organic compounds in plants. Also involved in anion exchange between roots and the soil medium and in aerobic respiration.
4. **Nitrogen (N):** Part of a large number of necessary organic compounds, including amino acids, proteins, coenzymes, nucleic acids and chlorophyll. Nitrogen affects plant growth in many ways at once.
5. **Phosphorous (P):** Part of many important organic compounds including sugar phosphates, ATP, nucleic acid, phospolipids and certain coenzymes. It is associated with many of the same vital functions in the cell as nitrogen and is necessary for the metabolism of carbohydrates, fats, and proteins and for respiration.
6. **Potassium (K):** Acts as a coenzyme or activator for many enzymes. It is essential for the synthesis of carbohydrates and proteins, regulation of cell hydration, and catalysis of reactions. High potassium levels are required for protein synthesis.
7. **Sulphur (S):** Sulphur is a component of some amino acids, vitamins and coenzymes, and seems to be related to chlorophyll formation, although it is not a constituent of the chlorophyll molecule. Incorporated into several organic compounds including amino acids and proteins.
8. **Magnesium (Mg):** Magnesium is a structural component of chlorophyll and is a cofactor of many enzymes involved in carbohydrate synthesis. It is an essential part of the chlorophyll molecule, is required for activation of many enzymes and is necessary to maintain ribosome structure.
9. **Calcium (Ca):** Calcium regulates the permeability of membranes, forms salts with pectins in cell walls as calcium pectate, which cements together primary walls of adjacent cells. It influences the activity of several enzymes active in the meristematic cells of the growing points. It is required to maintain membrane integrity and is part of the enzyme amylase.

MICRONUTRIENTS

10. **Iron (Fe):** Iron has a catalytic role in chlorophyll synthesis and is an essential part in photosynthesis and activates many enzymes of respiration and other oxidation systems.
11. **Chlorine (Cl):** Required for photosynthesis where it acts as an enzyme activator during the production of oxygen from water.
12. **Manganese (Mn):** Activates one or more enzymes in fatty acid synthesis, the enzymes responsible for DNA and RNA formation. It is a cofactor of many enzymes involved in cellular respiration, photosynthesis and nitrogen metabolism. It participates directly in the photosynthetic production of oxygen from water and may be involved in chlorophyll formation.
13. **Boron (B):** Regulates the transport of sugars through plant cell membranes, the rate of cell development, cell division and the synthesis of proteins. It appears to be involved in the translocation of sugars, and in utilization of calcium in cell wall formation. It may be required for carbohydrate transport in the phloem.
14. **Zinc (Zn):** Found in plants mostly as a component of several enzymes involved in auxin synthesis and in oxidation of carbohydrates. Required for the formation of the hormone indoleacetic acid and activation of enzymes.
15. **Copper (Cu):** Acts as an electron carrier and is a cofactor in many oxidative enzymes. Involved in photosynthesis and may be involved in $N_2$ fixation.
16. **Molybdenum (Mo):** Acts as an electron carrier and is a part of the enzyme that reduces nitrate to nitrite(ammonium) and is also essential for $N_2$ fixation.

### *Factors Controlling the Growth of Plants*

The essential elements are only one of the environmental factors which influence the growth of plants. The factors include light, mechanical support, heat, air, water, nutrients and absence of pests and disease. Plant growth is dependent upon a favorable combination of these factors and growth of plants can be reduced if any of the factors is out of balance. The factor which is least optimum will determine the level of crop production. This principle, known as the "principle of limiting factors", is stated as - the level of crop production can be no greater than that allowed by the most limiting of the essential growth factors.

As shown in Figure 5.1, the level of water represents the level of crop production. In the left barrel, nitrogen is the most limiting. Though the other elements are present in more adequate amounts crop production can be no higher than that allowed by the nitrogen. In the right barrel, nitrogen has been added and crop production is raised until it is controlled by the next most limiting factor, potassium.

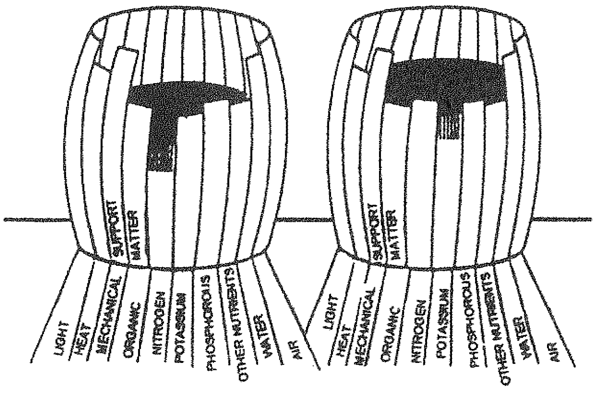



Figure 5.1 Principles of Limiting Factors

### *Plant Uptake of Nutrients*

The macronutrients, such as nitrogen, phosphorous, and potassium, are usually much less toxic when present in excess. The micronutrients, such as zinc, copper, manganese, molybdenum or boron are required only in trace amounts and could be toxic if applied in excess. Care should be taken that the right amount of a minor element is applied.

Crop uptake of nutrients can be restricted by soil and climatic conditions including:

- low soil moisture
- very high soil moisture
- poor aeration due to compaction and/or excessive moisture
- low soil temperature
- high levels of lime or salt in the root zone
- nutrient imbalances

#### Nitrogen

Nitrogen has the greatest impact on plant growth and quality as it is necessary for protein synthesis in plants. Protein is made of 16% nitrogen. A deficiency of nitrogen affects plant growth in many ways.

#### Sources of Nitrogen

Crops contain nitrogen from:

1. rainwater (very minor)
2. breakdown of soil organic matter
3. breakdown of manure or plowdowns of green manures, crop residues etc.
4. fertilizer (usually urea or ammonium nitrate)
5. nitrogen fixation by legumes

Most nitrogen is taken up in the nitrate ion form which is made of one part nitrogen and 3 parts oxygen with a negative electrical charge ($NO_3^-$). To a lesser extent nitrogen is taken up as an ammonium ion which is nitrogen attached to 4 hydrogens with a positive charge ($NH_4^+$). Ammonium becomes ammonia($NH_3$) and simply evaporates if there is no water to dissolve it. This happens in dry soils. Manure also releases ammonia gas. When plants take up water they take up the dissolved nitrate and ammonium. More than half the energy of plants is spent converting the nitrates to ammonium, which comes from the photosynthesis. If photosynthesis is reduced by cool/dark conditions or by hot/dry conditions than less nitrate will be converted and it will accumulate in the plant. Ammonium does not accumulate in the plant. (See Nitrates in Frozen Crops – Cereal Production and Nitrogen Cycle – Soil Management).

As nitrate is very mobile in the soil, the soil test nitrate measured in the fall is expected to be an index of available nitrogen levels in terms of yield attainable under optimum conditions. At average levels we can expect the best efficiency from both applied and residual nitrogen. A low soil test nitrogen does not necessarily indicate low soil fertility but a high soil test nitrate usually reflects poor soil nitrogen management. If the levels are very high (say over 80 lbs/acre) there is some likelihood that a lot of nitrate could be lost in early spring and could become a wasted resource. A very low result may indicate nitrogen immobilization, that is nitrogen tied up in organic matter and made unavailable to the plant.

With a balance amount of nitrogen in the soil the plant grows sturdily and matures rapidly, its foliage a rich dark green colour. Too little nitrogen and too much can cause weak growth. Excess nitrogen can also lower the plants resistance to disease as the nitrogen has displaced other nutrients it needs. Flavour, colour and food value also decline.

#### Phosphorous

Phosphorous is the major nutrient that helps plants grow strong roots, and aids in fruit development and a greater resistance to diseases. It is especially important for root crops like carrots, beets potatoes and turnips.

#### Potassium

Potassium helps to condition the whole plant to help it grow, bear fruit and increase resistance to disease. Approximately 50 lbs/acre K is adequate for most field crops.

### *Nutrient Requirement/Crop Type*

#### Macronutrients

Each crop type has a different nutrient requirement, for N, P, K, and S. The other macronutrients, including magnesium and calcium are not usually required as fertilizer applications in the Yukon. In Table 5.2 are estimates of macronutrients used by grains, vegetables, and forages to produce the particular yields:

Table 5.2 Macronutrients Used By Crops

| Crop | Yields | Pounds/Acre Used By Crops | | | |
|---|---|---|---|---|---|
| | | NITROGEN | PHOSPHOROUS | POTASSIUM | SULFUR |
| **Grains** | | | | | |
| Wheat | 40 bu/ac | 85 | 29 | 64 | 10 |
| Barley | 60 bu/ac | 90 | 30 | 87 | 11 |
| Oats | 80 bu/ac | 84 | 34 | 75 | 15 |

Table 5.2 Cont.

| Crop | Yields | Pounds/Acre Used By Crops | | | |
|---|---|---|---|---|---|
| | | NITROGEN | PHOSPHOROUS | POTASSIUM | SULFUR |
| **Vegetables** | | | | | |
| Potatoes | 15 tons/ac | 151 | 68 | 212 | 12 |
| **Forages** | | | | | |
| Grass | 3 tons/ac | 110 | 30 | 145 | 9 |
| Alfalfa | 4 tons/ac | 240 | 40 | 190 | 20 |

Source: Western Canada Fertilizer Association -Fact Sheet - 1986

### Micronutrients

Of the micronutrients boron is the most frequently deficient in the Yukon, with only a few incidences of soils requiring copper or zinc. Legumes have higher boron requirements. Alfalfa can stand higher concentrations than clovers. Cereals and grasses are also sensitive to high boron levels. (See Fertilizer Composition and Application – Soil Management). Overfertilizing or concentrating boron near seedling crops can result in toxic levels.

## *Plant Nutrient Disorders*

A nutritional disorder is a malfunction in the physiology of a plant resulting in abnormal growth caused by either a deficiency or excess of mineral elements. The disorder is expressed by the plant in the form of symptoms. A deficiency or excess of each essential element causes distinct plant symptoms which can be used to identify the disorder.

Elements are grouped into those that are mobile and those that are immobile. Mobile elements include: magnesium, phosphorous, potassium, zinc and nitrogen. Mobile elements can be translocated. They move from the older leaves to the younger and actively growing portions of the plant. The first symptoms will appear on the lower leaves and older growth of the plant and then to new growth.

The immobile elements include: calcium, iron, sulphur, boron, copper and manganese. These cannot be translocated and remain in the older leaves where they were first deposited. The first signs of deficiency appear in the upper young leaves of the plant.

The presence of lower than normal amounts of the most essential elements usually results in a reduction in growth and yield. When the deficiency is greater than a certain critical level, however, the plants develop acute or chronic symptoms and may even die.

It is important to detect a nutritional disorder early to prevent further affects on plant tissue. The disorders of one element often upset the plant's ability to accumulate other elements and shortly two or more elements become deficient simultaneously, the composite picture or syndrome expressed by the symptoms may resemble no given deficiency. Under such conditions it becomes dificult to virtually impossible to determine visually which elements are lacking.

### Determining Plant Symptoms

When observing a disorder determine what plant part or organ is affected:

1. Does it occur on the lower older leaves or the younger upper leaves ?
2. Are the symptoms, on the stem, growing point of the plant or the fruit or flowers ?
3. What is the appearance of the whole plant ?
4. Is the plant dwarfed, deformed or branched excessively ?
5. Is the tissue chlorotic (yellow) or necrotic – (brown) ?

The following terms are used to describe plant symptoms:

**Localized:** Symptoms limited to one area of plant or leaf

**Generalized:** Symptoms not limited to one area but spread generally over entire plant or leaf

**Drying:** Necrosis – scorched , dry peppery appearance

**Marginal:** Clorosis or necrosis on margins of the leaves initially usually spreads inward as symptom progresses

**Interveinal chlorosis:** Chlorisis (yellowing) between veins of leaves only

**Mottling:** Irregular spotted surface – blotchy pattern of indistinct light and dark areas, often associated with virus diseases.

**Spots:** Discolored area with distinct boundaries adjacent to normal tissue

**Color of leaf undersides:** Often a particular coloration occurs mostly or entirely on the lower surface of the leaves, eg. phosphorous deficiency – purple coloration of leaf undersides.

**Cupping:** Leaf margins or tips may cup or bend upward or downward, eg. copper deficiency – margins of leaves turn into a tube; potassium deficiency – margins of leaves curl inward.

**Checkered (reticulate):** Pattern of small veins of leaves remaining green while interveinal tissue yellows – manganese deficiency.

**Brittle tissue:** Leaves, petioles, stems may lack flexibility, break off easily when touched – calcium or boron deficiency.

**Soft tissue:** Leaves very soft, easily damaged – nitrogen excess

**Dieback:** Leaves or growing point dies rapidly and dries out – boron or calcium deficiencies.

**Stunting:** Plant shorter than normal

**Spindly:** Growth of stem and leaf petioles very thin and succulent

A key for determining nutrient deficiencies is presented in Table 5.3. Toxicity symptoms are not included in this key. To use this key, first decide if the deficiency is on the older leaves (A) versus affects on younger upper leaves (AA); then (B) versus (BB), (C) versus (CC) and (D) versus (DD) and so on. The final choice is iron deficiency.

## Table 5.3 A Key to Mineral Deficiency Symptoms

*Symptoms* — *Element Deficient*

A. Older or lower leaves of plant mostly affected; effects localized or generalized.
- B. Effects mostly *generalized* over whole plant: more or less drying or firing of lower leaves.
  - C. Plant *light* green; lower leaves yellow, drying to light brown color; stalks short and slender if element is deficient in later stages of growth ................................. Nitrogen
  - CC. Plant *dark* green, often developing red and purple colors; lower leaves sometimes yellow, drying to greenish brown or black color; stalks short and slender if element is deficient in later stages of growth .......... Phosphorus
- BB. Effects mostly *localized*; mottling or chlorosis with or without spots of dead tissue on lower leaves; little or no drying up of lower leaves.
  - C. Mottled or chlorotic leaves, typically may redden, as with cotton; sometimes with dead spots; tips and margins turned or cupped upward; stalks slender ........ Magnesium
  - CC. Mottled or chlorotic leaves with large or small spots of dead tissue
    - D. Spots of dead tissue small, usually at tips and between veins, more marked at margins of leaves: stalks slender ........... Potassium
    - DD. Spots generalized, rapidly enlarging, generally involving areas between veins and eventually involving secondary and even primary veins; leaves thick; stalks with shortened internodes ..................... Zinc

AA. Newer or bud leaves affected; symptoms localized.
- B. Terminal bud *dies*, following appearance of distortions at tips or bases of young leaves.
  - C. Young leaves of terminal bud at first typically hooked, finally dying back at tips and margins, so that later growth is characterized by a cut-out appearance at these points; stalk finally dies at terminal bud. Calcium
  - CC. Young leaves of terminal bud becoming light green at bases, with final breakdown here; in later growth, leaves become twisted, stalk finally dies back at terminal bud ........ Boron
- BB. Terminal bud commonly *remains alive*; wilting or chlorosis of younger or bud leaves with or without spots of dead tissue, veins light or dark green.
  - C. Young leaves permanently *wilted* (wither-tip effect) without spotting or marked chlorosis; twig or stalk just below tip and seedhead often unable to stand erect in later stages when shortage is acute ...................... Copper
  - CC. Young leaves *not wilted*; chlorosis present with or without spots of dead tissue scattered over the leaf.
    - D. *Spots of dead tissue* scattered over the leaf; smallest veins tend to remain green, producing a checkered or reticulating effect ................................. Manganese
    - DD. *Dead spots not commonly present*; chlorosis may or may not involve veins, making them light or dark green in color.
      - E. Young leaves with veins and tissue between veins *light green* in color .......... Sulfur
      - EE. Young leaves chlorotic, principal veins *typically green*; stalks short and slender ................................... Iron

Source: *Hydroponic Food Production*, H. Resh, Woodbridge Press Publishing Co., 1985, pg 48-49.

## Table 5.4 A Key To Nutrient Deficiency Symptoms

| Nutrient | Plant Symptoms | Occurrence |
|---|---|---|
| *Primary* | | |
| Nitrogen | Stems are thin, erect, and hard. Leaves are smaller than normal, pale green or yellow; lower leaves are affected first, but all leaves may be deficient in severe cases. Plants grow slowly | Excessive leaching on light soils |
| Phosphorus | Stems are thin and shortened. Leaves develop purple coloration, first on undersides and later throughout. Plants grow slowly, and maturity is delayed | On acid soils. Temporary deficiencies on cold, wet soils |
| Potassium | Older leaves develop gray or tan areas near the margins. Eventually a scorch around the entire leaf margin may occur. Chlorotic areas may develop throughout leaf | Excessive leaching on light soils |
| *Secondary and Micronutrients* | | |
| Boron | Growing points die; stems are shortened and hard; leaves are distorted. Specific deficiencies include browning of cauliflower, cracked stem of celery, blackheart of beet, and internal browning of turnip | On soils with a pH above 6.8 or on crops with a high boron requirement |
| Calcium | Stem elongation restricted by death of the growing point. Root tips die and root growth is restricted. Specific deficiencies include blossom-end rot of tomato, brownheart of escarole, celery blackheart, and carrot cavity spot | On acid soils, following leaching rains, on soils with very high potassium levels, or on very dry soils |
| Copper | Yellowing of leaves. Leaves may become elongated. Onion bulbs are soft, with thin, pale-yellow scales | Most cases of copper deficiency occur on muck or peat soils |
| Iron | Distinct yellow or white areas appear between the veins on the youngest leaves | On soils with a pH above 6.8 |
| Magnesium | Initially, older leaves show yellowing between the veins; continued deficiency causes younger leaves to become affected. Older leaves may fall with prolonged deficiency | On acid soils, on soils with very high potassium levels, or on very light soils subject to leaching |
| Manganese | Yellow mottled areas, not as intense as with iron deficiency, appear on the youngest leaves. This finally results in an overall pale appearance. In beet, foliage becomes densely red. Onion and corn show narrow stripping of yellow | On soils with a pH above 6.7 |
| Molybdenum | Pale, distorted, very narrow leaves with some interveinal yellowing on older leaves. Whiptail of cauliflower; small, open, loose curds | On very acid soils |
| Zinc | Small reddish-brown spots on cotyledon leaves of bean. Green and yellow broad stripping at base of leaves of corn. Interveinal yellowing with marginal burning on beet | On wet soils in early spring; often related to heavy phosphorus fertilization |

Source: *Knott's Handbook for Vegetable Growers*, O. Lorenz, D. Maynard, J. Wiley & Sons, 1988, pg 162.

In Table 5.4, the symptoms of plants for each nutrient deficiency and their occurrence is indicated.

Deficiency and toxicity symptoms for the essential elements are listed below:

1. **Nitrogen**

   *Deficiency Symptoms:* Growth is restricted and plants are generally yellow (chlorotic) from lack of chlorophyll, especially older leaves. Younger leaves remain green longer. Stems, petioles and lower leaf surfaces can turn purple.

   *Toxicity Symptoms:* Plants usually dark green in colour with abundant foliage but usually with a restricted root system. Potatoes form only small tubers and flowering and seed production can be retarded.

2. **Phosphorous**

   *Deficiency:* Plants are stunted and often a dark bluish green colour with purple tints. Anthocyanin pigments may accumulate. Symptoms occur first in the more mature lower leaves. These sometimes turn light bronze with purple or brown spots. The shoots are short and thin, upright and spindly. Plant maturity is often delayed.

   *Toxicity:* No primary symptoms yet noted. Sometimes copper and zinc deficiency occurs in the presence of excess phosphorous.

3. **Potassium**

   *Deficiency:* Symptoms are first visible on the lower leaves. Leaves are initially chlorotic but soon scattered dark necrotic lesions (dead areas) develop. Older leaves may show slight chlorosis with typical browning of the tips, scorching of the margins and many brown spots usually near the margins. In some plants the tips and margins of the leaves die first. Plants have thin shoots which can develop weak stalks and are easily lodged. In severe cases dieback can occur.

   *Toxicity:* Usually not excessively absorbed by plants. Excess potassium may lead to magnesium deficiency and possible manganese, zinc or iron deficiency.

4. **Sulphur**

   *Deficiency:* Not often encountered. General yellowing of the leaves, usually first visible in the younger leaves. Interveinal tissue is light green.

   *Toxicity:* Reduction in growth and leaf size. Leaf symptoms often absent or poorly defined. Sometimes interveinal yellowing or leaf burning.

5. **Magnesium**

   *Deficiency:* First the older leaves and then the younger ones become mottled or chlorotic, followed by reddening and sometimes appearance or necrotic spots. The tips and margins of leaves may turn upward so that leaves appear cupped. Defoliation may follow. Interveinal chlorosis first develops on the older leaves. The chlorosis may start at the leaf margins or tip and progress inward interveinally. Deficiencies of magnesium result in reduced chlorophyll synthesis.

   *Toxicity:* Little is known about visual symptoms.

6. **Calcium**

   *Deficiency:* Bud development is inhibited and root tips often die. Young leaves become distorted, with the tips hooked back and the margins curled and irregular with spotted or necrotic areas. Often the leaves are irregular in shape and ragged, with brown scorching or spotting. Terminal buds finally die. The plants have poor, bare root systems.

   *Toxicity:* No consistent visual symptoms. Usually associated with excess carbonate.

7. **Iron**

   *Deficiency:* Young leaves become severely chlorotic but their main veins remain characteristically green. This interveinal chlorosis is pronounced, usually a bright yellow.

   *Toxicity:* Not often evident in natural conditions. Has been observed after the application of foliar sprays where it appears as necrotic spots.

8. **Chlorine**

   *Deficiency:* Wilted leaves which then become chlorotic and necrotic, eventually becoming a bronze colour. Roots become stunted and thickened near tips.

   *Toxicity:* Burning or firing of leaf tip or margins. Bronzing, yellowing, and sometimes chlorosis. Reduced leaf size and lower growth rate also occur.

9. **Manganese**

   *Deficiency:* Initial symptoms are often interveinal chlorosis on younger or older leaves depending on the species. Necrotic lesions and leaf shedding can develop later.

   *Toxicity:* Sometimes chlorosis, uneven chlorophyll distribution and iron deficiency. Reduction in growth.

10. **Boron**

    *Deficiency:* Symptoms vary with species. The bases of young leaves of terminal buds become light green and finally break down. Stems and leaves may become distorted. Fruit or other large storage tissues may crack on the surface or rot in the centre such as in "heart rot" of beets. Stem and root apical meristems often die. Root tips often become swollen and discolored. Leaves show various symptoms including thickening, brittleness, curling, wilting and chlorotic spotting.

    *Toxicity:* Yellowing of leaf tip followed by progressive necrosis of the leaf beginning at tip or margins and proceeding toward midrib.

11. **Zinc**

    *Deficiency:* Reduction in interlode length and leaf size. Leaf margins are often distorted or puckered. Leaves show interveinal chlorosis. Later they become necrotic and show purple pigmentation. Few and small leaves, short internodes and low fruit production are common.

    *Toxicity:* Excess zinc commonly produces iron chlorosis in plants.

12. Copper

*Deficiency:* Natural deficiency is rare. Young leaves often become dark green and twisted or misshapen, often with necrotic spots. Leaves may fail to unroll and tend to appear wilted. Heading is reduced and the heads are dwarfed and distorted. The tips of young leaves of cereals wither and their margins become chlorotic.

*Toxicity:* Reduced growth followed by symptoms of iron chlorosis, stunting, reduced branching, thickening and abnormal darkening of rootlets.

13. **Molybdenum**

*Deficiency:* Often interveinal chlorosis developing first on older or midstem leaves, then progressing to the youngest (similar to nitrogen deficiency). Growing tips may become distorted and die. Sometimes marginal scorching or cupping of leaves.

*Toxicity:* Rarely observed. Tomato leaves turn golden yellow, cauliflower seedlings turn bright purple.

Source: *Hydroponic Food Production*, H. Resh, Woodbridge Press,1985, pg 51-53.

Besides the essential elements the following list of other possible disorders should be checked: insect damage, parasitic diseases, pesticide damage, pollution damage, water stress, light and temperature injury.

Plant losses can result from the application of chemicals, such as fungicides, insecticides, herbicides or fertilizer at too high concentrations or on plants sensitive to them. Spray injury resulting in leaf burn can be common.

### Haines Junction Mile 1019 1945-1952 Research Report

*"As each block of new land is brought under crop the variability in soil response was noted. This could not be explained on the basis of soil structure but was assumed to be associated with plant food content, as distinct from texture. In all original sowings this characteristic showed up as circumscribed, irregular patches of anaemic growth, bordered by lush stands of healthy grain. There was no gradual merging of the two varying growths but invariably a sharp division. The cause may be a lack of bacterial activity, since most of this patchiness disappeared with subsequent cultural operations."*

### Tolerance of Plants To Soil pH

Pasture grasses, many legumes, small grains, field crops and a large number of vegetables are included in a broadly tolerant group for pH from 5.8 to slightly above 7.0. (See pH Affects Nutrient Availability – Soil Management and YCDP Lime Trial – Cereal Production).

### Tolerance of Plants to Salinity

Crops vary in their tolerance to salinity. With an increase in soil salinity plant roots extract water less easily from the soil solution. This situation is more critical under hot and dry than under humid conditions. The same crop can respond differently, according to the stages of development and conditions. Barley can be quite sensitive during the early stages of growth but able to withstand high levels of salinity at maturity. Under dry conditions slender wheatgrass can be more salt tolerant than tall wheat grass. (See Electrical Conductivity – Soil Management)

**Sensitive:** Beans, Red Clover, Alsike Clover, Timothy, Carrot, Onion, Radish, Lettuce, Pepper, Cauliflower, Peas, Strawberries, Raspberries

**Moderately Sensitive:** Wheat, Barley (During germination & early crop growth) Alfalfa, Brome, Meadow fescue, Intermediate Wheatgrass, Potato, Cabbage, Squash

**Moderately Tolerant:** Wheat, Oats, Fall Rye, Barley (forage), Sweet Clover, Crested Wheatgrass, Perennial Ryegrass, Tall Fescue, Spinach, Cucumber, Brocolli, Beets

**Tolerant:** Barley (During late stages of crop growth), Altai wild ryegrass, Russian wild ryegrass, Slender wheatgrass, Tall wheatgrass

### Salinity Research Project

The Yukon Soil Survey Unit of Agriculture Canada undertook this project which was funded by National Soil Conservation Program and Green Plan. The site was located near Mile 10 of the Mayo Road, north of Whitehorse. Four plots were located on areas with different salinity levels, ranging from non-saline to extremely saline. Soil tests completed at Norwest Labs, after breaking the plots in 1990, revealed the Electrical Conductivity (E.C.) levels, as indicated in Table 5.5. The extremely saline plot is part of an "alkali flat" area where there is white surface crusts of salts.

Table 5.5 Salinity Research Project – E.C. Levels (1990)

| | Electrical Conductivity (E.C) | (0-6" depth) |
|---|---|---|
| Non - Saline | 1.9 mS/cm | (Caution) |
| Slightly Saline | 4.9 mS/cm | (Toxic) |
| Moderately Saline | 8.9 mS/cm | (Very Toxic) |
| Extremely Saline | 14.3 mS/cm | (Very Toxic) |

Soil analysis for E.C. and pH levels was completed from 1991-1993 and are indicated in Table 5.6. E.C. values are in mmhos/cm and pH levels are for 0-6" soil depth. Millimhos/cm (mmhos/cm) and microsiemens per cm (mS/cm) are equivalent E.C. units of measure.

Table 5.6 Salinity Research Project – E.C. and pH Levels (1991-1993).

| | EC | | pH |
|---|---|---|---|
| | Mean | Range | |
| Non Saline | 0.98 | 0.37 - 1.55 | 6.0 - 7.65 |
| Slightly Saline | 1.53 | 0.82 - 2.86 | 7.2 - 7.7 |
| Moderately Saline | 11.42 | 6.96 - 17.3 | 7.5 - 8.1 |
| Extremely Saline | 19.30 | 15.0 - 23.6 | 8.0 - 8.2 |

Crops of bromegrass, alkaligrass, Altai wild rye, oats, and alfalfa were tested over three years. The best growth was on the Non-Saline plot with the Slightly Saline second, where all crops performed satisfactorily. In the Moderately Saline plot germination and growth of the crops was poor and the alfalfa eventually died out. In the Extremely Saline plot, the alkaligrass performed the best, brome was sparse and the other crops did not produce. At the end of three years, plant growth was primarily salt tolerant grasses and weeds.

## GREEN MANURE CROPS

Green manure crops, including legumes are grown for the purpose of "plowing down" to improve soil quality and structure.

### *Inoculation of Legumes*

Legumes, when properly inoculated, have the ability to take nitrogen from the atmosphere and fix it on their roots in a form that can be utilized by subsequent crops. (See Nitrogen Fixation & Plowdowns – Soil Management). Soil bacteria called rhizobia infect the root hairs of the plants causing the development of nodule clusters. The bacteria obtain carbohydrates from the plant and the growing legumes secures nitrogen in the ammonium form ($NH_4$) from the bacteria. The appropriate strain of Rhizobium must be used for specific legume crops:

Table 5.7 Rhizobium Species for Legumes

| Legume | Rhizobium Species |
|---|---|
| Alfalfa | Rhizobium meliloti - A' Culture |
| Sweet Clover | |
| Alsike/Red Clover | Rhizobium trifolii - B' Culture |
| White Clover | |
| Field Peas | Rhizobium leguminosarum - C' Culture |
| Lentils, Garden Peas | |
| FlatPeas, Common Vetch | |
| Bird's-Foot Trefoil | Rhizobium loti |
| Field/Garden Beans | Rhizobium phaseoli |
| Sainfoin | Sainfoin rhizobia - F'Culture |

An innoculant is made of one or more strains of Rhizobium species in a carrier material that supports and protects the live bacteria. The most common carrier is finely ground peat moss with some lime added to prevent acidity. Usually the innoculant is in a powdered form in packages which are sufficient to innoculant 25 kg of seed. Usually the innoculant provided by Yukon suppliers is made by Nitragin. The expiry date is noted on the package. Fresh innoculant is the best but may still be effective after the expiry date, if it has been stored properly in a refrigerator or a cool place, avoiding dryness and the harmful rays of the sun.

The utilization of a sticking agent with the Rhizobium innoculant is highly recommended. An adhesive sticker material, containing a sugar in solution, increases the effectiveness of inoculation and serves to feed the rhizobia and to protect them from drying conditions. Rhizobium can be adhered to the seed using a commercial sticking agent, such as Nitracoat, milk, or soft-drinks. A 10% solution of corn syrup, table sugar or honey in water can also be used.

> *" For the Brome plots, two distinct linear relationships exist between yield and surface EC. Yields tend to be highest but most variable where EC values are < 5 mmhos/cm. Above 5 mmohs/cm yields are much less but span a less range at any given EC value. Between EC values of 5 and 25, yields drop to 20% of the non saline yields."*
>
> *" Brome shows a consistent sensitivity to salinity throughout the range of conductivity values observed in this study. Productivity of Brome is affected at EC values more than 5 mmohs/cm. Alfalfa was the most sensitive crop to salinity in this study and appears to be unsuited as a treatment cover for salt affected soils. Oats, wildrye and alkaligrass do well on moderately saline conditions. It is unlikely that soils as saline as that represented in the extremely saline plot would ever be cultivated but for instances of reclamation the alkaligrass appears to be superior to any of the other domestic grasses as a suitable cover species."*
>
> *" Capability/suitability assessment systems like that used presently in the Yukon should probably place EC values >8 into classes considered unsuitable for development and those with EC values between 4 and 8 as marginal for development."*
>
> -Source: *Effect of Soil Salinity on Yukon Forage Crops, for Green Plan*, C.A.S. Smith, Yukon Land Resources Unit, Agriculture Canada, 1994.

In the YCDP trials, a cement mixer was used to mix the innoculant with the seed. Usually a 25 kg bag of seed was separated into two batches, the sticking agent was applied in sufficient quantities to coat all the seed, the innoculant sprinkled on and the batch thoroughly mixed so that all seed was uniformly covered (black). The sticking agent used included milk, or soft drinks. The seed was then spread on tarps to dry. This should be done out of sunlight if possible but if it has to be done outside, cover the seed with a tarp to keep out the suns rays.

Seed should be inoculated as close to planting time as possible for maximum benefits. Commercially pre-inoculated is available on the market, though this is more expensive and the viability of the rhizobia decreases once it is applied to the seed.

### *Planting of Legumes*

Plant legumes shortly after inoculation to maximize response. Avoid exposure of the inoculated seed to sunlight as much as possible. Soil conditions at the time of seeding are important for the survival of the applied Rhizobia. Inoculated seed should be sown into a moist seedbed on cool days if possible. Any adverse soil condition or environmental stress that effects plant growth is likely to slow down the nitrogen fixation process. Rhizobia do not survive well in dry and very warm soil. If legumes are planted under soil stress conditions, then 3-5 times the usual amount of innoculant should be applied. Warm, moist conditions are the best for fast germination and survival of the rhizobia to produce successful nodulation.

Every precaution should be taken to insure that the right quantity of good quality, well inoculated seed be placed at the right depth in a well prepared seed bed, where quick and even germination is promoted. The most effective implements for placing the desired seeding rate of small seeds at precise depth include the double disk press drill, the double disk end wheel drill, the hoe press drill, Brillion seeder, and broadcast spreader. Small seeded legumes (alfalfa,clover) should be placed shallowly at 1/2-3/4" depth (1-2cm) and for larger seeded legumes (field peas,lentils) placed at 1-3" depth.

Legumes also use soil and fertilizer nitrogen. Where soil nutrient deficiencies occur, apply adequate fertilizer nutrients to promote vigorous growth, high yields of dry matter and good $N_2$ fixation. Calcium and magnesium are also very important in the nodulation and $N_2$ fixation processes. The amount of nitrogen fixed also differs for different legume species and varieties.

Legumes used for green manure crops are divided into three types:

**Perennial Legumes:** Alfalfa, Red clover, Alsike clover, Sainfoin clover, Birdsfoot trefoil
**Biennial Legumes:** Yellow sweetclover, White sweetclover
**Grain Legumes:** Fababeans, Field Peas, Lentils, Beans

Most grain legumes can obtain between 50 and 80% of their total nitrogen requirements from fixation. Grain legumes generally have smaller and shorter-lived effects on soil quality than perennial legumes. Their shallow root system and short growth period limit the amounts of $N_2$ fixed.

The greatest benefits are generally obtained with the deep-rooted perennial legumes, grown as green manures on soils with poor structure and low organic matter, where annual rainfall is sufficient for good growth.

The amount of N fixed for inoculated legumes grown in southern Alberta is indicated in Table 5.8.

Table 5.8 Nitrogen Fixed By Inoculated Legumes

| Legume | Plant-N Derived from atmosphere | N-Fixed Symbiotically kg/ha | lbs/ac |
|---|---|---|---|
| Alfalfa | 80 | 300 | 267 |
| Sweetclover | 90 | 250 | 223 |
| Fababeans | 90 | 300 | 267 |
| Field Peas | 80 | 200 | 178 |
| Lentils | 80 | 150 | 134 |
| Fieldbeans | 50 | 70 | 62 |

Source: Alberta Forage Seed Council, Edmonton Alberta.

### *Yukon Experience*

Different green manure crops have been planted by farmers and have been studied in research trials. Oats, field peas, clovers and alfalfa have been planted most often.

Experience has indicated that the following seeding rates of green manure crops provide a good crop growth for a "plowdown":

**Broadcast:** Oats - 125 lbs/acre
Clover & Alfalfa - 30 lbs/acre
Field Peas - 200-300 lbs/acre
Mix - Oats (100 lbs/acre) & Field Peas (200lbs/acre)
**Seed Drill:** Reduce to 1/2 of broadcast rate

At the Agricultural Branch research plots, a mixture of oats and peas proved to yield high amounts of plant material. Indianhead Lentils were also planted as a soil improvement crop. This provided for ground cover but the amount of organic matter produced was less than field peas or oats. Two varieties of field peas were tried, Tipu and Sirus, both suitable as a soil improvement crop.

Over 26 farmers completed plowdowns as part of the National Soil Conservation Program, with 287 acres planted to an cover crop of oats, barley, winter rye, alfalfa or field peas. Field peas were the most commonly planted with several farmers seeding an oats and field peas mixture. The oats help to keep the field peas standing to provide for an easier incorporation. Alfalfa was tried by one farmer to reduce salinity problems.

Fababeans were tested in the 1986 Crop Development trials. These grew adequately in most regions but were found to be frost sensitive. Protein content was 13-17%.

Alsike and red clover as well as field peas were planted in the Yukon Crop Development trials as a plowdown. Nodules were better formed on the field peas than clover plants. When a pinkish colour is present in the nodule then nitrogen fixation is occurring.

### Alaska Research

Research in Alaska with N-fixation of forage legumes has found that field peas fixed 80-170 kg/ha of N, fababeans fixed 70-230 kg/ha and clovers from 40-110 kg/ha. N-fixed was higher in Fairbanks than Delta Junction. In Delta Junction, fababeans interseeded with oats fixed approximately 50 kg of N per ha.

Source: *Seedling-Year Growth and Nitrogen Accumulation by N-fertilized and Non-fertilized Legumes in Interior Alaska*, S.D. Sparow, M. Panciera, Proceeding of 1st Circumpolar Agricultural Conference, Whitehorse, YT, 1994.

## CROP ROTATIONS

Crop rotations are a recommended management practice to improve soil fertility and plant growth. In addition, crop rotations are effective for weed and pest control.

### *BC Experience*

Experimental Farms were established in Smithers in 1938 and at Prince George in the early 1940's. Some of the very first research included a number of crop sequence and crop rotation experiments.

Conclusions from these studies include:

1. Fallow is not a necessary practice.
2. A good rule of thumb in designing rotations is to maintain a ratio of two years legume/forage crops to one year grain crops.
3. The main farm rotation at Smithers consisted of 2 years grain and 4 years hay.
4. Seeding too deeply was the most common cause of failure in forage stand establishment. Depth of seeding 1/4 to 1/2 inch is optimum depth.
5. Fall ploughing at depths of 4-7 inches and disced in the spring gave the highest oat yields over a six year period (1945-1951).
6. Barnyard manure applied and incorporated in the first year of a three year rotation (oats,alsike, barley) resulted in a good response in the oats and in the subsequent hay crop. When the alsike clover was used as a green manure crop there was little effect on the yields of the grain crop. Harvesting the alsike for hay would have provided for greater total returns.
7. Yields of oats following a legume or grass-legume mixture were considerably higher than oats after a grain crop.
8. Continuous grain crops declined sharply in the third year. Cereal crops should not be grown for more than two successive years.
9. Various organic materials markedly improved the soil structure, dry matter yields, moisture holding capacity, and aggregation of particles increased.
10. The organic matter and soil structure can be improved and yields can be greatly increased by including forage crops, especially legumes, in the rotation.
11. All available manure and trash cover should be utilized , preferably by incorporating and mixing with the surface soil. A soil structure that will allow water penetration and aeration must be maintained.
12. Plow shallow – no deeper than subsequent tillage operations, so that all manure and crop residues can be reached and mixed with the surface soil by discs and cultivators.
13. Cultivation operations should be as few as possible in order to maintain good structure.
14. Summerfallowing or even partial fallowing should be avoided if possible except under special circumstances. Ploughing should be done in the fall and any additional cultivation should be left until the spring.

Source: *Crop Rotations in Central BC*, BC Ministry of Agriculture & Fisheries Factsheet, Agdex 515.

## IRRIGATION PRACTICES

Water management should be viewed as a priority in agricultural production and development. Irrigation scheduling should be such that only sufficient water is added to the soil to meet the daily requirements of a growing crop. More than this is excess water which is wasted through evaporation from the soil surface and through drainage. Water wastage should be reduced to a minimum.

When determining the suitability of land for irrigation, a more thorough evaluation of the soil, drainage and topography are needed than when planning for dryland farming. Soil structure and texture, permeability and drainage are all important factors for successful irrigation. (See Soil Characteristics & Irrigation – Soil Management).

The topography is important in designing the conveyance system, application and control of water, and control of erosion. Areas with slopes greater than 5 percent are generally considered unsuited for irrigation of crops but in some cases may be suitable for pastures. Permissible slopes vary with soil conditions and with the method of water application. For example, sandy soils usually erode more readily with surface irrigation systems than with trickle systems.

### *Regulations for Irrigation*

In the Yukon, irrigation systems which require the use of a fishbearing water source and require more than 300 cubic metres of water daily are of concern to government agencies.

#### Yukon Waters Act

Pursuant to the Yukon Waters Act, the Yukon Waters Regulations, require any agricultural operation pumping more than 300 cubic metres of water per day to acquire a water use license from the Water Board, Northern Affairs Program.

Schedule X of the Yukon Waters Act indicates the licensing criteria for agricultural undertakings involving irrigation operations. Producers usually require a class "B" License from the Water Board. This involves:

1. The use of 300 or more cubic metres per day: (This does not include water taken from an artificial reservoir with no natural inflow.)

2. Construction of a watercourse 5 m or more cubic metres in width at ordinary water mark at point of construction.
3. Construction of a permanent structure where there is no potential for significant adverse environmental effects.
4. Diversions of water courses that are 2 or more metres in width at ordinary highwater mark at point of diversion.
5. Construction of a dam, maximum height 8 m or higher or where there is less than 60,000 cubic metres of water is stored or a hazard is posed.

If you fall within this category then you must fill out an application, available from the Yukon Territorial Waterboard which requires that you give a complete description of your operation, including:

1. Site description (Location, Area to be Irrigated, Topography, Soil Type)
2. Crops to be Irrigated (Indicate Area for each Crop).
3. Water Use (Water Source, Rate of Withdrawal*, Duration of use in hours per day)
4. Method of Water withdrawal (Pump, Gravity Feed)
5. Method of Conveying Water (Ditch, Pipeline)
6. Description of Irrigation system. (Sprinklers, Trickle, Surface Flooding)
   - Pump ( Type, Size,)
   - Pipes ( Diameter, Length)
   - Sprinkler Heads (Size, Numbers)
   - Water Gates (Type, Size)
7. Description of water use structures (Height, Length, Ditches, Storage Ponds etc.)
8. List fertilizers, pesticides or herbicides that will be used:
9. How will Excess Water be Disposed
10. What adjacent lands or water users may be affected by water use.

* The rate of withdrawal should be indicated in cubic metres per minute per day. A sketch is also required showing the general layout and components of your irrigation system.

The application then goes through a Level I Environmental Assessment Review Process (EARP) screening. Department of Fisheries and Oceans (DFO) and First Nations as well as other government agencies review it. It is also advertised to the public. In some cases a public hearing may be required to resolve issues. Water Resources (Northern Affairs Program) reviews the application attaching particular conditions for operation. They administer the licenses and conduct inspections. Fees are also required for water used per cubic metre/day.

**Fisheries Act**

If the water source is fish bearing, the Fisheries Act (Section 30) requires that all intake systems must have a proper type and size of screen to prevent fish from going through the system.

No person can undertake work that alters or disrupts fish habitat without authorization (Section 35).

1. The screen material shall be either aluminum, stainless steel brass or bronze.
2. Screen mesh size is 8 strands per lineal inch, square mesh wire cloth with .028 or .025 inch diameter wire. Clear openings of the screen (the space between strands shall not exceed 0.10 inch (3/32" or 3mm). The open screen area shall not be less than 50% of total screen area.
3. A minimum unobstructed screen area of 10 square ft shall be provided for each cubic foot per second * entering the intake.
   * One cubic foot per second = 450 U.S gallons per minute = 375 Imperial gallons per minute
4. The screen shall be readily accessible for cleaning and inspection
5. The design and location of the intake structure shall be such that a uniform flow distribution is maintained throughout the total screen area.

Contact Habitat Management at DFO to determine the proper design of your screen and intake setup.

Source: Dept. of Fisheries and Oceans Fact Sheet

***Types of Irrigation Systems***

Selection of the irrigation system requires consideration of the crops to be grown, financial position, soil type, topography and quantity of water available. Irrigation can take place by a variety of methods, namely subirrigation, surface or gravity, overhead or sprinkler, and trickle irrigation. Whatever the type of system certain crop and land characteristics are important in designing an irrigation system. Most important of these are crop root zone depth, intake rate, waterholding capacity and crop water use rate.

The shape and size of the area, crops to be irrigated and natural rainfall levels are factors used to determine the size and type of equipment and the water supply requirements. The distance and lift from the source must be considered to determine operating pressure.

**A general rule is that vegetables will need about 1 in. of water per week from rain or supplemental irrigation in order to grow vigorously. In arid regions, about 2 in/week is required. In general, vegetable crops are more sensitive to water deficiency during emergence, flowering and early yield formation than they are during early (vegetative) and late growth periods (ripening).**

The frequency of irrigation will depend on the rate of water use and the total supply of available moisture reached by the roots. When applying water use enough o bring the soil moisture content of the effective rooting zone up to field capacity. This is the quantity of water that the soil will hold against the pull of gravity. (See Soil Characteristics & Irrigation – Soil Management).

## Sprinkler Irrigation

Technological improvements in sprinkler irrigation have made it the most popular method or irrigation. The most common sprinkler systems include the handmove or solid set, the sideroll or wheelmove, the travelling gun, the centre-pivot and linear or lateral move. Sprinkler irrigation systems provide better control in the application of small amounts of water, ease of converting from dryland to irrigation farming and reduced labour requirement, especially with the automated systems. The disadvantages are high operating costs, uneven distribution of water when wind speeds exceed 15km/hr and the necessity to irrigate almost continuously through the growing season.

**Hand Move System** This is generally the cheapest type of system but it requires considerable labour. Many variations of layout are possible and it can be used on irregularly shaped fields and rolling terrain. Big guns can be set up on the mainline or set up on lateral lines off the main line. Small sprinklers can be also be set up on the laterals. For each irrigation set or area to be irrigated the system is set up, then drained, dismantled and moved to a new location.

**Solid Set System** When a hand move system is permanently set up, usually for a whole field or particular area, it is then called a solid set system. The solid set may be buried or an above ground pipeline system, with enough sprinklers to irrigate the entire area. This involves high costs and these systems are generally limited to very intensive uses such as orchards, vineyards, greenhouses, market gardens, and lawns. The main advantages are convenience, control and reduced labour to irrigate. These systems are usually designed to use low flow medium pressure sprinklers. Only a portion of the system is normally operated at one time. The operating laterals are usually scattered throughout the irrigated area. Control may be manual or automatic.

**Sideroll or Wheelmove System** The lateral is set up perpendicular to the mainline. Alignment may be difficult to maintain in rolling topography and field shapes other than rectangular are difficult to accomodate. This system consists of a sprinkler line of 4-5" aluminum pipe supported by 1.2-3m (4-10 ft) diameter wheels. The pipe or lateral, serves as an axle and is rigidly fixed to the wheels. It is intermittently propelled by an air cooled engine mounted on a carrier usually in the centre of a line. The height of the pipe from the ground is determined by the radius of the wheels. Low growing forages are best for this type of system. Water is supplied to the sprinkler line from a mainline pipe, usually lying on the surface of the ground. This system, stationary while irrigating, is rolled as a unit between irrigation sets by the power of a gasoline engine, located on a mover at the midway point of the lateral. When the power unit is engaged, the wheels roll the sprinkler line to the next hydrant, usually a distance of 18m or 60ft. Labour is required to connect and disconnect the moveable line from the mainline as well as to move the sprinkler line. Pressure requirements are low but this system is not easily portable from one field to the next.

**Travelling Gun System** This type of irrigation system is useful for crops of different heights and for odd shaped fields. It requires a high operating pressure. In this system, a single large capacity sprinkler gun is mounted on a trailer and is moved continuously by a winch, powered by a water turbine. Water is supplied to the gun through a flexible hose or polyethylene pipe which is fed by a mainline.

The two types of travelling guns include a "cable tow type" and reel irrigator or "hose tow type". On the "cable tow type" the gun is mounted on a four wheeled carriage on which is also a water turbine, water piston, gasoline or diesel engine which winches the trailer along by a cable anchored on the opposite side of the field. The hose drags behind the carriage. This type will irrigate a strip twice the length of the hose without any attention from the operator. On the "hose tow type" the carriage is positioned at the mainline and continuously reels in the hose at the end of which is attached the gun mounted on a small wheeled trailer or sled. This type irrigates a strip the length of the hose only. The reeled hose is usually located at the centre of the strip to be irrigated. The sprinkler and hose are then towed to the end of the strip with a tractor and from there they are automatically pulled into the reel by the winch. The reel can then be swivelled to irrigate in the opposite direction. Water application rates can be altered by adjusting the travel speed. A strip approximately 90m (300 ft) wide and up to 800m (2625 ft) long can be irrigated before moving the machine to the next valve on the mainline. The hose tow type is somewhat more versatile in irrigating irregularly shaped fields and no cable or anchors are required.

**Centre Pivot System** This is a self propelled system consisting of a sprinkler line supported on wheeled towers which is continuously moving in a circular fashion around a pivot point. Water is usually delivered to the pivot point through a buried mainline pipe, though it may be above ground. At the pivot point, water is supplied to the single lateral. The two wheeled towers that support the lateral or sprinkler line are driven individually by electricity, oil, water or air. The pivot's rate of movement is variable and is the most automated of the overhead systems since it can run continuously and can operate on rough terrain. The irrigated area is circular and is usually used for light quick applications. This system can vary in length from approximately 60m to 800m (200-2500ft). The most common system on the prairies irrigates a circle of 54 ha (133 acres). This system could be modified for smaller areas. The system can have a wide range of operating pressures, depending on the sprinkler selection. Pressure required at the pivot may vary, from approximately 200 kPa (30psi) when low pressure spray nozzles are used, to 550 kPa (80 psi) when high pressure impact sprinklers are used. Low pressure pivots have a higher rate of application and should be used on lighter soils with relatively flat topography to prevent ponding of water and erosion.

**Linear or Lateral Move System** This automatic system irrigates rectangular or square areas. The appearance of the lateral is basically the same as the centre pivot. Instead of pivoting around a central point, it moves in a straight line down the length of the field. Water is supplied by either an open ditch or a mainline and may be centre or end fed. The maximum practical distance of travel is approximately 3 times the lateral length but depends on the system design. This system is capable of irrigating slightly heavier soils at low operating pressures without danger of runoff and soil erosion. The sprinkler lateral is supplied by the mainline pipe, a flexible hose is connected to the mainline and towed by the machine. The hose must be reconnected at intervals. The practical limit in hose length is approximately 240m (785 ft.) limiting the length of travel before a new connection is made to 480m (1575 ft). Most linear systems require more labour than a centre pivot.

### Sprinkler Systems

When planning a sprinkler irrigation system, which is most common in the Yukon, these aspects must be considered:

1. Size of power unit and pump:
2. Pipe sizes and lengths for mains and laterals.
3. Operating pressures of sprinklers.
4. Size and spacing of sprinklers.
5. Friction losses in the system.

The pump size, distance to be traveled from water source to irrigated site, friction losses in pipe materials and fittings, size of pipe and numbers of sprinklers will determine your actual water application rate. The specifications provided by the manufacturers for pumps and sprinklers are incorporated into the formula to determine the pumping capacity, rates and amounts of applied water over a given time period.

### Spacing of Sprinklers

To avoid uneven water distribution there should be enough distance between sprinklers to allow a 40% overlap in diameter of the area they are to cover. Figure 5.2 shows the approximate depth of water penetration on various classes of soil from a 3in irrigation.

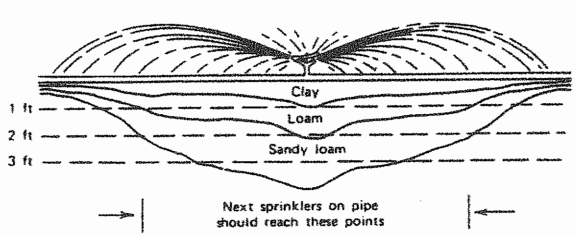



Figure 5.2 Sprinkler Irrigation/Depth of Water Penetration

Source: *Knott's Handbook for Vegetable Growers*, O. Lorenz & D. Maynard, J. Wiley & Sons, 1988, pg 183.

1. Determine diameter and area of coverage of sprinkler used.
   **Example:** Diameter = 60 Ft. Radius = 30Ft.
   ($\pi R^2$) = 900 = 2,827 sq ft (area of a circle for each sprinkler). Normal sprinkler spacing is 30' x 50'.
2. Determine Adjustments for average wind speed.

To avoid uneven water distribution spacing of sprinklers it is important to take average wind speeds into consideration: For wind speeds up to 7 Miles per Hour (M.P.H.) there should be a 40 % overlap in the diameter of the area each sprinkler covers and 65% overlap between laterals. For wind speeds 7 - 10 M.P.H. spacing is 40% between sprinklers and 60 % between laterals. For wind speeds more than 10 M.P.H space sprinklers with a 30 % overlap and 50% between laterals.

A summary of small scale sprinkler irrigation systems has been prepared by a Dawson producer. The components of the system and requirements for four types of systems are indicated.

### Drip or Trickle Irrigation

This is defined as a frequent slow application of water to soil through emitters located at selected points, often at each plant, along the lateral water delivery lines. Low flow rate emitters are the key to minimum pipe, pressure and power requirements. Trickle irrigation lacks the wind drift and or evaporation losses of sprinkler systems. This type of system allows for frequent applications of small amounts of water directly to the plant root zone, where it will maintain adequate soil moisture conditions.

A typical wetted "bulb shape (Figure 5.3) is obtained with proper operation of the trickle system. The actual shape will vary with soil type and rate of application. The wetting pattern in a sandy texture soil will generally be a deep narrow profile while in a clay soil it will be shallower and wider.

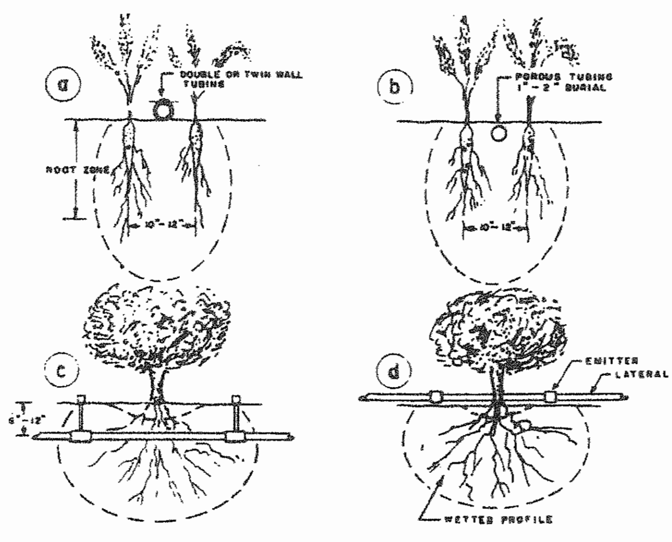



Figure 5.3 Trickle Irrigation/Water Penetration

Source: Trickle Irrigation for Home Gardens and Shelterbelts Alberta Agriculture, Agdex 568-1

These small irrigation systems are for individual households or small market gardens. Each system is made up of four basic components, a single sprinkler, an electric pump, a hose or pipe connecting the two and a thermostat.

**SPRINKLER**

Only a single sprinkler is recommended for these systems as it gives more uniform water distribution than multiple overlapping sprinklers. It is also easier to set up at the start of the season and to store in the winter. Recommended Rainbird sprinklers for four different size gardens are given in the table. The gardens are assumed to be rectangular. The output nozzles on these sprinklers are removable and a large selection of sizes and styles is available for each model. Recommended sizes and styles are shown. Sprinklers from other manufacturers that have the same "Essential Specifications" as shown in the table may be used if desired.

A garden should get about one inch of water per week including rainfall. The table shows what fraction of an inch of water per hour would fall in the garden for each system. It also shows how long each system would have to be run each week, assuming no rainfall, to provide one inch of water. It is a good idea to use a rain gauge to determine the amount of natural rainfall occurring between the periods the sprinklers are used and to adjust the length of time they are run accordingly.

**PUMP**

The recommended pumps are electric and are Manufactured by Monarch Industries. The 3/4 hp unit in the first system is a household jet pump. The three larger models are called Lawn and Turf pumps and are made specifically for irrigation. Gas or diesel pumps as well as electric pumps from other manufacturer's could be substituted if they meet the Essential Specifications shown in the table as to Gallons per Minute and PSI shown for the sprinkler in any given system.

All pumps in the table are assumed to be lifting water from a depth of 25 feet. If the lift is greater than 25 feet, the output of the pump will be less than that shown in the table. If the lift is less, the output will be greater than that shown in the table. In most cases a greater pump output will not affect the system at all. If the actual pump output will be less than that shown in the table, either a larger pump should be used or the sprinkler nozzle size should be reduced.

**HOSE OR PIPE**

Many types are available. The important thing is that it is of the proper diameter. Using too small a diameter will cause a loss in pressure and water volume between the pump and the sprinkler which can severely affect the performance of the system. The table shows the proper sizes to use for each system for distances of from one hundred to five hundred feet.

**THERMOSTAT**

This is optional, but is a good idea in the Yukon. These are available from heating, air conditioning or refrigeration contractors or suppliers. They should be commercial units capable of being mounted outdoors and should have a temperature range extending below freezing. They are generally available for about $60.00. A thermostat can extend the growing season by two or three weeks and protect against midsummer frosts by turning the system on when the outside temperature drops below freezing.

| | System 1 | System 2 | System 3 | System 4 |
|---|---|---|---|---|
| **RECTANGULAR GARDEN** | | | | |
| LENGTH OF LONGEST SIDES IN FEET | 73 | 92 | 117 | 151 |
| ACRES IF SQUARE | .12 | .19 | .31 | .52 |
| **RAINBIRD SPRINKLER SPECIFICATIONS** | | | | |
| MODEL | 14070WH | 70CWH | 85EWPSH | 102D |
| BASE THREAD SIZE | 3/4 inch | 1 inch | 1 1/4 inch | 2 inch |
| NOZZLE SIZE | 13/64 in | 5/16 in | 5/8 in | .6 in |
| NOZZLE TYPE | Standard | Standard | CD-5 | Ring |
| **ESSENTIAL SPECIFICATIONS** | | | | |
| DIAMETER OF SPRAY IN FEET | 103 | 130 | 166 | 214 |
| PSI | 30 | 40 | 40 | 50 |
| US GAL PER MIN | 6 | 17.7 | 65.4 | 74 |
| INCHES PER HOUR ON GARDEN | .07 | .13 | .29 | .20 |
| HRS PER WEEK RUN TIME WITH NO RAINFALL | 14.3 | 7.7 | 3.5 | 5.0 |
| **ELECTRIC PUMP with 25 ft or less of vertical lift** | 3/4 hp | 2 hp | 3 hp | 5 hp |
| **SIZE OF HOSE OR PIPE LEADING FROM PUMP TO SPRINKLER** | | | | |
| 100 FT | 1 1/4 in | 2 in | 4 in | 4 in |
| 200 FT | 1 1/4 in | 2 in | 4 in | 4 in |
| 300 FT | 1 1/4 in | 2 in | 4 in | 4 in |
| 400 FT | 1 1/2 in | 2 in | 4 in | 4 in |
| 500 FT | 1 1/2 in | 2 in | 4 in | 4 in |

Source: M. Heydorf, Dawson, Yukon, 1994.

## YCDP Crop Trials

A trickle irrigation system was used in the vegetable/row cover trials which included: A mainline or header of 1" polyethylene pipe with 1/2" polyethylene lateral lines; low pressure plastic emitters were inserting into the tubing every 2 ft. for cabbages and 6" for beet, carrot and lettuce trials. Two laterals were placed in the beds planted to 3 rows of beets, carrots or lettuce and one lateral was used for the cabbages planted in a single row. A filter was attached between the water source and the mainline to prevent clogging of the emitters. This system was very successful for cabbage and vegetable production with a minimal amount of labour required.

## Surface Irrigation

This kind of irrigation may range from automated flood methods requiring considerable land leveling, high initial capital to minimum control flooding methods requiring little investment but considerable labour. The advantages of surface methods are low pumping costs, distribution is unaffected by wind, large flow rates and irrigation can be done quickly and large depths of water can be applied without difficulty on most soils. The disadvantages are that land leveling costs may be prohibitive, land is lost to ditches and difficulties may arise in soils with high infiltration rates. The types described include:

1. **Border Dyke System:** Parrell dykes 4-6" high are constructed 10-20m (33-66 ft) apart running in the direction of the slope. Water is turned from the head ditch into each strip at the top end and flows down the length of the strip between the dykes. The length of the run depends on the soil type. Lighter soils require shorter lengths of run to prevent over irrigating the upper end of the strip. This method can be used on most crops and is especially suited to forage crops. It is usually limited to land having a downfield slope less than 2 percent, although it has been used successfully on steeper lands.

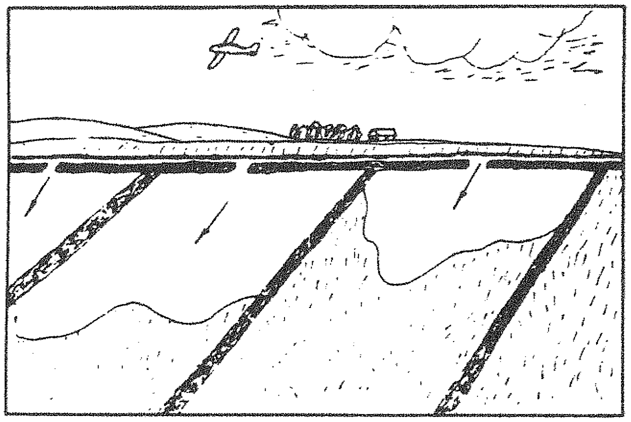


Figure 5.4 Border Dyke Irrigation

2. **Furrow and Corrugation:** This method involves utilizing small channels running down-field and usually spaced 1m apart. Furrows are used in row crops with the water confined in the channel between each row. Corrugations are used in close growing crops. Where slopes are not more than 1% and very little cross slopes exists, the corrugations may be used as directional guides. Gated pipes are frequently used to distribute water from the head ditch to the furrows or corrugations. Where slope is greater than 1% and where a cross slope exists, corrugations are operated similar to furrows in that the water is turned into the corrugation at the upper end and kept confined to the channel. Both furrow and corrugation irrigation methods are suited to finer textured soil types, since a longer length of run can be used. They are especially suited to soil with surface crusting because only a portion of the ground surface is flooded.

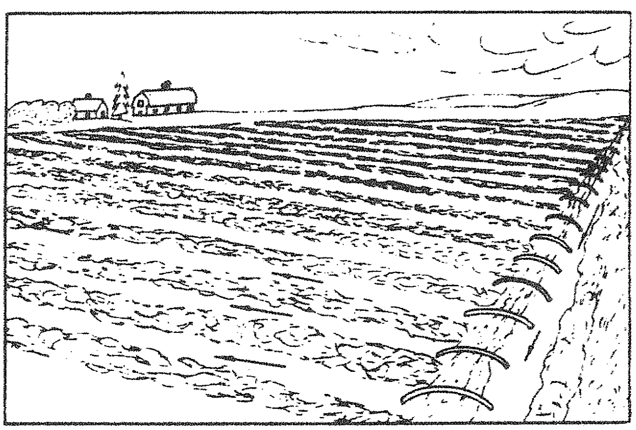
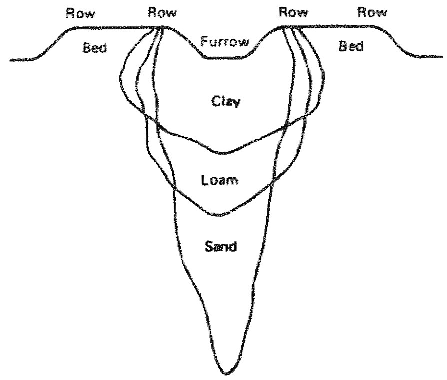


Figure 5.5 Furrow Corrugation Irrigation

The arrangement of beds for furrow irrigation is shown in Figure 5.6 with beds intended for two rows,usually on 36, 40, or 42 inch centers with the surface 4-6" above the bottom of the furrow. The depth of penetration of water according to the type of soil is indicated.




Arrangement of beds for furrow irrigation. Beds intended for two rows are usually on 36-, 40-, or 42-in. centers, with the surface 4–6 in. above the bottom of the furrow. The depth of penetration of an equal quantity of water varies with the class of soil as indicated.

Figure 5.6 Depth of Water Penetration with Furrow Irrigation

Source: *Knott's Handbook for Vegetable Growers*, O. Lorenz & D. Maynard, J. Wiley & Sons, 1988, pg 172.

3. **Spring Flood:** Spring runoff is diverted, either by gravity or pumping into fairly level areas where it is retained and spread by dykes. Each flooded area has an outlet structure for draining. The water should be held only until it has soaked down about 1 metre (3.3 ft) and then the excess should be drained away. This method is suitable for most soils used for hay or cereal production. This is a low cost method of applying additional moisture and even a moderate increase in yield may justify a development of this kind.

Sources: *Guide to Farm Practice in Saskatchewan*, Saskatchewan Agriculture, 1984.
*Irrigation Manual* - Manitoba Agriculture

### *Irrigation Applications*

To determine the proper water application rates:

1. Determine crop water requirements and plant feeder root depth (majority of Feeder Roots).

Table 5.9 Plant feeder Root Depth

| Crop | Feeder Foot Depth (Ft.) |
|---|---|
| Beans | 2 |
| Beets | 2-3 |
| Cabbage | 1.5-2 |
| Carrots | 1.5-2 |
| Cucumbers | 1.5-2 |
| Tomatoes | 1-2 |
| Lettuce | 1 |
| Onions | 1.5 |
| Peas | 2.5 |
| Potatoes | 2 |
| Grain | 2-2.5 |
| Alfalfo | 3-6 |
| Pasture (Grasses) | 1.5 |
| Pasture (with clover) | 2 |

2. Determine Soil Type Holding Capacity per Foot of Soil Type
3. Determine Net Amount of Moisture Per Application

The irrigation requirements for different soil types is indicated in Table 5.10. The amount of inches required for each irrigation to meet crop requirements (root zone depth) on 3 soil types (Light, Medium and Heavy) is shown. This information was summarized from Rainbird irrigation equipment information sheets. (See Soil Characteristics & Irrigation – Soil Management).

Table 5.10 Irrigation Requirements for Soil Types

**Light Sandy Soil Type**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Root Zone Depth (Ft) | | 1 | 1.5 | 2 | 2.5 | 3 | 4 |
| Field Capacity (in.) | | 1.25 | 1.88 | 2.50 | 3.13 | 3.75 | 5.00 |
| Amt Held at Wilting Point | (%) | 20 | 20 | 20 | 20 | 20 | 20 |
| | (in.) | 0.25 | 0.38 | 0.50 | 0.63 | 0.75 | 1.00 |
| Available Moisture * | (in.) | 1.00 | 1.50 | 2.00 | 2.50 | 3.00 | 4.00 |
| Net Inches | 67% | 0.33 | 0.50 | 0.66 | 0.83 | 0.99 | 1.32 |
| Per Irrigation * | 50% | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 2.00 |
| | 33* | 0.07 | 1.00 | 1.33 | 1.67 | 2.00 | 2.66 |

**Medium Soil Type**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Root Zone Depth (Ft) | | 1 | 1.5 | 2 | 2.5 | 3 | 4 |
| Field Capacity (in.) | | 2.25 | 3.38 | 4.50 | 5.62 | 6.75 | 9.00 |
| Amt Held at Wilting Point | (%) | 25 | 25 | 25 | 25 | 25 | 25 |
| | (in.) | 0.56 | 0.85 | 1.12 | 1.41 | 1.69 | 2.25 |
| Available Moisture * | (in.) | 1.69 | 2.53 | 3.38 | 4.21 | 5.06 | 6.75 |
| Net Inches | 67% | 0.57 | 0.84 | 1.11 | 1.39 | 1.67 | 2.23 |
| Per Irrigation* | 50% | 0.85 | 1.26 | 1.69 | 2.11 | 2.53 | 3.38 |
| | 33* | 1.13 | 1.70 | 2.26 | 2.82 | 3.38 | 4.52 |

**Heavy Soil Type**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Root Zone Depth (Ft) | | 1 | 1.5 | 2 | 2.5 | 3 | 4 |
| Field Capacity (in.) | | 3.67 | 5.50 | 7.34 | 9.17 | 11.00 | 14.68 |
| Amt Held at Witing Point | (%) | 35 | 35 | 35 | 35 | 35 | 35 |
| | (in.) | 1.28 | 1.92 | 2.66 | 3.20 | 3.84 | 5.12 |
| Available Moisture * | (in.) | 2.39 | 3.58 | 4.78 | 5.97 | 7.17 | 9.56 |
| Net Inches | 67% | 0.79 | 1.18 | 1.58 | 1.97 | 2.36 | 3.15 |
| Per Irrigation* | 50% | 1.20 | 1.79 | 2.39 | 2.98 | 3.58 | 4.78 |
| | 33* | 1.59 | 2.36 | 3.25 | 3.97 | 4.77 | 6.37 |

Note:

* Available Moisture/Plant Use = (Field Capacity - Amount held at Wilting Point)

* Net Inches to apply per Irrigation: based on 67%, 50% and 33% Available Moisture retained in the soil at irrigation.

- For optimum yield of high valued shallow rooted crops maintain 67% Available Moisture
- For lower valued deeper rooted crops maintain 50 % Available Moisture
- For low value deep rooted crops maintain 33% Available Moisture.

A 3 foot plant root zone depth in a medium soil with 50% moisture retained at irrigation means that 2.53 inches of water must be applied per irrigation.

- 22,624 Imperial Gallons (102849 litres) of water are required to cover 1 acre to a 1 inch depth
- 27,170 U.S. Gallons of water are required for to cover 1 acre to a 1 inch depth
- In order to pump 1 inch of water on 1 acre in 1 hour it would require a pumping rate of 377 imperial gallons per minute.
- 3.7 gallons/minute = 1 cubic metre per hour

Peak moisture use of common irrigated crops is indicated in Table 5.11.

Table 5.11 Moisture Use of Common Irrigated Crops

| Crop | Cool Climate | | Moderate Climate | |
|---|---|---|---|---|
| | In./Day* | GPM/Acre* | In./Day | GPM/Acre |
| Alfalfa | .20 | 3.8 | .25 | 4.7 |
| Pasture | .20 | 3.8 | .25 | 4.7 |
| Grain | .15 | 2.8 | .20 | 3.8 |
| Potatoes | .14 | 2.8 | .20 | 3.8 |
| Beets | .20 | 3.8 | .25 | 4.7 |

* Acre inches per acre per day.

* Continuous flow required per acre at 100% irrigation efficiency.

Estimated irrigation efficiencies are:

Moderate Climate -75%  Cool Climate - 80%

**Example:** Required to apply 2in. depth of irrigation in a cool climate at 80% efficiency = 2.50 Acre inches/acre per irrigation.

Precipitation Rates to Use on Level Ground:

Light Sandy Soil 0.50 - 0.75 " per hour
Medium Textured Soil 0.25 - 0.50 " per hour
Heavy Textured Soil 0.10 - 0.25 " per hour

Maximum Water Infiltration Rates for Various Soil Types:

| Soil Type | Infiltration Rate (in./hr) |
|---|---|
| Sand | 2.0 |
| Loamy sand | 1.8 |
| Sandy loam | 1.5 |
| Loam | 1.0 |
| Silt and clay loam | 0.5 |
| Clay | 0.2 |

Source: *Knott's Handbook for Vegetable Growers*, O. Lorenz & D. Maynard, J. Wiley & Sons, 1988, pg 174.

### *Quality of Irrigation Water*

The parameters of general concern in water quality for irrigation include electrical conductivity (EC). This is a measure of the total dissolved solids (salts) content in the water. The addition of irrigation water to soils adds to the salt concentration which can interfere with the extraction of water by the plant. A measure of the sodium hazard of the water or sodium adsorption ratio (SAR) is also an important parameter. The source of water intended for irrigation use should be tested for pH, salt content and elemental concentration.

#### Total Salt Content

This is the most important criteria in evaluating water quality for irrigation. There are three ways of expressing salinity:

1. Total Dissolved Solids (TDS) measured in: parts per million (ppm) and milligrams per litre (mg/L)
2. Millequivalents per litre (meg/L)
3. Electrical Conductivity (EC) measured in: microsiemens per centimeter (mS/cm) (equivalent to micromhos/cm) or millisiemens per centimeter (mS/cm)
   = (equivalent to millimhos/cm or millihos/cm) (mmhos/cm) 1 decisiemens per metre (dS/m) = 1 millimho per centimetre
   = (mmhos/cm) = approximately 640 milligrams/litre salt.
   EC (mS/cm) x 640 = TDS (mg/L)

The total concentrated soluble salts is expressed in terms of electrical conductivity (EC x 10^6) or salinity. Electrical conductivity as measured by the saturated paste method gives EC values approximately one half the value of the soil solution at field capacity, and one quarter the value at the permanent wilting percent.

Quality of water is considered good for horticultural crops at E.C.value of 7.5 mS/cm and for field crops at 10 mS/cm. Water with 15 mS/cm is acceptable for field crops. Only salt tolerant crops can be grown with 20 mS/cm. Use of water above 20 mS/cm is not recommended.

#### Sodium

Sodium levels have a direct effect on soil structure and permeability as well as affecting total salinity. The relative proportion of sodium to the other cations is expressed by the sodium absorption ratio (SAR) in milieqivalents per litre (meg/l). As the sodium (Na) Calcium (Ca and Magnesium (Mg) increases in solution this leads to dispersion of the soil colloids, resulting in swelling of clay particles, clogged soil pores and decreased permeability. Sodium replaces exchangeable calcium and magnesium. Sodium can be expressed in terms of exchangeable sodium percent (ESP), and sodium absorption ratio (SAR). This is a good estimation of the amount of sodium on the exchange complex in the soil colloid. Sodium may be toxic to some crops.

When irrigating with natural waters parameters of concern include:

Table 5.12 Guidelines for Salinity of Irrigation Water

| Category | Total Dissolved Solids (mg/L) | Conductivity (mS/cm) | S.A.R. |
|---|---|---|---|
| 1. No Detrimental Effect | <500 | 2.0 - 7.5 | <4 |
| 2. Effects sensitive crops | 500 - 1000 | 7.5 - 15.0 | <6 |
| 3. Effects many crops | 1000 - 2000 | 15.0 - 30.0 | <8 |
| 4. Use on salt tolerant crops only | 2000 - 3000 | 30.0 - 75.0 | 8+ |

Source: *Irrigation Manual*, Manitoba Agriculture, Brandon, Manitoba, 1982.

Table 5.13 Ratings for Salinity

| | Safe | Possibly Safe | Hazardous |
|---|---|---|---|
| EC mS/cm | <1.0 | 1.0 - 2.5 | >2.5 |
| SAR | <4 | 4-9 | > 9 |

Source: *Guidelines for Irrigation Quality*, Alberta Agriculture, Agrifax, Agdex 562-1, 1883.

Note: Limits that are safe are good for all conditions, possibly safe means okay for some conditions and hazardous is for most conditions.

#### Boron

This element is necessary to consider while assessing water quality. Essential for plant growth, boron becomes toxic at concentrations only slightly above optimum. Boron is adsorbed by soil particles and tends to accumulate over time. Water with marginal boron levels can be used for years with no adverse effects until soil levels have built up concentrations equal to or greater than those in the irrigation water. Prolonged use of water having levels greater than 3 mg/L is not recommended.

### *Water Quality Monitoring of the Takhini River:*

A study, funded by the Green Plan during 1993 was conducted along the Takhini River to monitor water quality, including fertilizer, pesticide/herbicide residues. A report was prepared which indicated:

*"The data presented shows that there is no impact on the surface waters of the Takhini River within the study area from agricultural land uses. Surface waters of the Takhini exceed the maximum acceptable concentrations for drinking water for parameters iron and total fecal choliforms. The Takhini River surface waters should not be used as a drinking water source."*

*Their presence at all main stream river stations and in all tributary streams with or without land use cannot be attributed to development."*

*"The guidelines for livestock watering and crop irrigation are met at all sample locations."*

*" The pH of Takhini River stations ranged from 7.2-7.9."*

*" Boron was not tested for during this study."*

Table 5.14 Summary of Canadian Water Quality Guidelines (CCREM)

| Parameter | Drinking Water | Aquatic Life | Livestock Water | Irrigation Water |
|---|---|---|---|---|
| Aluminum | - | 0.005 | 5.00 | 5.00 |
| Arsenic | 0.05 | 0.05 | 0.5 | 0.1 |
| Barium | 1.00 | - | - | - |
| Beryllium | - | - | 0.10 | 0.1 |
| Boron | 5.00 | - | 5.00 | 0.5 - 6.0 |
| Cadmium | 0.005 | 0.002 | 0.02 | 0.01 |
| Calcium | - | - | 1000 | - |
| Chloride | 250 | - | - | - |
| Chromium | 0.05 | 0.002 | 1.00 | 0.1 |
| Cobalt | - | - | 1.00 | 0.05 |
| Copper | 1.00 | 0.002 | 1.00 | 0.2 |
| Cyanide | 0.2 | 0.005 | - | - |
| Iron | 0.3 | 0.3 | - | 5.00 |
| Lead | 0.05 | 0.001 | 0.1 | 0.2 |
| Manganese | 0.05 | - | - | 0.2 |
| Molybdenum | - | - | 0.5 | 0.01 |
| Mercury | 0.001 | 0.0001 | 0.003 | - |
| Nitrate | 10.00 | - | 100.00 | - |
| Nitrate | 1.00 | 0.06 | 10.00 | - |
| Nickel | - | 0.025 | 1.00 | 0.2 |
| pH | 6.5 - 8.5 | 6.5 - 9.0 | - | - |
| Selenium | 0.01 | 0.001 | 0.05 | 0.02 |
| Silver | 0.05 | 0.0001 | - | - |
| Sulphate | 500.00 | - | 1000.00 | - |
| T.D. Solids | 500.00 | - | 3000.00 | 500 - 3500 |
| Uranium | 0.02 | - | 0.02 | 0.01 |
| Vanadium | - | - | 0.1 | 0.1 |
| Zinc | 5.00 | 0.03 | 50.00 | 1.00 |
| | mg/l | mg/l | mg/l | mg/l |

Source: *Water Quality Monitoring of the Takhini Watershed*, J. Gibson & Assoc., 1993.

The irrigator must know the soil texture of the root zone of each irrigated field to estimate the readily available moisture. The effective root zone is 600mm (24") deep for shallow rooted vegetable crops, 1m (3.3ft) for most grasses, cereals and root crops and as much as 2m (6.6ft) for alfalfa. It is recommended to bring the effective root zone up to field capacity early in the growing season. About 70% of the plants' moisture requirements are taken from the upper half of the root zone. Adequate soil moisture in the lower root zone helps to tie over temporary periods of stress but is not sufficient to promote maximum growth. Good irrigation scheduling results in keeping soil moisture within the readily available range. (See Soil Moisture Evaluation – Soil Management).

Aside from frost danger, irrigation should be curtailed when there is sufficient readily available moisture in the soil to mature the crop without moisture stress. As a rule of thumb if there is 75mm (3") of soil moisture available, irrigation can cease when cereals are in the early dough stage. Over irrigation or late irrigation can reduce crop profitability because of extra pumping, lodged grain losses, possible increased disease losses, and wet fields at harvest.

### *Irrigation Scheduling*

The scheduling of irrigation is of utmost importance to maximize yield by maintaining optimum soil moisture. When a crop has to exert extra effort to get water, it is under stress, and yield is usually reduced. A crop's water requirement is dependent on the stage and length of growth period and the subjected heat and wind. Other considerations are: some soils hold more moisture, some soils release water more readily than others, some crops have a natural ability to extract more water without stress. The producer needs to know the local climatic effects, the soil moisture levels and crop water use characteristics to obtain maximum benefits from irrigation.

#### Irrometers

Soil moisture can also be measured by the use of instruments such as tensionmeters or irrometers for sands and sandy loams and gypsum blocks for loams and clays.

Irrometers measure soil tension which is directly related to the amount of soil moisture available to plants. They are an important management tool to tell you when to water and how much. Capilarity is established between the water filled irrometers and the soil water via the ceramic tip. As oil water tension increases, water is drawn by suction from the irrometer and a negative pressure created, which is representative of soil tension, is read from the vacuum gauge.

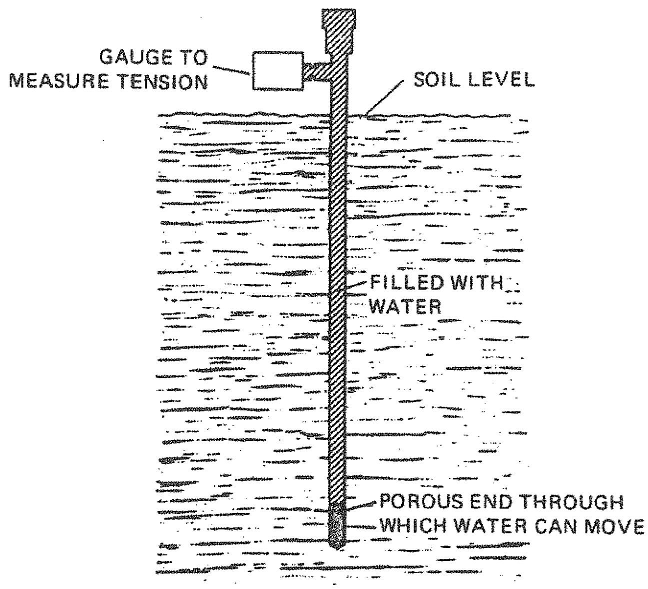



Figure 5.7 Irrometer

**Irrometer Readings**

The irrometer gauge is graduated 0-100, the graduations representing hundredths of an atmosphere. The unit of measurement is centibars or kilopascals. A gauge reading of 50 represents 1/2 atmosphere or about 7 pounds of negative pressure (vacuum). This reading is a direct measurement of how hard the root system has to work to extract water.

0 - 10:·Indicate saturated soil which often occurs a day or two following irrigations. Continued readings in this range indicate over irrigation ie. water logged soils orr high water table.

10 - 20: Indicate field capacity for sprinkler and furrow irrigations. Drip irrigations is applied in low volume in this range.

30 - 60: Range for starting irrigation in coarse texture soils (lower portion of range), and in the upper part of this range for heavier soils with higher moisture holding capacity. Starting irrigations in this range ensures maintaining readily available soil moisture at all times, which is essential for maximum plant growth.

70 - 100: Readily available moisture is getting dangerously low for maximum plant growth; plant stress is occurring and irrigation is required.

Irrometers are available in 6", 12", 18", 24", 36", 48" and 60" lengths. Irrometers installed at two or more depths register soil moisture conditions at different root horizons and thus give a more accurate picture of the moisture profile. When root crops have a root system exceeding about 18" irrometers should be installed at two depths – one at about 25% of root zone depth and one at about 75% depth. The 6" irrometers were suitable for the oats and brome crops representing at least 75% of the root zone.

**Soil Moisture Project**

During the 1993 growing season, a soil moisture research project was funded by the Green Plan. Eight irrometers were located at four sites along the Mayo Road north of Whitehorse, each under a brome and oat crop to determine soil moisture levels under natural rainfall. Soil moisture levels under the brome crop were consistently higher than that under the oat crop. Irrometer readings were compared to rainfall data at three climate stations, the Whitehorse Airport, Mile 3 Mayo Road and at Mile 5 Mayo Road.

Source: *Soil Moisture Research Project*, K.Bisset & Associates, for Green Plan, 1993.

## WEED CONTROL

There are a number of weeds which cause a problem to Yukon producers. Look up the particular weed in a plant identification book or contact the Agriculture Branch for species identification. The weeds causing the most problem have included:

Quackgrass (Agropyron repens)
Lamb's-Quarters (Chenopodium album)
Foxtail Barley (Hordeum jubatum)
Narrow Leaved Hawk's-Beard, (Crepis tectorum)
Chickweed (Stellaria media)
Sheppard's Purse (Capsella bursa-pastoris)

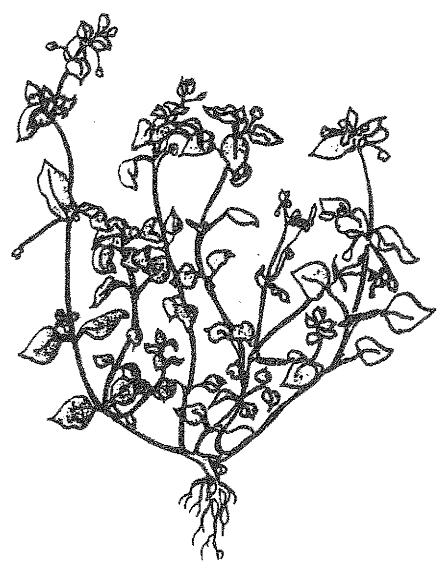


Figure 5.8 Chickweed

Source: *Identifying Weeds on Home Grounds*, N.A. Korven, B. Todd, Manitoba Agriculture, Agdex 644-646, 1986, pg 6.

Basic methods of weed control include cultural, mechanical and chemical.

### *Cultural Control*

Crop Rotation is a good practice. Different weeds tend to increase with different crops. Alternating crops will disrupt many weed species and a healthy competitive crop can aid greatly in weed control. Any practice promoting dense, vigorous stands will reduce the yield loss due to weeds. Such practices include the use of healthy clean seed, adequate seedbed preparation; early, shallow seeding at heavy rates; packing after seeding; and the use of fertilizers.

Crops differ in their ability to compete with weeds. Perennial forage crops provide excellent competition for perennial weeds. The weed populations may be greatly reduced or even eliminated. Crested wheatgrass can be used in conjunction with tillage, alfalfa, sweet clover and brome are effective in weed control. Legumes are the preferred crop if the producer wants to add nitrogen to the soil. A grass-legume combination such as crested wheatgrass and alfalfa may be even more effective than crested wheatgrass alone.

Hand weeding is often the best alternative to maintain weed populations under control. Lambsquarters are best removed while young, especially before seeds form. In the YCDP vegetable trials, plots were hand weeded in the rows and cultivated with a small rototiller between rows. In Dawson, lambsquarters were prolific in one garden. Each year these were handweeded. By the third year of trials, lambsquarters were no longer a problem.

### Mechanical Control

Establish and maintain good weed control by proper well timed cultivation. Don't let weeds go to seed. Non-chemical control measures must be properly matched to plant growth to ensure maximum weed destruction and minimal crop damage.

1. Ensure that farm equipment is clean so that weeds are not spread from field to field or to one farm to another.
2. Do not allow weeds to set seed. Grazing, mowing and tillage can be done to reduce seed set.
3. Control weeds in waste areas and on uncultivated lands by mowing and grazing.

Pre-seeding tillage forms a good seedbed and destroys weed seedlings. Avoid excessive or unnecesary tillage as this dries out the soil, promotes erosion and may bring up dormant seeds.

**Summer Fallow** is useful in controlling perennials which are not dependent on seeds to survive from year to year. Intensive tillage to repeatedly kill top growth can deplete food reserves in the roots and eventually kill the weeds. One year of intensive tillage will kill quackgrass. Alternating between cropping and intensive tillage can reduce the weeds to the point where they do not depress yields. The number of tillages varies according to the producers's objective. More than four tillages are usually unnecessary but 8 or 9 tillages may be necessary to eradicate some perennial weeds. In general it is best to start fallow tillage as early in the spring as possible.

**Mowing** prevents seed formation and reduces competition with crop plants. It is particularly useful for tall growing weeds and in areas where tillage is not possible. To prevent seed formation, mow as soon as the first flowers appear or immediately prior to flowering. Recut every 3 weeks during the growing season to weaken the weed root systems.

*I use a small "weedwacker" which is a small gas powered engine on a bar with a spinning nylon cord attachment. This whips and thereby cuts the plant. I use this on weeds to spot remove them from the garden or fields prior to them going to seed. This works well for foxtail barley, cut down before it heads out.*

-Whitehorse Producer

### Chemical Control

There are a number of herbicides available for weed control, which will not be listed. Field guides available from Alberta Agriculture and B.C. Ministry of Agriculture and Fisheries give specific recommendations for herbicide use on grain, forage, vegetable and berry crops. These also give recommendations for pesticide use.

On the product label, the rate of application for certain weed species is given. Most herbicide recommendations and product labels indicate the proper stage of plant growth for spraying. Recognition of plant growth stages is essential for effective weed control, as the weeds are only controlled when they are at a susceptable growth stage. The lowest rates in the range should be used only on seedlings under good growing conditions. Use the higher rates if the weeds have reached an advanced stage of growth, or under adverse growing conditions, or on extremely heavy infestation of weeds. Fields are rarely infested with one weed species; therefore apply enough of the right type of herbicide to give satisfactory control of the most resistant species. Most herbicides require good soil moisture for activation. No herbicide will control all weeds under all circumstances and conditions. Select the most appropriate herbicides and apply at the correct rate, time and under the best conditions possible.

#### Application

Care should be used in handling herbicides or pesticides. Read the label carefully and use the specific measurements to determine dilutions. Calculations/conversion factors for volume measurements are presented in Appendix C. Be cautious of drift. Windy days are not suitable for applications. Herbicides can be applied by the use of a small backpack sprayer, by a hand held rod with a wick, or by the larger tractor drawn or mounted sprayers. For the later, calibrating the spray application rate is a key factor in proper herbicide applications. The pressure, nozzle size and amounts (boom coverage), and the speed are the constants in determining application rate, as these must be the same for each application.

Calibration of a sprayer may be done with the following simple formula for all herbicide or pesticide formulations or mixes:

$$\frac{A}{B} = \frac{C}{D}$$

A test strip is done with the sprayer for a measured distance; the amount of pesticide applied is determined to determine the volume used/test area and the application rate; where:

A= Unit Measures to be Applied per Unit Area (Field to be Covered) (Gallons/acre, lbs/acre, oz./100ft$^2$, Litres/ha; kg/ka; g/m$^2$ etc.)

B= Unit Measures of Herbicide/Pesticide Used in Test (Gallons, pounds, ounces, litres, kilograms, grams)

C= Unit Area (Field to be Covered) Square feet : 1 acre = 43,560 sq ft. Square meters : 1 ha = 10,000 sq meters.

D= Area covered in test strip: in sq ft. or sq meters

**Example:** Your 100 gallon sprayer is filled with water, the attached spray boom sprays a swath of 30 ft. At 4 MPH at a pressure reading of 25 psi you travel 200 feet. 3 Gallons are needed to refill the tank.

A = ? Gal/Acre
B = 3 Gallons
C= 1 Acre expressed as 43,560 sq.ft.
D= Area of swath test = 30ft x 200 ft = 6000 sq.ft.

1. $\frac{\text{Gal/acre}}{3} = \frac{43560}{6000}$

2. Gal/acre = $\frac{43560}{6000} \times 3 = 21.78$ gal/acre

Thus the application rate for 1 acre to be covered is determined and the herbicide is diluted according to recommendations for the size of your sprayer tank.

Source: *"Handbook for Pesticide Applicators and Pesticide Dispensers"*, British Columbia, Pesticide Control Branch, 1980.

**Quackgrass**

*Round Up*, a glycophosate herbicide is used to control quackgrass and chickweed in the Yukon. *Round Up* is a registered trademark for a water soluble, non-selective herbicide manufactured by Monsanto. This is used as a broadspectrum postemergence herbicide for the control of most perennial weeds. It will kill all vegetation it comes in contact with. It moves through the plant from the point of foliage contact to and into the root system. Visible effects such as gradual wilting and yellowing of the weeds may not occur until 7-10 days. After application one should wait five or more days before tillage.

At the YCDP trial at Pelly Farm there was a problem with quackgrass (*Agropyron repens*) in a field which was to be used for cereal and forage trials. In the spring 1988 the field was disced and left fallow for the summer. In the fall, *Round Up*,

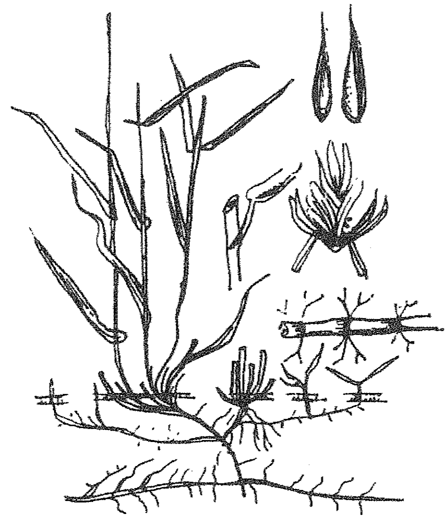


Figure 5.9 Quackgrass

Source: *Identifying Weeds on Home Grounds*, N.A. Korven, B.Todd, Manitoba Agriculture, Agdex 644-646, 1986, pg 24.

was applied using the Agriculture Branch herbicide sprayer. This consists of a 454 litre tank and sprayer boom, mounted on the back of a four wheel drive truck. Five litres of *Round*

## *Yukon Pesticide Regulations:*

Under the new Pesticide Regulations, administered by Government of Yukon, a permit and a pesticide application certificate is required for anyone applying pesticides on property other than their own. Pesticides include herbicides, insecticides and rodenticides. In general, a certificate is not required for a producer applying pesticides on their own farm property. However, farmers will require a Pesticide Use Permit for:

1. using pesticides within 30 metres of an open body of water;
2. using restricted pesticides;
3. using toxic pesticides as identified in Schedule 4 of the Pesticide Regulations
4. applying pesticide from an aircraft.

People or companies who apply pesticides as a business service must be certified pesticide applicators who possess a Pesticide Service Permit. Farmers applying pesticides on another's persons farmland would require a Pesticide Applicators Certificate and a Pesticide Service Permit. (Contact the Environmental Protection & Assessment Branch, Department of Renewable Resources.)

*Up* were diluted into the 454 litre tank of water to cover the 5 acre (2.02 ha) field. Application rate was calculated for nozzles, pressure and speed of travel (5 mph). Approximately 9.5 litres/min. were applied. The first application was on September 1, 1988, 2/3 of the field had quackgrass in the early seedling stage (before 4 leaves).

On the second application, May 18, 1989 the following spring, quackgrass regrowth was present at roughly 50% coverage. Quackgrass should have been more advanced but due to scheduling it was necessary to apply the RoundUp at this time. Cereal and forage trials were planted on May 25th. At harvest, it was estimated that less than 40% of the field had quackgrass growth and was much improved. In the adjacent fields where Roundup had never been applied, quackgrass was prevalent and in some locations was adversely affecting the growth of the oat crop.

**Lambsquarters**

MCPA, was sprayed by the Agriculture Branch to control lambsquarters in cereal research plots. A backpack sprayer was used. The lambquarters was effectively killed but cereal growth was also affected in mid June. Where it had been applied too heavily, the cereals turned golden much earlier. Care must be taken to keep applications evenly distributed at the recommended rate.

Touch applicators, which have a wick which is saturated with the herbicide have been successfully used in small gardens and lawns for spot applications for lambsquarters and other weed plants. Hand weeding or using a "diamond shaped" hoe works well when lambsquarters are small. Removing lambsquarters before it goes to seed is very important to reduce future growth.

**Foxtail Barley**

This has especially become a problem in the Takhini Valley, north of Whitehorse for forage producers. Control by cultivation has not been completely successful. Farmers have reseeded certain portions of forage fields trying to compete with this weed. Chemicals have also been used, including MCPA and Roundup. Hay is inspected for weed content if it is to be exported to Alaska. If bales have too much foxtail (or other weeds) they are not suitable for export.

## INSECT CONTROL

For the most part, one of the benefits of the north is reduced numbers of insect pests to affect crops. For forage or cereal crops insect pests have not been a problem. On vegetable crops, we have two groups of insects which cause problems. The first group, below ground feeders, consists of cutworms, root maggots and wireworms. The second group, above ground feeders consists of aphids, flea beetles, and red turnip beetles. The red turnip beetle is a problem on cabbage, brocolli and cauliflower crops. (See Vegetable Production). A number of insecticides are available which will not be listed. Field guides available from Alberta Agriculture and B.C. Ministry of Agriculture and Fisheries etc. give specific recommendations for insecticide use on grain, forage, vegetable and berry crops.

Figure 5.10 Foxtail Barley

Source: *Identifying Weeds on Home Grounds*, N.A. Korven, B. Todd, Manitoba Agriculture, Agdex 644-646, 1986, pg 12.

There is not a high use of chemical pesticides by Yukon farmers. A few vegetable producers have used malathion and diazinon to control high insect populations when other methods have failed. Most producers prefer the more environmentally friendly pesticides such as Rotenone and Diatomaceous Earth.

Rotenone is an organic insecticide derived from certain tropical plants, including derris, cube, barbasco, timbo and a few others. It is a contact and stomach poison, often mixed with pyrethrum, another plant insecticide, and is of low toxicity to man and animals. It can be safely used on all crops and ornamentals. It kills many types of insects but has little residual effect and the period of protection it offers is short. Plants should be dusted regularly to reduce the insect population.

> *I prefer to use rotenone or diatamaceous earth for red turnip beetle, fleabettles and aphids. These are less toxic than the other chemicals, applied as a dust.*
>
> -Whitehorse Producer

Diatamaceous Earth which is fossilized marine plants is also a component of natural bug and killer dusts. The sharp fragments in the diatomaceous earth keep bugs off plants. Commercial natural bug killer dusts are available locally which consist of 80% Diatomaceous Earth and 0.9% rotenone (ground cube root).

## RODENT CONTROL

The Richardson's Ground squirrel, better known as gophers, are a pest of gardeners and field producers in the Yukon, mainly in the Whitehorse and Carmacks areas.

A Sundry permit which is free must be acquired from the Fish and Wildlife Branch of Renewable Resources. This gives you the right to rid your farm of nuisance gophers, by shooting, or trapping.

*I use a .22 rifle with a scope. The method is to shoot a gopher and then leave it in a good shooting location. Adjacent gophers will come to feed on the dead and these can be shot one by one. A good shot with patience can effectively reduce the numbers of gophers in an afternoon.*

-Whitehorse Producer

*I use small # 1 traps, setting several near my garden area. I put them in locations where dogs cannot get at them. I check them daily and stop trapping when the local gopher population is reduced.*

-Whitehorse Producer

*I place five gallon buckets along the perimeter of my field. I dig them in so that the rim is not too high above ground level. I then fill them with water and grain. Gophers end up falling into the water and drowning as they are not able to get out.*

-Whitehorse Producer

*I,ve found that the use of black plastic mulch actually decreased gopher predation. They don't like the feel of the smooth plastic surface which gets very hot on warm days.*

-Whitehorse Producer

Commercial rodenticides are available on the market. "Liquid Lightening", consisting of 0.07% Chlorophacinone, is locally available. Several rodenticides, which were available two-three years ago are no longer sold by local suppliers as they are now restricted pesticides, such as cyanide and strictnine. One product called Gopher Rid had 2% Zinc Phosphide as the active ingredient. This was thought to be more environmentally friendly. This is now considered a particularly toxic pesticide, is no longer sold locally and a Pesticide Use Permit is required for its application. Rodenticides are usually mixed with grain and added to the burrow as required.

*I use a long funnel, which I extend down into the gopher burrow to place about 1-2 cups of the treated grain into each burrow. I then cover the hole.*

-Whitehorse Producer

## DETERMINING YOUR YIELDS

Keeping records of your yields is a good way to determine if your management practices are working.

During the YCDP trials, a 1 metre square harvest was taken to determine yields of forage and cereal crops. Usually 3 samples were taken within each plot, representing low, medium and high growth. Wet weights were taken for each sample. Samples were later air dried and dry weights taken. An average sample weight was determined for each crop, then yields in lbs/acre or kg/ha were determined.

**Forage or Green Feed Cereal Crop Yields:**

1. Sample Size: Each sample = 1 m2 or 3.28' x 3.28 occupies 10.76 square ft.
2. A conversion figure is determined to convert the dry weight yield of the sample size figure to an acre or hectare figure:

   To lbs/Acres:

   $$\frac{43{,}560 \text{ sq ft/acre}}{10.76 \text{ sq ft}} = \text{Conversion figure } 4{,}048$$

   To kg/Hectares

   $$\frac{10{,}000 \text{ sq metre/ha}}{1 \text{ sq metre}} = \text{Conversion figure } 10{,}000$$

3. Multiply Dry Matter Yield (lbs or kg) x Conversion figure = yield lbs/acre or kg/ha.

   **Example:** Yield of Carlton Bromegrass = .69 lbs Dry Weight/1m$^2$ sample x 4048 = 2793 lbs/acre .31 kg Dry Weight/1m$^2$ sample x 10,000 = 3100 kg/ha

4. The yields of each forage or green feed cereal type can then be expressed as tons/acre or tonnes/ha.

   **Example:** $\frac{2793 \text{ lbs/acre}}{2000 \text{ lbs/ton}} = 1.40$ tons/acre

   1.40 tons/acre x 2.24 (Conversion figure) = 3.13 tonnes/ha

The same method can be used for vegetable yields to determine productivity per so many ft. or metres of row etc. For determining grain yields the bushel weight should be known. (See Determining Grain Yields – Cereal Production.)

# FORAGE PRODUCTION

In the 1991 Yukon Farm Survey, 79 farms reported land in crops, at 1114 ha (2785 acres), a majority of which is used for forage production, and improved pasture. The raising of forages for sale and "on farm" use has become a valuable part of the Yukon agricultural industry.

In this section, the principles of grass growth, varieties of grass and legumes grown in the Yukon, forage establishment, seeding methods and rates, forage quality and pasture management are discussed.

## PRINCIPLES OF GRASS GROWTH

The process of photosynthesis is unique to green plants where the plant makes it own food by capturing radiant energy from the sun. It is limited to periods when plants have green leaves, stems or both. In the presence of sunlight, a simple sugar, glucose is formed when water and carbon dioxide are fixed in chlorophyll, the green tissue of plants. Carbon dioxide ($CO_2$) enters through the stomata or small pores on the surface of the leaves and water ($H_2O$ ) through the plant roots. During the growing season the location of photosynthesis and chlorophyll shifts from the leaf blades to the leaf shealths and stems. As green chlorophyll tissue decreases, photosynthesis declines. Glucose from photosynthesis is used as a building block to form proteins, carbohydrates, fats and oils.

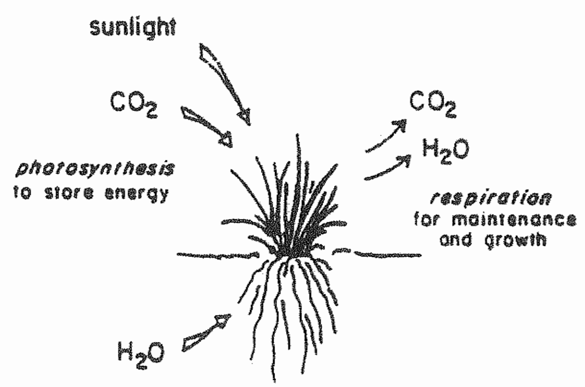



Figure 6.1 Requirements of Grass Growth

Source: *Basic Principles of Grass Growth and Management*, BC Agriculture Factsheet, Forage Information Series, 92-17, pg 1.

Carbohydrates reserves are linked with the regrowth potentials of grasses. Reserves are often the lowest following the start of spring growth and the highest at seed ripening time, declining during the dormant season. Plants decline in their ability to grow and compete with other plants and eventually die if more carbohydrates are used than what is replenished by photosynthesis. The maintenance of carbohydrate reserves is thus critical for grass and pasture management. The most critical factor affecting regrowth is the amount of green leaf and stem tissue remaining after defoliation or grazing. The more tissue remaining, the greater the potential regrowth.

### *Grass Morphology*

Roots of grasses are fibrous or "bunch" roots, rhizomatous with underground spreading, creeping roots or stoloniferous, with above ground shoots capable of producing new roots and plants. Figure 6.2 illustrates the different type of grass root systems.

Grass stems are usually hollow and jointed. The joints (nodes) are short, compressed areas from which leaves grow. Each leaf has two main parts, the blade and the sheath. The sheath clasps tightly around the stem, whereas the blade extends away from the stem. Tillers or shoots are composed of growing points (apical meristems), stems, leaves, roots, nodes and dormant buds. A grass' susceptibility to grazing is influenced by the height at which its growing points are elevated as well as the growth form and ratio of seed-head tillers to vegetative tillers. In general, grasses producing mostly vegetative stems are more resistant to grazing.

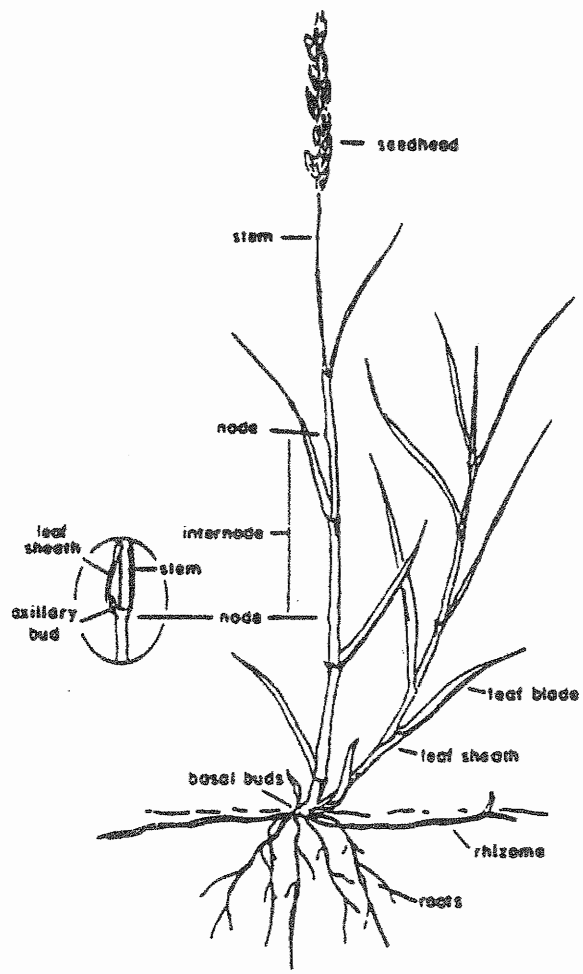



Figure 6.3 Structure of Grass Plant

Source: *Basic Principles of Grass Growth and Management*, BC Agriculture Factsheet, Forage Information Series, 92-17, pg 2.

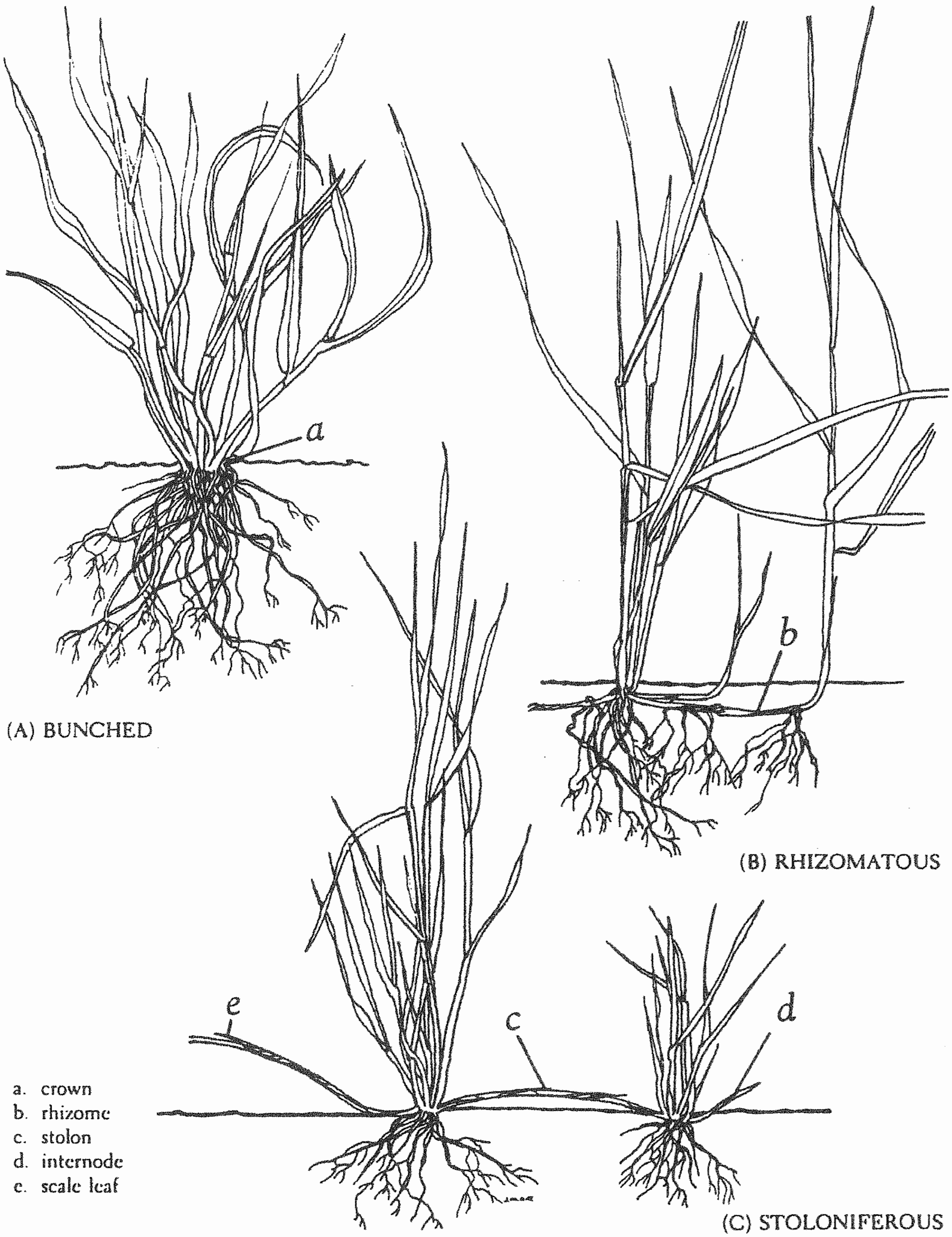



Figure 6.2 Grass Root Systems

Source: *Production and Management of Cultivated Forages*, P.D. Walton, Reston Publishing Co., 1983, pg 8.

## FORAGE CROP RESEARCH

### *YCDP Trials*

16 different varieties of grasses, legumes and hay mixes were planted in 1988 and harvested in 1989 and 1990. No irrigation was applied. This included commercially available seed, from Foster's and Hannas seed companies. Two mixes were created: Peace alfalfa/Carlton Brome and a special YCDP mix for this project. Based on dry weights the following order occurred for production:

Table 6.1 YCDP Forage Trial Results (1989 & 1990)

| 1990 | 1989 |
|---|---|
| 1. Brome-Carlton | 1. Timothy-Climax |
| 2. Alfalfa-Peace/Brome-Carlton | 2. Meadow Foxtail |
| 3. Brome-Polar | 3. Brome-Carlton |
| 4. Foster's High Hay Mix | 4. Brome-Polar |
| 5. Hannas Hay Mix | 5. Hannas Hay Mix |
| 6. Foster's Stockman's Mix | 6. Foster's High Hay |
| 7. YCDP Mix | 7. Foster's Stockman's Mix |
| 8. Timothy-Engmo | 8. YCDP Mix |
| 9. Timothy-Climax | 9. Alfalfa-Peace/Brome-Carlton |
| 10. Meadow Foxtail | 10. Red Clover |
| 11. Meadow Brome-Regar | 11. Timothy-Engmo |
| 12. Alsike Clover | 12. Alfalfa-Peace |
| 13. Hannas High Tech Blend | 13. Alsike Clover |
| 14. Kentucky Bluegrass-Nugget | 14. Meadow Brome-Regar |
| 15. Red Clover | 15. Hannas High Tech Blend |
| 16. Sainfoin Clover | 16. Sainfoin Clover |

There was a difference in yield for both years harvested. In 1990, the best producer was *Carlton* Bromegrass. This was also the best in the NCDP grass trials. This is the most commonly planted grass for hay production in the Yukon as it is dependable and persists longer than other grasses.

> *" The hay crops grown throughout the territory consist of timothy, western rye and bromegrass, also oats cut green. The bromegrass has proved to be the most dependable and a relatively large quantity is grown."*
>
> - *The Yukon Territory 1926*, Department of Interior Report, Ottawa, 1926.

By 1990, the alfalfa had mostly died out within the Peace alfalfa plots, the *Peace/Carlton* (50-50 mixture), the YCDP mix, and Hannas High Tech Blend at most locations. The best growth was in the Whitehorse area. In the mixes, brome grass had become the most dominant by the third year. The clovers (red and alsike) had also died out in most locations by the third year. Alsike performed better than red clover at most sites. Sainfoin clover had died out in most plots by the spring 1990. Even though this appears to survive well in the mixes grown along the roadside (seeded by Highways) it is not winter hardy enough for field conditions.

### *Grass Variety Descriptions of YCDP Trials*

**Single Varieties:**

Grasses

*Carlton* Smooth Bromegrass: This is a northern type cultivar from the Pacific Northwest. It is long lived, sod forming perennial which develops a deep root system and has a tolerance to drought and temperature extremes and is winter hardy. This was the best producer in the YCDP trials as a single variety and in the mixes.

Figure 6.4 Smooth Bromegrass

Source: *Production and Management of Cultivated Forages*, P.D. Walton, Reston Publishing Co., 1983, pg 30.

*Polar* Bromegrass: This variety was developed in Palmer Alaska in 1971 and is a cross between smooth bromegrass and pumpelly bromegrass. In Alaska, Polar is very winter hardy and yields have been similar to smooth bromegrass varieties. Yields in the YCDP trials were less than Carlton brome.

*Regar* Meadow Bromegrass: This is the only licensed variety of meadow bromegrass in Canada, licensed in 1980. It is not creeping rooted and has slower establishment than smooth bromegrass. In the YCDP trials, yields were less than the other bromegrass varieties and it proved to be less persistent. In Alaska it has proven less hardy than *Polar* or *Carlton* bromegrass.

*Climax* Timothy: This is widely grown in Canada for pasture silage and hay. It is a fairly short lived bunch grass with a shallow fibrous root system. It lacks drought resistance and is not tolerant of alkaline conditions or salinity. In the Yukon, producers have found that timothy eventually dies out about 5 years from seeding.

*Engmo* Timothy: This cultivar originally came from Norway and is hardy to northern conditions. This provided less yields than Climax Timothy in 1989 but was a better yielder in 1990.

Figure 6.5 Timothy

Source: *Production and Management of Cultivated Forages*, P.D. Walton, Reston Publishing Co., 1983, pg 54.

*Nugget* Kentucky Bluegrass: This variety was developed in Palmer, Alaska in 1965. It has been used in Alaska as a turfgrass as well as a pasture grass and has proven to have excellent winter hardiness. It makes good grazing with a protein content lower than timothy. Competition with weeds was the main problem to establishment in the YCDP trials.

Meadow Foxtail- Common No.1 seed was used. This is a long lived perennial grass which begins as a bunch type but forms a dense sod with time. The panicle resembles that of timothy. It has a preference for soils with a high water table and is tolerant of alkalinity. It heads out earlier than other hay grasses and regrowth is rapid after cutting. It is primarily used as a pasture grass and produces a nutritious forage over a long grazing season. It can be used for hay, although lodging may be a problem.

**Legumes:**

*Peace* Alfalfa: This was the best commercially available alfalfa grown in the NCDP trials. This is a hardy variety developed at the Agriculture Canada Research Station in Beaverlodge, Alberta. It has a creeping rhizomatous root system and is part of the variegated group of cultivars (Medicago media). This is a popular variety in the Peace region and has good persistence and growth after cutting. It is more resistant to fall cutting than any other variety, although it requires four weeks of growth before the ground freezes. Research has shown that adequate moisture levels especially during the establishment period, and having adequate growth after cutting to allow for plant reserves into winter is important for yields and survival.

Figure 6.6 Alfalfa

Source: *Production and Management of Cultivated Forages*, P.D. Walton, Reston Publishing Co., 1983, pg 81.

Red Clover: Common No 1 seed was used. This is a single cut type most commonly grown in Alberta which is more persistent and winter hardy than the double cut types. It is a short lived perennial with stands persisting for 2-3 years. Red clover is intolerant of salinity or lengthy periods of drought. It is best used as a smaller component of hay mixtures as it has a high moisture content and is difficult to dry as well as causes bloat. As the seed is relatively cheap compared to other legumes, red clover is used for a soil improvement crop or plowdown. This was also grown for soil improvement plowdowns in the YCDP trials.

Aurora Alsike Clover: This is a diploid type bred at the Agriculture Canada Research Station in Beaverlodge, Alberta. This is adapted to cool climates, grows on many soil types, and can survive short periods of flooding. This is less susceptible to winter kill than red clover. Alsike is usually grown in mixtures for hay and pasture. It is used as a soil improvement crop and was also tested for this purpose in the YCDP trials. It was a better yielder than red clover.

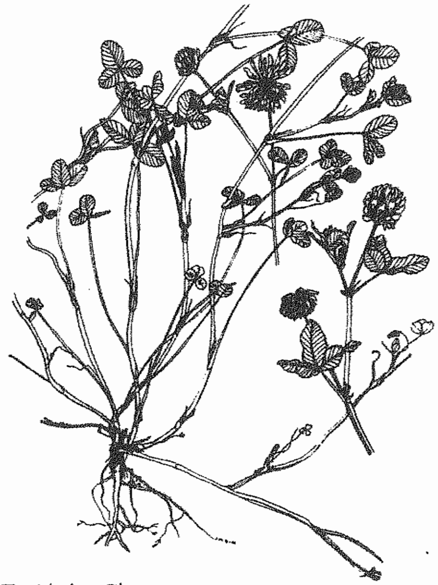


Figure 6.7 Alsike Clover

Source: *Production and Management of Cultivated Forages*, P.D. Walton, Reston Publishing Co., 1983, pg 87.

**Forage Mixes/Commercial Blends:**

Foster's High Hay Mix: (50% Bromegrass, 20% alfalfa, 20% crested wheatgrass, 10% red clover). This mix sold by Foster's Seed Co. combines the persistence of bromegrass, the nutrition of alfalfa and the drought tolerance of crested wheatgrass. The alfalfa and red clover had mostly died out by the third year.

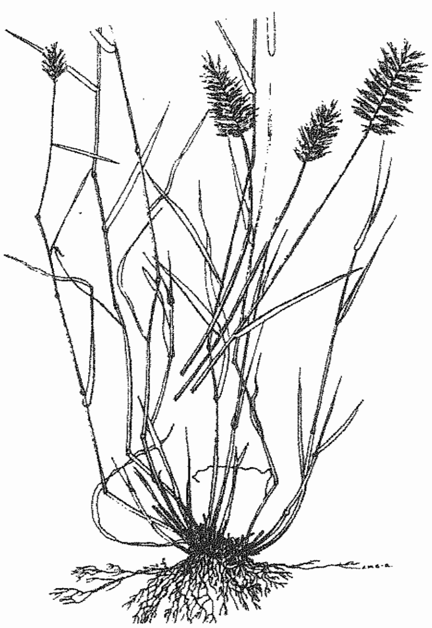


Figure 6.8 Crested Wheatgrass

Source: *Production and Management of Cultivated Forages*, P.D. Walton, Reston Publishing Co., 1983, pg 55.

Foster's Stockman's Mix: (40% Bromegrass, 40% Crested Wheatgrass, 10% Russian Wild Rye, 5% Alsike Clover, 5% Sweet Clover). This mix sold by Foster's Seed Co. is adapted for prominently drier areas where a longer lived stand is desired. This mix was dominantly bromegrass and crested wheatgrass by the third year.

Hannas High Tech Blend: This is blend of 5 certified alfalfa varieties selected for winterhardiness and wilt resistance made by Hannas Seeds in Lacombe, Alberta. The mixture is made of cultivars of which 20% have creeping root systems and 80% have tap root systems.

Hannas Hay Mix: (55% Hannas High Tech Blend, 30% bromegrass-Carlton, 15% Timothy-Climax. This is popular hay mix in Alberta and provides a good quality feed. The alfalfa had primarily died out by the third year, with

**Haines Junction Mile 1019**
**1945-1952 Research Report**

*"Forage legumes have produced at Mayo Landing, the Pelly River valley, the Stewart Valley and the Klondike. Most of the hardy forages grasses, ie. brome, slender wheat grass, crested wheat grass, creeping red fescue and Kentucky bluegrass have proved hardy and adaptable."*

**Haines Junction Mile 1019**
**1953-1959 Experimental Farm Progress Report**

*Grasses: "Bromegrass was the hardiest grass tested and produced satisfactory forage. It was used as the main species in pasture and hay mixtures for upland areas. It was relatively easy to establish, tolerated drought and was damaged little by insects or disease. Crested wheat grass is hardy and adapted to the area. Because of its early spring growth it was used in pasture mixtures. It withstood considerable drought. Intermediate and slender wheat grasses tolerate drought and are hardy in the area. They were readily established on light textured soils. Russian wild ryegrass is winter hardy and adapted to the area and was used in pasture mixtures. Engmo, a recently introduced variety of timothy was very promising. Creeping red fescue and Kentucky bluegrass are winter-hardy and were easily established but were often damaged by snow mold. Other promising species as secondary grasses in pasture mixtures were wild ryegrass and tall fescue. Timothy is best suited as a low land hay crop. When used as such it will produce hay of good quantity and quality."*

bromegrass and timothy remaining. YCDP Mix: (50% Bromegrass-Carlton, 30% Alfalfa-Peace, 10% Timothy-Climax, 5% Alsike Clover-Aurora, 5% Red Clover). This mixture was created for the YCDP trials using the varieties which were good producers in the NCDP trials. By the third year, this mix was dominantly bromegrass and timothy.

### *Agriculture Branch Trials*

At the Agriculture Research Branch plots north of Whitehorse, grass trials were established in 1988 to test species suited for forages, pasture mixes and reclamation purposes. Species with the best growth and > 50% success are listed in Table 6.2.

Table 6.2 Agricultural Branch Forage Trials

**Grasses:**
*Nugget* Kentucky Bluegrass
*Banff* Kentucky Bluegrass
*Garrison* Creeping Foxtail
*Altai* Wild Rye
*Durar* Fescue
*Arctared* Red Fescue
*Boreal* Creeping Red Fescue
*Manchar* Smooth Brome
*Carleton* Smooth Brome
Meadow Foxtail
Intermediate Wheatgrass
Slender Wheatgrass
Tall Wheatgrass
Russian Wild Rye

### *Alfalfa Research*

Alfalfa, has shown promise in the Yukon. It requires a good seedbed and adequate moisture conditions. Alfalfa does not like it too wet, or too dry. The pH and balance of nutrients is also very important. It does not like soils with a high pH above 7.8. or acid soils. (See Salinity Research Project – Crop Management.)

**Haines Junction Experimental Farm**

In 1961, at the Haines Junction Experimental Farm-Mile 1019, 56 alfalfa plants were selected for a breeding program to develop an alfalfa resistant to brown root rot. The parents were selected on the basis of their ability to tolerate the disease. BL1019 alfalfa was developed from these strains and after the closure of the Haines Junction Station in 1968 was further developed at the Beaverlodge Research Station in Beaverlodge, Alberta. Beaverlodge intends to release BL 1019 as a northern cultivar of alfalfa to seed producers for multiplying the seed. At this time there is not enough seed available for additional research in the Yukon.

**NCDP Trials 1985-1987**

Eight varieties of alfalfa, provided by Beaverlodge Research Station, were planted in rows to compare growth. Commercial varieties included Anik, Peace, Beaver and Drylander. Numbered varieties from Beaverlodge included BL1019, Krasnou-6, NRG-84-4 and S7312. BL1019 developed at Beaverlodge was the best producer. Of the commercial varieties, order for best production was Anik, Peace, Beaver, and Drylander.

#### *Haines Junction Mile 1019 Report*

*Alfalfa :Ninety nine species, varieties, and strains of legumes were tested. Yellow flowered alfalfa, Medicago falcata, is the only legume which survived each season. All varieties of* Medicago media *were attacked by brown root and did not survive through the winters. Of the* M. media *varieties, Rambler alfalfa, was the most tolerant of brown root rot. "Brown root rot" is caused by a parasitic fungus, Plenodomus meliloti, which attacks the tap roots of legume plants 4-5" below the ground level; and infected plants are soon weakened and killed. The lateral roots help to sustain growth. Medicago falcata has a more extensive lateral root system and shows quite marked resistance and hence is recommended as the most suitable species of domestic field legume for the Yukon. This organism thrives in cold soils and was first noted at the Farm in 1952. It has since been found to be common in Yukon soils.*

**Agriculture Branch Research Plots**

*Peace* alfalfa was planted in 1990, at the Agriculture Branch research plots within the Forestry Reserve north of Whitehorse, and has survived 3 winters. In 1993, plots were beginning to thin out and reseeding would probably be done if it was a commercial operation. Yields have been promising with application of fertilizer as per soil test recommendations at planting and each following spring. Plots were mowed at 10% bloom the second and third year. Bl1019 also performed well at the Agriculture Branch research plots.

**Salinity Research Plots**

(See Salinity Research Project – Crop Management for project description). A plot of alfalfa was seeded in the non-saline area, similar to many field conditions along the Mayo Road and Takhini Hotsprings Road, north of Whitehorse. It was seeded in dry conditions in the middle of August 1990. Seed was inoculated and handbroadcast with a cyclone spreader along with the recommended fertilizer rate, and then lightly rototilled in with a small rototiller. Germination was excellent in the following spring and a good dense stand was established in the first year. Recommended fertilizer was applied in the spring of 1991, 1992 and 1993. The effects of winter 1991-92 were better than expected and over 75% of the plot survived. The plot was very productive in the 1992 season and was mowed to simulate a field harvest in mid August. In 1993, density of the stand was reduced and growth was about 1/2 of the original growth in the first year.

### *Tolerance of Forage Crops to Salinity*

For soils with a higher degree of salinity (See Electrical Conductivity (E.C.) – Soil Management), one has to consider the tolerance of a forage variety to salinity.

**Non-Saline- Slightly Saline:**

- Red Clover
- Alsike
- Timothy

**Moderately Saline:**

- Bromegrass
- Crested Wheatgrass Alfalfa
- Sweet Clover
- Intermediate Wheatgrass
- Meadow fescue

**Severly-Very Severley Saline:**

- Altai Wild Rye
- Russian Wild Rye
- Slender Wheatgrass
- Tall Wheatgrass
- Alkaligrass

## SEEDING RATES

Using the proper seeding rate is fundamental to good forage production. Too low of a seeding rate can result in a sparse stand while too high a seeding rate can cause growth too dense for proper development. There are many factors which can affect the success of a particular seeding rate, including viability or germination %, soil and climate conditions, planting and maintenance methods. In drier conditions usually a higher seeding rate is recommended, and if broadcast, rates used for planting with a seed drill should be adjusted by increasing the amount by about 1/2. If plantings are done in the fall, for drill seeding, rates should be increased by roughly 1/2 and for broadcast seeding, rates should be doubled to provide for potential losses during the winter months.

> *"Generally very little attention is made to seed size and how it relates to seeding rates and proportions in mixes. When determining forage seeding rates consider seeding density (number of seeds per square foot or square metre. Seeding densities of 50 seeds per square foot (533 per square metre ) are common for many forage stands. However, this density will result in seeding rates from 3-30 kg/ha and discretion must be used in determining rates."*
>
> - *Selecting a Pasture Mix for the Peace*, BC Ministry of Agriculture and Fisheries, Factsheet, Agdex 130.34.

Table 6.3 indicates the recommended seeding rates for single forage varieties and Table 6.4 indicates seeding rates for mixtures of grasses and legumes, suitable for the Yukon. These tables have been compiled from Alberta Agriculture publications. Rates are for seeding with a seed drill at various row spacings.

Table 6.3 Seeding Rates for Pure Forage Stands

| | Approx. No of Seeds | | Seeding Rate in lbs/ac or kg/ha for various row spacings | | |
|---|---|---|---|---|---|
| | seeds/lb | seeds/kg | 6 in. (15cm) | 12 in. (30cm) | 24 in. (60cm) |
| **Legumes** | | | | | |
| Alfalfa | 200,000 | 440,000 | 10 | 5.5 | – |
| Alsike Clover | 700,000 | 1,540,000 | 5.5 | – | – |
| Sweet Clover | 260,000 | 572,000 | 9 | 6 | – |
| Red Clover | 275,000 | 605,000 | 7 | 4.5 | – |
| White Clover | 800,000 | 1,760,000 | 5 | – | – |
| **Grasses** | | | | | |
| Smooth Bromegrass | 136,000 | 300,000 | 9 | 6 | – |
| Meadow Bromegrass | 80,000 | 176,000 | 12 | 7 | – |
| Timothy | 1,230,000 | | | | |
| Kentucky Bluegrass | 2,180,000 | 4,800,000 | 7 | 5 | – |
| Crested Wheatgrass | 175,000 | 385,000 | 7 | 5 | 3 |
| Intermediate Wheatgrass | 88,000 | 194,000 | 11 | 7 | – |
| Slender Wheatgrass | 160,000 | 350,000 | 9 | 6 | – |
| Tall Wheatgrass | 79,000 | 174,000 | 13 | 10 | – |
| Northern Wheatgrass | 155,000 | 340,000 | 8 | 6 | 4 |
| Western Wheatgrass | 110,000 | 242,000 | 11 | 7 | 4 |
| Pubescent Wheatgrass | 100,000 | 220,000 | 11 | 7 | 5 |
| Creeping Red Fescue | 615,000 | 1,353,000 | 5.5 | 3.5 | – |
| Meadow Fescue | 230,000 | 506,000 | 9 | 6 | – |
| Tall Fescue | 225,000 | 500,000 | 8 | 5 | – |
| Meadow Foxtail | 575,000 | 1,270,000 | 6 | 3.5 | – |
| Creeping Foxtail | 750,000 | 1,657,000 | 5 | 3 | – |
| Orchard grass | 650,000 | 1,439,000 | 6 | 4 | – |
| Russian Wild Rye | 175,000 | 385,000 | – | 5.5 | 3.5 |
| Altai Wild Rye | 55,000 | 121,000 | – | 13.5 | 9 |

Table 6.4 Seeding Rates for Forage Mixtures

| | Approximate Seeding Rate lbs/acre of kg/ha | |
|---|---|---|
| Mixture | Hay | Pasture |
| Smooth Bromegrass + Alfalfa | 6 + 5 | 8 + 3 |
| Crested Wheatgrass + Alfalfa | 5 + 4 | 7 + 3 |
| Russian Wild Rye + Alfalfa | – | 3 + 2 |
| Creeping Red Fescue + Smooth Bromegrass + Alfalfa | – | 2 + 6 + 3 |
| Timothy + Alfalfa + Red Clover | 4 + 2 + 3 | – |
| Timothy + Alsike Clover | 4 + 4 | – |

Sources: *Alberta Forage Manual*, Alberta Agriculture, Agdex 120/20-4, 1985.
*Varieties of Perennial Hay and Pasture Crops for Alberta 1987*, Alberta Agriculture, Agdex 120/32, Print Media Branch, Edmonton, Revised March 1987.

### *Single Varieties\Mixtures*

Pure stands of forages are often planted in the Yukon, smooth bromegrass being the most commonly planted grass. Mixtures of a grass and legume are often better than single species stands, and are recommended for hay and pasture. The use of one grass and one legume, if well adapted to the environment and intended use, will frequently give maximum yield.

The percentage of each species desired in the mixture should first be determined. Then the quantity of seed required to seed a pure stand can be used as a guide for determining the amounts of each species required.

### *How to Calculate Your Seed Requirements:*

For each crop, determine your field area: in acres or hectares

**Example** 150' x 450' = 67,500 sq ft divided by 43,560
= 1.5 acres

**Example** 45.7m x 137m = 6261 sq metres divided by 10,000
= .63 ha

Multiply area x seeding rate = amounts of seed needed/area.

Seeding rates for kg/ha and lbs/acre can be considered the same. To be exact use the conversion figures:

lbs/acre x 1.12 = kg/ha

kg/ha x 0.89 = lbs/acre

An easy formula for calculating seeding rates and calibrating the seed drill is presented in Seeding Rates – Cereal Production.

### YCDP Trials

Seeding rates used during the YCDP trials (1988-1990) are indicated in Table 6.5 in lb/ac. These seeds were broadcast and rates were roughly doubled from the recommended Alberta rate. No plots were irrigated. For description of mixtures see the variety description section.

Table 6.5 Seeding Rates – YCDP Trials

| Single Varieties | lbs/acre |
|---|---|
| **Grasses:** | |
| Brome-Carlton | 18 |
| Brome - Polar | 18 |
| Meadow Brome-Regar | 18 |
| Timothy-Climax | 14 |
| Timothy-Engmo | 14 |
| Meadow Foxtail | 12 |
| Kentucky Bluegrass-Nugget | 10 |
| **Legumes:** | |
| Alfalfa-Peace | 16 |
| Alfalfa - Hannas High Tech Blend | 16 |
| Sainfoin Clover | 35 |
| Red Clover | 10 |
| Alsike Clover - Aurora | 10 |
| **Hay Mixtures:** | |
| Brome-Carlton + Alfalfa-Peace | 9 + 7 |
| YCDP Mix | 18 |
| *Table 6.5 Cont.* | |
| Foster's High Hay Mix | 18 |
| Foster's Stockman's Mix | 18 |
| Hannas Hay Mix | 18 |

### Agriculture Branch

For seedings for the Agriculture Branch plots and the salinity research project (1990-1993) north of Whitehorse, it was found that, for hand broadcasting, a higher seeding rate provided for better establishment. Seeding rates were increased for alfalfa to 30 lbs/acre and for bromegrass to 25 lbs/acre.

## FORAGE ESTABLISHMENT

There are a number of factors to good forage establishment:

1. Choose the best variety to suit your needs, a suitable location (climatic parameters) and soil type. Hardiness is a key factor in most forage selections, as well as, potential period of growth.
2. Good seedbed preparation.
   The requirements of a good seedbed are tillage to proper rooting depth, available moisture that allows for a continuous supply to the seed through the germination and early seedling period and good aeration. A crusted soil surface can prevent germinating seeds from emerging.
3. Good nutrient availability.
   Get a soil test (See Soil Sampling – Soil Management) and apply appropriate nutrients as required. A forage stand which lacks vigour will not become competitive and will be taken over by weed growth.
4. Soil moisture and temperature levels.
   Drought or drying is most serious in the seedling stage. Seeding should be done when there is adequate soil moisture. Low soil temperatures for a long period of time may also affect germination. Waterlogged soils due to poor drainage and/or overwatering, are cold soils with a lack of oxygen. This soil condition can greatly reduce vigor of an establishing stand.
5. Wrong Seeding Depth
   Soil freezing can cause damage to germinating seed and young seedlings. The frost can lift the seedlings with roots near the surface, out of the ground. If well covered with soil, injury is less likely. Planting too shallow or on the surface can dry out after germination takes place. Planting too deep, especially in heavier soils will cause forages not to emerge.

Source: *Forage Establishment*, *BC Agriculture Fact Sheet*, Forage Information Series, 90-38, Agdex 120.22.

### *Field Preparation*

Small seeded forages require a fine,firm seedbed which is moist and free of weeds. A firm seedbed helps to control depth of seeding, hold moisture near the surface and provides a good anchorage for seedling roots. Many factors affect the success of forage growth. Two very important factors, are removal of competition from existing vegetation and placement of seed in a warm, moist soil for good germination to take place.

Fields should be cultivated near planting time to reduce weed growth, surface cover residues, and maintain soil moisture. A proper balance needs to be maintained between the extremes of low moisture-high aeration and high moisture-low aeration. Cultivated soils tend to dry out more quickly. If cultivation is done too soon before seeding, soils may be too dry and weeds may have had an advantage (in time) to re-establish and provide competition to the forage crop.

*I had cultivated a small area about 2 weeks before planting, then handbroadcast the area to alfalfa, which was then lightly rotilled to incorporate the seed. Before the alfalfa had time to establish weeds (Narrow Leafed Hawksbeard, Dandelion,etc.) had germinated throughout the plot. The alfalfa seedlings had difficulty competing and the quality of the stand was adversely affected. If the area had been cultivated just before planting, I think the alfalfa would have been able to better compete with the weeds.*

-Whitehorse Producer

### *Seeding Methods*

Forage grasses and legumes must have shallow placement in the soil. Best results are obtained when the seed is placed between 0.5-1.5cm (1/4-3/4 inch) below the soil surface. Deeper than 2.5cm (1 inch) can be detrimental to many small seeded grasses and legumes. Deeply planted seeds have a better survival rate on sandy soils than on clay. It is important to seed shallower on heavy textured soils.

A grain drill can be used to plant forages as long as the depth of seeding is kept relatively shallow(less than 2.5cm (1in.). For small seeded forage grasses and legumes, grain drills may be fitted with a forage seedbox. The best method of placement is by using a precision packer seeder such as a Brillion Seeder. It has two corrugated rollers and a forage seedbox. The soil surface is firmed into shallow corrugations by the first roller. The seed is broadcast, and the second roller firms the soil around the seed. Seed may be broadcast over the prepared seedbed with a "spinner" or oscillating" type seeder. This can be a broadcast spreader normally used for fertilizer or the small hand 'Cyclone' broadcaster. Seeds should be harrowed soon after seeding and adequately covered. Care must be taken to ensure seeds in pasture or hay mixtures with a variety of seed sizes, re well mixed, ie. in pasture or hay mixes and that the application rate is as desired.

Some seed drills do not exactly seed as the seeder indicator is set to; ie. 30 lbs/acre could indeed be less. A trial run should be done to determine actual seeding rate/ft or metres and thus over the field area. (See Seeding Rates – Cereal Production)

#### YCDP Trials

'Cyclone' hand broadcasters were used for seeding most of the forage plots. Tractor drawn broadcasters and a Brillion seeder were also used when available. Seed was then harrowed or lightly incorporated into the soil with a rototiller immediately after seeding.

#### Timing of Planting

Seeding to coincide with favorable moisture conditions is the most important factor in establishing forage stands. Dry conditions in the spring, especially in the Whitehorse area can be a limitation to early spring plantings. For non-irrigated fields, some producers in the Whitehorse area wait until July to seed forages as there is usually more moisture. Fall seeding is also an option and has been successful in the Whitehorse area. This should be done in late fall, when temperatures are cool and there is no chance of germination. Seeding rates should be increased by 1/2 the normal rate using a seed drill and roughly twice the amount if broadcasting to compensate for potential seed loss.

## COMPANION CROPS

Companion planting forages with oats, barley or annual ryegrass has been done by local producers. Seed the companion crop at 1/2 of the usual seeding rate. This can be done by mixing the companion crop with the forage seed and broadcasting or drill seeding it. When using a seed drill, the companion crop can be seeded in alternate rows.

In B.C., generally the use of companion crop is not recommended as they can cause reduced forage vigor and increased mortality of forage seedlings due to competition. To reduce competition, it is advisable to cut the companion crop for hay or silage or graze it when it is 10-14" (25-36cm) tall. This will allow seedling grasses and legumes more light and less competition, hence better establishment.

## MANAGEMENT METHODS

### *Fertilizer*

The effect of nutrients on forage quality:

**Nitrogen** - increased crude protein

**Phosphorous** - increased P content and earlier maturity may increase energy levels.

**Potassium** - main effect is on mineral content and can improve legume winter hardiness

**Sulphur** - main impact on yield and protein level an is necessary for legume survival and cereal production

**Magnesium** - alfalfa has higher requirement than grasses or cereals

**Boron** - affects legume growth and survival and protein content of feed

**Copper** - increase nutrients, yields and protein

Boron Deficiencies: Alfalfa and Clovers develop specific visual symptoms:

**Alfalfa** - At the growing tips of plants the youngest leaves turn yellow, then red , progressing to a light brown colour. The main stem between leaf offshoots becomes shorter and the growing tip develops a rosette appearance. Older bottom leaves retain their colour. The plant develops a stunted appearance. Flowers may fail to form or are delayed. Buds will turn white or light brown when the deficiency is severe.

**Clovers** - Leaf symptoms are similar to alfalfa but there is a tendency for more reddish or purplish colours to develop. Stems at the tips become thickened.

**YCDP -Boron Trial on Alfalfa**

Alfalfa requires 20 Lbs/acre boron applications if the soil is deficient. At a farm north of Whitehorse and a farm near Mayo, both sites were deficient in boron and this was applied at the rate of 20 lbs/acre on alfalfa. This application improved alfalfa growth and was much better than adjacent growth with no boron fertilizer at both sites.

> **Haines Junction Mile 1019 1945-1952 Research Report**
>
> *"Three varieties of brome-grass, Manchur, Manadan and Canadian commercial had increased yields on the Pine Creek Silty clay when nitrogen was applied at 33 lbs/acre. Protein content of the forage was not increased significantly. Seed yield was not increased nor was the rate of germination improved by the fertilizer. The root weight of the soil in the top 6 inches tended to decrease with the addition of fertilizer. There was no varietal differences in response to the application of nitrogen."*

### Weed Control

Forage grasses and legumes are small seeded and not very competitive in the seedling stage. They are very susceptible to competition from other plants for light, moisture and nutrients.

Controlling weeds in a newly established forage may be accomplished by clipping or the use of herbicides. If good cultural practices are used throughout the establishment phase, herbicides may not be required. Weeds are cut low to remove tops and active growing buds. Care should be taken when conditions are too dry as clipping too low can be detrimental to the forage stand. Local forage producers have found success with clipping.

**YCDP Trials**

At a 5 Acre forage trial north of Whitehorse, there was volunteer oats (from the previous year's oat crop) and a number of weeds in the first year of forage establishment (1988). In late August, the forage trials were mowed to a height of 13" (33cm) to prevent the volunteer oats and weeds from reaching maturity. This height was to allow for adequate plant reserves of the forages for the winter. There was no further oats and reduced weeds in 1989.

In excessively weedy forage stands it may be necessary to use a rotation with an annual crop for clean up of perennial weed problems. In BC, research has shown the benefits of using rotations for weed control.

### Assessing Winter Injury of Alfalfa

A field method to evaluate low temperature winter injury of alfalfa can be used early in the spring as soon as the soil thaws, to allow time to make reseeding plans in case of significant low temperature winter injury. To assess look for this:

1. Viable buds are white, turgid and may be pink tipped.
2. Injured buds are dry, discoloured limp or shriveled.
3. Root bark is more easily peeled, roots are soft and easily squeezed when injured.

Do a random sampling of your field or plot area, at regular intervals dig up an alfalfa plant and inspect the injury. Inspect and rate for three characteristics: bud vigor, interior root colour and resistance of bark to peeling. Determine bark resistance to peeling by scratching the root surface with a thumbnail.

1. Bud Vigor
   - 1: Obviously Dead
   - 2: Healthy tips, base soft and discolored
   - 3: A few healthy Buds
   - 4: Majority healthy; white or pink, firm throughout bud
2. Root Resistance to Peeling
   - 1: Low
   - 2: Medium
   - 3: High
3. Root Interior Colour
   - 1: Brown or Yellow
   - 2: Slightly Brown or Yellow
   - 3: White or Cream

Separate the symptoms of winter injury from those of possible root rot. Root rot symptoms include dark brown streaks extending down from the crown and are sufficiently decayed to distinguish them from winter injury lesions. If the root is discolored and soft at the top 3cm, but firm and white at 15 cm deep then it is given a low rating. Healthy lower root tissue is of no advantage if the upper root and crown are dead.

Source: *Rapid Evaluation of Alfalfa Frost Injury*, BC Fact Sheet, Forage Information Series,90-26, Agdex 121.20

As the top growth of a alfalfa crop increases and matures, a larger part of the accumulated daily carbohydrates (the material form of energy captured from sunlight) is diverted underground for storage in the grounds and roots. Stored energy reserves consist of Total Nonstructural Carbohydrates (TNC), or the sum of all sugars, starches etc. available for the growth of the alfalfa plant. When TNC storage levels are high, resumption of growth after winter or cutting will be rapid, so long as water and temperature are not limiting factors. High levels of TNC going into winter is a major requirement for survival of alfalfa.

Source: *Managing Alfalfa for High Quality Hay*, BC Agriculture Factsheet, Forage Information Series, 91-20.

## FORAGE QUALITY

### Characteristics of A Good Hay

1. It is made from plants cut at an early stage in maturity, thus ensuring the maximum content of proteins, minerals and vitamins and the highest digestibility.
2. It is leafy thus giving assurance of high protein content
3. It is bright green in colour, thus indicating proper curing, a high carotene or provitamin A content and palatability.
4. It is free from foreign material such as weeds, stubble etc.
5. It is free from must, mold and dust and has a pleasant aroma.
6. It is fine stemmed and pliable – not coarse, stiff and woody.

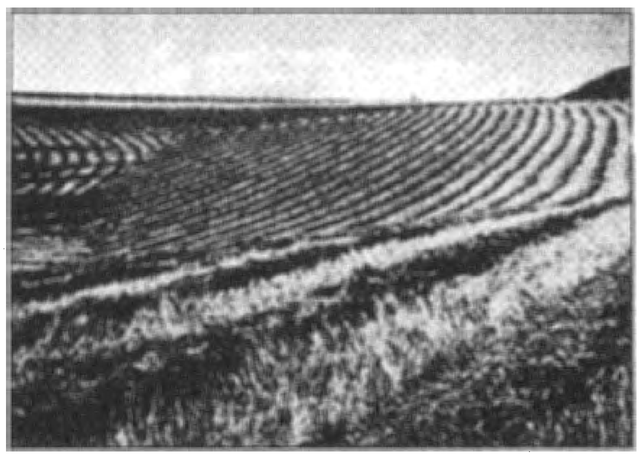


Figure 6.9 Hay Production

### How to Produce Good Quality Hay

1. Select a known successful variety
2. Order certified seed or get good quality common seed.
3. Cut at an Early Stage of Maturing
   *Grasses* - Heading Out to Bloom stage
   *Legumes* - Alfalfa - Prior to 1/10 bloom, or when new shoots develop from the crown
   *Alsike/Red Clover* - Early Bloom to 1/2 bloom stage
   *Sweet Clover*- When blooming begins
   *Field Peas* - When pods are 1/2 to fully matured
   *Cereals* - When the grain is in the milk to soft dough stage.

> ***"When to mow is more important than how to mow."***

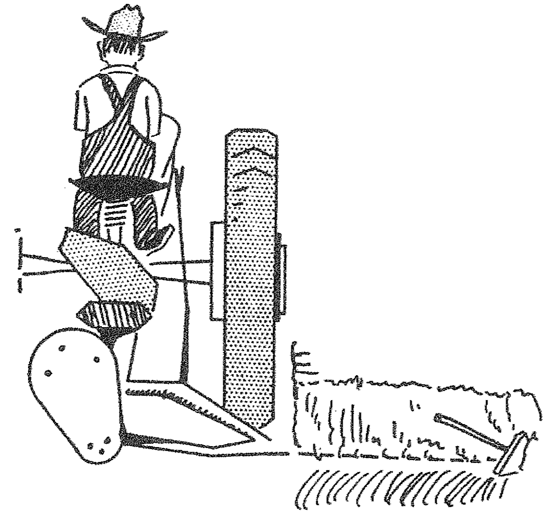


Figure 6.10 Cutting Hay

4. Cure Properly
   *a) Moisture Content* - Freshly cut hay contains 75-80% moisture; the maximum moisture content for safe hay storage is as follows:
      Loose Hay - 25% moisture
      Baled Hay - 20-22% moisture
      Chopped Hay - 18-20% moisture
   Hay should not be stored at a higher moisture content due to the possibility of mold, nutrient loses accompanying fermentations and the danger of spontaneous combustion and a costly fire.

**Two rule of thumb methods** used in determining when hay is dry enough for storage are:

1) the Twist Method - Twist a wisp of the hay in the hands. If the stems are slightly brittle and there is no evidence of moisture on the twisted stems, the hay can be stored safely.

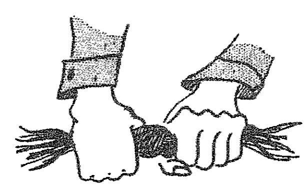


Figure 6.11 The Twist Method

2) the Scrape Method - Scrape the outside of the stems with the finger or thumb nail. If the epidermis can be peeled from the stem, the hay is not sufficiently cured. If the epidermis does not peel off, the hay is usually dry enough to stack or put in the mow.

*b) Shattering Losses* - In field curing hay, losses from leaf shattering range from 2-5% for grass hay and 3-39% for legume hays. Legume leaves dry out faster than the stems and 15-20% shattering can occur even under the most favorable conditions.

c) *Bleaching and fermenting losses* - The carotene or provitamin A content of freshly cured hay is proportional to greenness. With severe bleaching more than 90% of the vitamin A potency may be destroyed. There is unavoidable loss through fermentation especially losses in sugars,starch and carotene. With proper curing these losses will not be excessive.

d) *Leaching Losses from Rain* - Repeated showers are more damaging than one heavy rain. They are less severe soon after mowing but increase in severity with the curing process.

*Know your window of dry weather for proper curing. You can do everything perfectly, soil preparation, seeding and fertilizing but rain can ruin a whole crop. It is the most important factor in good hay production.*

- Dawson Producer

Field Curing;:

1. Cutting and curing in the swath

It is desirable to mow in the same direction as will be traveled in raking and in picking up the hay in subsequent operations.

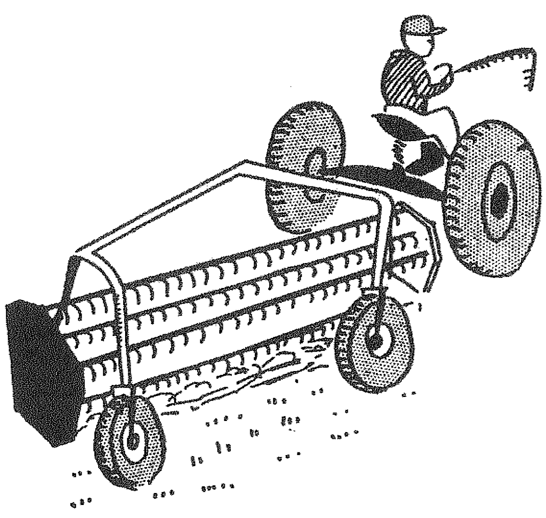


Figure 6.12 Raking Hay with a Side Delivery Rake

2. Hay conditioners assist with the drying process in the swath. No definite period for swath curing can be assigned as it will vary according to the tonnage of hay per acre, temperature, sunshine, wind and atmospheric humidity.

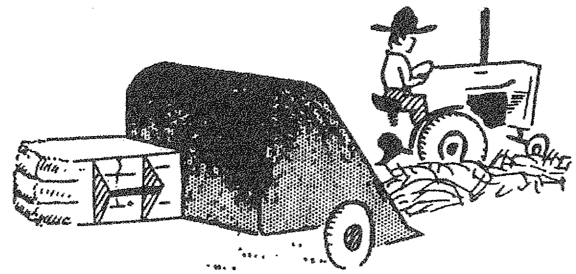


Figure 6.13 Baling Directly from the Windrow

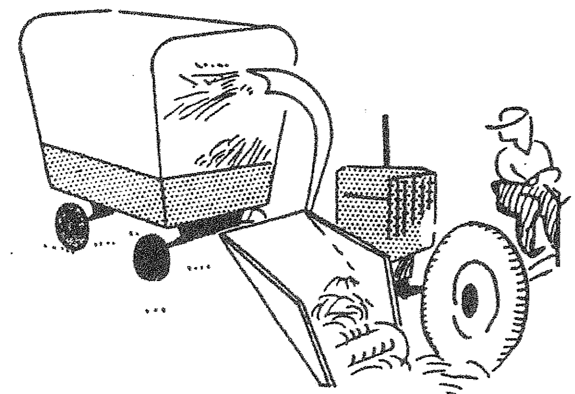


Figure 6.14 Collecting Cured Hay Directly from the Windrow

Source: Figures 6.10-6.14 from *The Stockman's Handbook*, Fourth Edition, 1970, with the permission of Interstate Publishers, Inc. Danville, Il. and of the author, Dr. M. E. Ensminger, P.O. Box 429 Clovis, CA, 93612.

*We've made silage for years to feed our herd of cattle. We mow our hay and directly collect it in wagons which is deposited in the silage pit and compacted to remove oxygen. Black plastic over the pit keeps off the rainfall. This is a labour saving method of harvesting, as one doesn't have to deal with moving bales. This method is also good for weed control as all the weeds are collected off the field when harvested and the weeds that go into the silage pit are killed from the heat of decomposition*

- Pelly Farm

## FEED QUALITY

The four most important agronomic factors which affect forage quality are choice of variety, nutrients and soil fertility, stage of maturity at harvest and crop management interactions.

Knowing the protein levels in your hay are a key factor in sales as the most common question for people buying hay is:

**What's the protein level?** Providing a copy of the feed test is is a good idea to help with marketing.

### Feed Testing

The Agriculture Branch has completed forage testing on locally grown forage crops. Growers may take in a sample of their hay and the Branch will test it for you. These samples are sent to Northwest Labs in Edmonton, Alberta, the same lab used for soil testing at the Agriculture Branch. Take a sample from the cut forage, spread it out to dry on a newspaper in a good drying area. Package it tightly in a small plastic garbage bag. About 1-2lbs (.45-.90 kg) is an adequate sample size. There are several feed testing packages from Norwest Labs:

1. Moisture, Protein (This is most commonly ordered.)
2. Moisture, Protein, Calcium, Phosphorous
2. Moisture, Protein, Acid Detergent Fibre (This was ordered for all YCDP trial feed samples.)
3. Moisture Protein, Calcium, Phosphorous, Acid Detergent Fibre
4. Moisture, Protein, Calcium, Phosphorous, Acid Detergent Fibre, Zinc, Copper, Magnesium, Manganese

There is an additional charge for chopping bulk forage. Additional individual tests are also available for vitamins, acids, pH, salts,crude fibre etc.

## *How to Interpret Your Feed Test*

Nutrient composition is expressed by "as fed basis" or "dry matter basis". All packages will have moisture % indicated on an "as fed basis" and protein % indicated for both "as fed" and "dry matter basis". Depending on the additional tests ordered results are given on an "as fed" and "dry matter" basis.

### Moisture %

The determination of dry matter is probably the most common procedure carried out in nutrition laboratories. Feed samples may be quite different in water content. It is necessary to know the water content if analytical data are to be compared for different feeds. This is expressed only on an "as fed basis".

### Crude Protein (CP)%

Crude Protein (CP) analysis determines the amount of Nitrogen (N) in the sample, though it does not distinguish one form of N from another. This means that it is not possible to determine if a feed mixture has urea or the highest quality of protein such as casein (from milk).

Crude protein levels are an indication of maturity of your crop, as CP % for grasses and legumes fall towards maturity. In Figure 6.15, the drop in CP % from first flower or boot stage to early seed stage is shown, where there is a potential drop of CP, from 21% to 14% for alfalfa, and 12% to 6 % for grasses.

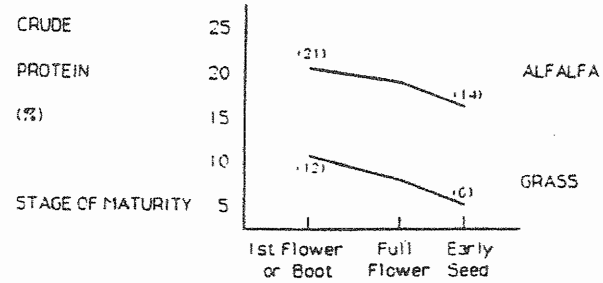



Figure 6.15 Effect of Maturity on Crude Protein Level

Crude protein levels below 6% are often due to late harvest of the stand with little or no legume content. In B.C., it has been shown that crude protein levels of grasses also fall with the age of the stand and that fertilized stands have a higher CP content than non fertilized.

There is also a drop in digestibility (energy) in grasses and legumes from the first flower or boot stage to early seed stage. (See Cereal Crop Physiology – Cereal Production). As shown in Figure 6.16, alfalfa declines from 76% to 52 % and grass declines from 69 % to 63%.

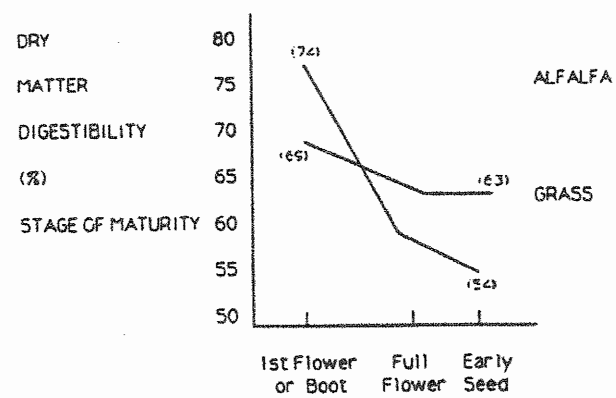



Figure 6.16 Effect of Forage Maturity on Digestibility

Source: (Fig. 6.15, 6.16): *Using Agronomic Practices to Improve Forage Quality*, BC Agriculture Factsheet, 90-44, Agdex 120.10.

### Acid Detergent Fibre % (ADF)

This analysis is done with an acid solution. Components of plant tissue soluble in acid detergent include primarily hemicelluloses and cell wall proteins. The residues include cellulose, lignin and lignified N, which is indigestible N , cutin, silica and some pectins. It is referred to as acid detergent fibre (ADF), expressed as a percentage on an "as fed" and "dry matter" basis.

ADF is the best indicator of stage of maturity and timeliness of cutting. If the ADF levels in the forage are high, indicating late harvesting, and crude protein levels are also high, it would suggest that large quantities of nitrogen have been applied and that non-protein nitrogen, especially nitrates may also be high. It may also indicate inefficient use of fertilizer.

*"Research in B.C. indicates that at low rates of N, yields respond in a linear fashion to additional nitrogen while crude protein remains relatively unaffected. At high rates of application, additional nitrogen will increase crude protein content more than yield. There is no evidence that nitrogen application has an affect on the digestibility (ADF) of grasses."*

- Source: *Using Agronomic Practices to Improve Forage Quality*, BC Ministry of Agriculture and Fisheries Factsheet, Forage Information Series, Agdex 120.10, 1990.

**Total Digestible Nutrients (TDN)%**

The TDN is a measure of energy and is the sum of digestible crude protein and carbohydrates. TDN is determined by carrying out a digestion trial, and summing the digestible protein and carbohydrates,which is crude fiber and nitrogen free extract (NFE) plus crude fat x 2.25. Fat is multiplied by 2.25 in an attempt to account for its higher caloric value which is about 2.25 x that of digestible carbohydrates. The relative value of TDN is comparable to digestible energy (DE).

**Digestible Energy (DE)**

The energy value of a feed where the Gross Energy (GE), or quantity of heat resulting from the complete oxidation of the feed minus the fecal energy is called Digestible Energy (DE). This is measured in Mecacal (Mcal) per pound or kilogram. A range of 1.1 to 1.3 Mcal/lb is a good level of digestible energy for a feed.

Source: *Basic Animal Nutrition and Feeding*, D. Church,W. Pond, J. Wiley & Sons, 1988.

**YCDP Trials - Protein Levels.**

Feed analysis was completed in 1989 and 1990 on the best yielders of grasses and pasture/hay mixes, harvested in mid July. Ranges or amounts of protein % for each species tested were as follows:

Table 6.6 Protein Levels - YCDP Trials

| | 1989 (%) | 1990 (%) |
|---|---|---|
| Brome-Carlton | 7.0 - 19.6 | 6.8 - 11.8 |
| Brome-Polar | 4.8 - 24.1 | 8.6 - 12.0 |
| Peace/Carlton Mix | 5.9 - 14.5 | 7.4 |
| YCDP Mix | 6.29 - 24.4 | 7.8 |
| Hannas Hay Mix | 4.1 - 17.3 | 10.4 - 10.5 |
| Hannas High Tech Blend | 15.7 - 17.5 | 13.8 |
| Foster's High Hay Mix | 5.7 - 16.9 | 4.4 - 12.2 |
| Foster's Stockman's Mix | 6.0 - 21.7 | 6.8 - 8.5 |
| Timothy-Engmo | 11.6 | 6.8 - 9.8 |
| Timothy Climax | 5.7 - 15.7 | 8.3 |
| Meadow Foxtail | 9.2 - 18.2 | 12.5 |
| Meadow Brome-Regar | 12.2 | 8.3 |

Table 6.6 Cont.

| | 1989 (%) | 1990 (%) |
|---|---|---|
| Alsike Clover | 18.0 | 13.0 |
| Alfalfa-Peace | 14.5 | - |
| Kentucky Bluegrass-Nugget | 16.2 | - |

**Agriculture Branch - Protein Levels**

Feed tests completed on bromegrass for crude protein content in the central, southeast and southwest regions of the Yukon include the following:
Southwest: Kluane east to Whitehorse
Southeast: Watson Lake
Central: Carmacks north to Dawson

Table 6.7 Protein Levels – Agriculture Branch

| Region | # of Samples | Average Protein (%) | Range of Protein (%) |
|---|---|---|---|
| Southwest | 38 | 10.23 | 3.57 - 19.30 |
| Southeast | 8 | 10.35 | 5.97 - 13.60 |
| Central | 10 | 10.66 | 5.82 - 15.90 |

There is very little difference in the average protein levels between regions, though there is a slight difference in the range of protein levels.

### *Feed Quality of Alfalfa*

Research indicates that the nutritional quality of alfalfa is more closely tied to morphological growth development of the plant than to other any " in field" indicator. Results suggest that the first cutting of hay should normally be made during bud stage. Definitions of maturity are "pre-bud, bud 1/10th bloom and early bloom. Most guides recommend the 1/10th bloom stage for harvesting the first cutting of alfalfa. Research in BC has shown that this is later than necessary affecting forage quality. If the stand is healthy and vigorous, cutting can safely be made in the early or mid-bud stage. However, if the stand is weak or has suffered considerable winter injury it might be best to forego quality and let it go to midbloom or later to enhance stand recovery. Of all the quality factors the producer can control, timing of cutting is most important. The management challenge is to time the cutting so that both tonnage and quality are at an optimal threshold.

The first cutting should usually be cut before first bloom. Delaying cutting to avoid rain will often result in a greater loss of quality than from rain damage. Having a dry soil surface beneath rained on hay can help the producer to save and retain good quality.

Premium quality alfalfa hay should be free of odour, foreign material and contain greater than 20% crude protein (CP) and less than 20% acid detergent fibre (ADF). As the alfalfa plant matures the ADF increases while the crude protein and total digestible nutrients (TDN) decrease.

Rapid drying of windrowed hay results in lower losses of dry matter, due to respiration. This has been estimated to be a 1 to 2% weight loss for each day in the field.

Sources: *Field Tool for Predicting Quality of First Cut Alfalfa*, BC Agriculture Factsheet, Forage Information Series, 91-26. *Managing Alfalfa for High Quality Hay*, BC. Agriculture Factsheet,Forage Information Series, 91-20.

### *Pasture Bloat*

The type of forage determines the risk of bloat. Grasses very rarely cause bloat and are regarded by farmers and ranchers as bloat safe. Bloat causing forages include: alfalfa, sweetclover,red, white and alsike clover, and winter wheat. Oats and perennial ryegrass are low risk, and sainfoin, vetch, fall rye and most perennial grasses are considered bloat-safe. Reports of bloating from grasses are rare and are usually restricted to very lush pastures, where initial digestion rates are very high. Bloat potency is highest at the vegetative or prebud stage of growth and decreases progressively as the plant increases in height and matures to full flower. The potential is greater when moisture conditions are optimum for vegetative growth. Bloat potential of alfalfa is reduced when soil moisture is insufficient, either from drought or saline soil. Grazing alfalfa after flowering and avoiding drought or frost situations will reduce the risk of bloat. When irrigation is managed to maintain the soil moisture at 50% field capacity, (See Irrigation Practices – Crop Management) the bloat potential of alfalfa was not significantly affected by irrigation. In BC, bloat was more common in dry years than in years of high moisture.

Source: *Pasture Bloat*, B.C. Agriculture Factscheet, Forage Information Series, 90-34, Agdex 130.

## PASTURE MANAGEMENT

### Pasture Mixes

In the Peace area of BC, the trend in recent years has been toward "simple" mixtures of 2-3 species, since the most competitive forages prevail after a couple of years. The traditional forage "oldies" include smooth bromegrass, timothy, creeping red fescue as well as alsike clover and/or alfalfa.

The ideal horse pasture combines legumes and grasses. In general, grasses offer high dry matter intake, earlier spring and later fall grazing, than legumes. They also tend to develop a thick turf which discourages weeds and reduces damage from trampling. Grasses also reduce the risk of digestive upsets. Legumes on the other hand, are higher in protein and mineral content, maintain or improve nitrogen fertility and generally provide higher summer production. Legumes should be considered in the pasture blend for their superior nutritive value rather than their nitrogen ($N_2$) fixation, which is usually negligible under pasture conditions in most cases.

Alfalfa is difficult to maintain in the stand under continuous grazing. Rotational grazing should be considered. Alsike clover is probably the most important pasture legume because of its nitrogen ($N_2$) fixation, despite grazing, and its low growth habit. Red clover might also be considered for short term pasture, especially on acidic areas.

Sources: *Selecting a Pasture mix for the Peace*, BC Agriculture Factsheet, Forage Information Series, 90-16, Agdex 130.34. *The Basics of Pasture Management*, BC Agriculture, Forage Information Series, 92-07.

**Haines Junction Mile 1019**
**1953-1959 Report — 1957-1958 Highlights**

*Studies on hay and pasture mixtures were begun in 1956. Although alfalfa did not survive more than a few years, the mixture of alfalfa, bromegrass and crested wheatgrass appeared to be the most promising for hay and pasture.*

*Tall Fescue is very winter hardy and does well in a pasture mixture.*

*Crested wheatgrass starts early in the spring making it a very suitable grass for use in early pasture mixtures.*

*Slender and Intermediate wheat grasses are very winter hardy. They are best suited for use on poor sandy soil where they will provide some light grazing and will prevent soil erosion.*

*Russian wild rye grass produces an abundance of basal leaves and produces good spring pasture. However, the herbage becomes quite coarse in texture during mid-summer.*

*Creeping red fescue produces good plant growth on low land. It should be used only as a minor component of a pasture mixture.*

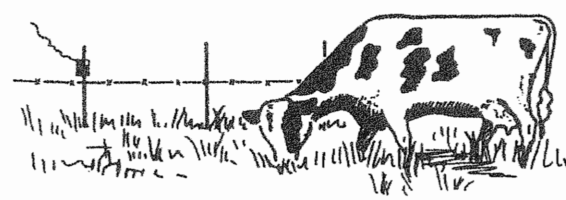


Figure 6.17 Control Grazing

Source: *From The Stockman's Handbook*, Fourth Edition, 1970, with the permission of Interstate Publishers, Inc. Danville, Il. and of the author, Dr. M. E. Ensminger, P.O. Box 429 Clovis, CA, 93612.

Good pasture management involves the following practices:

1. Controlled grazing

   *a) Protect first year seedlings* First year seedlings should not be grazed or only lightly during the first year. This helps the pasture become established. If the crop has sufficient growth it is better to mow it, 3in. (7.6cm) above the ground for hay or silage, instead of grazing.

**Research Station Mile 1019 - 1960-1964 Report**

*Five grass-alfalfa mixtures were seeded on a Pine Creek Silty clay and studied for hardiness, persistence and productivity under grazing. Mixtures consisted of combinations of bromegrass, crested wheatgrass, intermediate wheatgrass, Russian wild ryegrass, yellowed flowered alfalfa, Medidago falcata and M. media (Var. Grimm).*

*Bromegrass,yellow flowered alfalfa and crested wheat grass appear to be the best mixture for this region. The recommended rates of seeding per acre with a drill seeder) are bromegrass 6 lbs, crested wheatgrass 4.6 lbs and alfalfa 4 lbs, consisting of M. falcata and M.media.*

*The M.media (Grimm) variety was susceptible to Brown rot and decreased in the stand. Yellow flowered alfalfa was very slow in becoming established compared with Grimm, but because of its tolerance to brown root rot, it persisted better in the stand.*

*Russian wild ryegrass in the mixtures was very slow in becoming established. Intermediate wheatgrass was the least persistent of the grasses in the mixtures, also the least palatable. Crested wheatgrass dominated the stands in all these mixtures.*

*b) Rotation or alternate grazing* Divide the pasture area into 2-4 areas of equal size so that one area is grazed and the others are allowed to make new growth. Early grazing in the spring is the most critical time for pasture management. Allow 6-8 inches of growth before turning out to pasture in the spring, thus giving grass a needed start.

c) Shifting the location of salt, shade and watering areas can create a more uniform dispersal of droppings for pasture improvement.

*d) Avoid Overgrazing* Graze uniformly but never graze more closely than 5cm (2") and allow recovery until growth is at least 10cm high (4") Do not overgraze pastures in late fall as this will delay growth in the spring. With most pastures 3-5 inches (8-13cm) should be left over for winter cover.

*e) Avoid Undergrazing* A mature forage is unpalatable and of low nutritive value, tall grasses may cause shading and could reduce growth of lower plants in the mix. Weeds, brush and coarse grasses are more apt to gain a foothold when the pasture is grazed insufficiently.

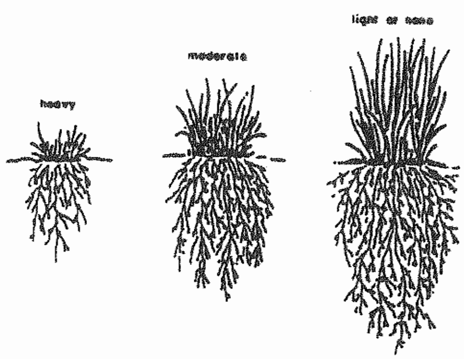



Figure 6.18: How Grazing Affects root Growth

Source: *Using Agronomic Practices to Improve Forage Quality*, BC Ministry of Agriculture and Fisheries Factsheet, Forage Information Series, Agdex 120.10, 1990.

2. Clipping pastures and controlling weeds

   Pastures should be clipped at intervals to control weeds, brush and to get rid of uneaten clumps and other unpalatable coarse growth left after grazing. Continuously grazed pastures may be clipped at or just preceding the usual haymaking time; rotated pastures may be clipped at the close of the grazing period. Weeds and brush can also be controlled by burning or chemicals.

3. Topdressing

   In most areas it is desirable and profitable to topdress pastures with fertilizer annually. These treatments should be based on soil tests and are usually applied in the spring or fall. Nitrogen fertilizers will often stimulate the growth of grasses so that they are ready for grazing 10 days to 2 weeks earlier than unfertilized areas.

4. Scattering Droppings

   The droppings should be scattered at the end of each grazing season in order to prevent animals from leaving ungrazed clumps and to help them fertilize a greater area. This is best done with a brush or chain harrow.

5. Variety of Grazing Animals

   Grazing of different types of animals makes for a more uniform pasture utilization and fewer weeds, providing the area is not overstocked.

6. Irrigating where possible and feasible.

   It alleviates the necessity of depending on the weather. Early season irrigation would increase growth thereby allowing for earlier grazing.

**Renovating Old Pastures**

Where a fair but unproductive permanent pasture stand exists, pasture improvement or renovation can be done by fertilizing, and seeding or overseeding. The fertilizer and seed can be worked into the soil by a harrow in the necessary patches. Overseeding should be harrowed or raked to cover the seeds as best as possible.

There was limited success with overseeding to improve forage trial plots during the YCDP trials. A chain harrow was used at one site and this was the most successful. Where the seeds were not worked into the soil, growth was poor due to reduced germination.

# CEREAL PRODUCTION

Small grain crops, including barley, wheat, oats, and rye have been grown in the Yukon since the turn of the century. Oats have been the main cereal produced, for green feed and grain.

Covered in this section, is cereal physiology, varieties of cereals grown in the Yukon, cereal crop establishment and management methods, and feed quality.

## CEREAL CROP PHYSIOLOGY

Cereal crops, including wheat, barley, oats and rye are members of the grass family known as "bunch grasses" grown for their edible seed. The bunch habit results from the development of basal buds near the base of the main stem that produce branches or stems called tillers. Each plant develops two separate root systems, the primary root develops first from the seed and later.

The secondary root system develops from the crown, just below the soil surface, which is the source of tillers as well as crown roots. The primary roots are joined to the crown by a sub-crown internode.

The seedling stage is a critical period of growth. The crown root system is responsible for supplying most of the plant's moisture and nutrient requirements. During unusually dry seasons, few or no tillers and crown roots form so that the primary roots must supply all nutrients to the main stem. When this happens yields are low even when the soil moisture is adequate when the heads are filling. The growth of a cereal plant and its various stages is important for management decisions.

The Feekes scale of growth, shown in Figure 7.1, was developed for the wheat plant but can be applied equally to the barley plant up to the boot stage. There are 11 stages of cereal growth. Cereal plants pass through a typical vegetative cycle including emergence, tillering, shooting and then a reproduction cycle, including jointing, boot stage, heading, then kernel formation: including filling out, and the milk, dough and mature stages of ripening.

### *Cereal Growth Stages*

**Vegetative Period:**

1. *Emergence:* The seed germinates and emerges.
2. *Seedling:* The plant forms one leaf,then 2-3 leaves.
3. *Tillering:* Shoots called tillers arise from the crown.

**Reproduction Period:**

4. *Jointing:* Stem extension, nodes 1 and 2 are forming to appearance of last leaf (flag leaf).
5. *Boot:* The head is prominent inside the upper leaf sheath which begins to open.
6. *Heading:* Ear emerges as a spike or panicle and flowering is completed. Barley pollinates before emerging from the boot. Flowering is completed.

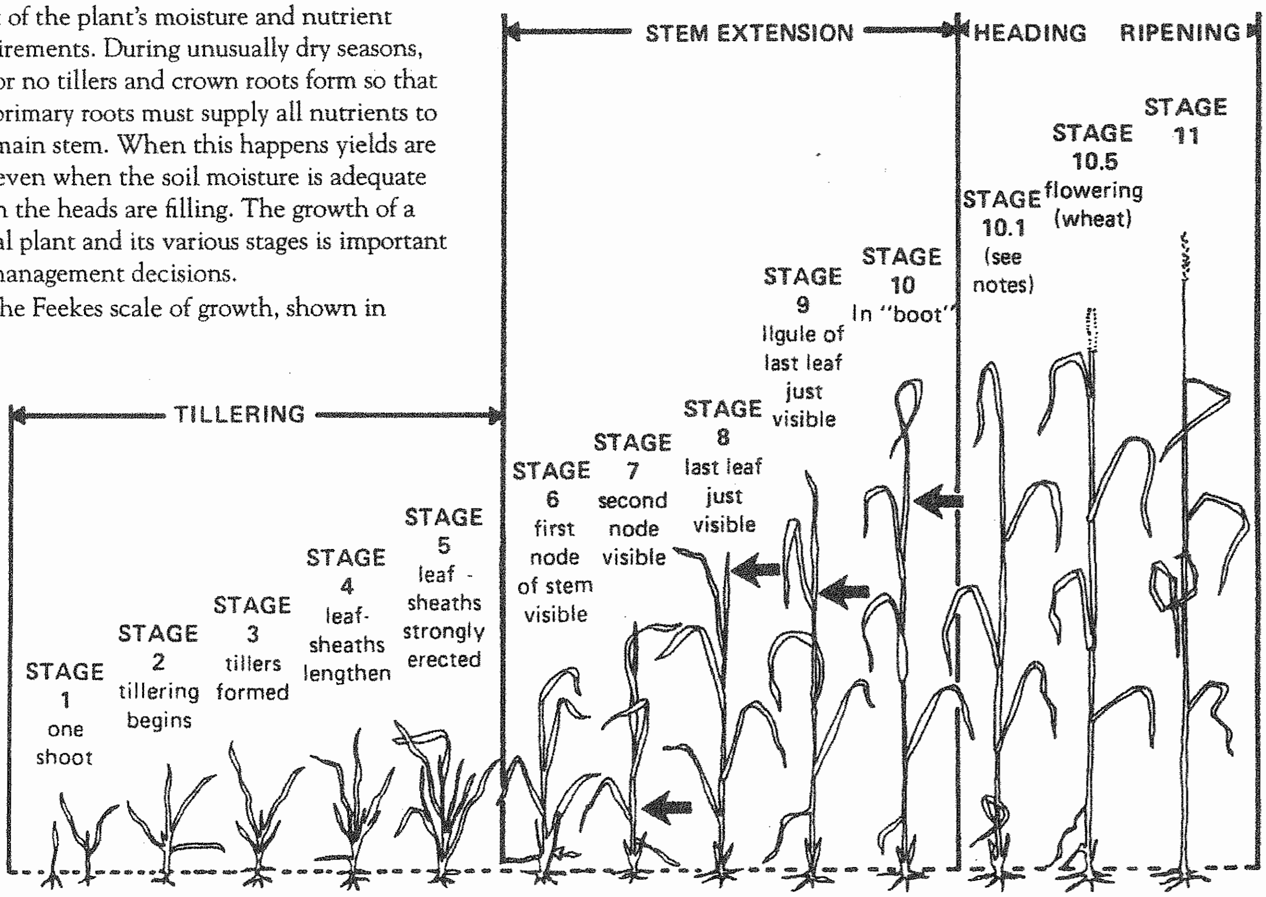



Figure 7.1 The Feekes Scale of Growth

Source: *Barley Production in Alberta*, Alberta Agriculture, Agdex 114/20-1, 1984, pg 19.

**Kernel Formation and Ripening:**

7. *Filling:* The fertilized ovary or kernel is enlarging and assumes full size.
8. *Milk:* A white fluid or endosperm can be squeezed from the kernel.
9. *Soft Dough:* The kernel still indents when squeezed but is becoming firm. (Early Dough-Mid Dough-Thumbnail leaves an indent).
10. *Hard Dough:* The kernel is almost firm and changing colour.
11. *Mature Seed:* Kernel is firm and contains 35 per cent or less moisture. Thumbnail barely leaves visible or no mark.
    *Fully Ripe:* Kernel has about 12-15 per cent moisture.

**Cereal Growth Stages 1 -11**

The actually time from seeding to maturity will depend on temperature, light, nutrition, moisture and variety.

Germination to one shoot stage will probably take 6-12 days, and stages 2-5 an additional 5-6 weeks. Stages 6-10 proceed very quickly and usually in July plants are in the boot stage and by early August extending in height from stage 10.1-11. Grain filling and maturity will occur in late August to early September. Figure 7.2 shows stages 9-10.5, from the appearance of the last leaf or flag leaf, through early-late boot stage and ear emergence.

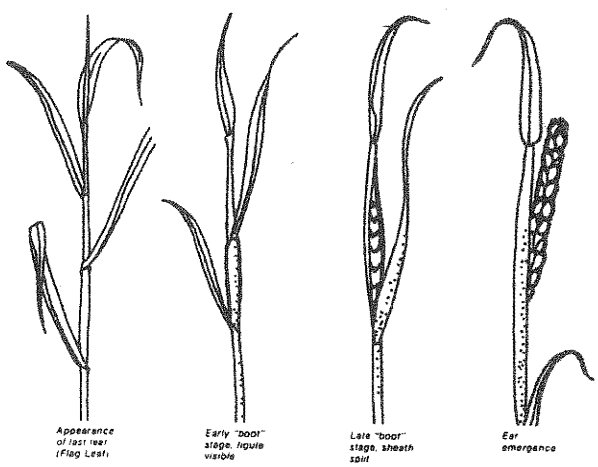



Figure 7.2 Advanced Growth Stages of Wheat

Source: *Weed Facts, Plant Growth Stages for Weed Control*, Manitoba Agriculture, Agdex No. 640, pg 2.

Seed is produced on a spike in wheat, barley, and rye and on a panicle in oats. The entire seed head is known as the inflorescence and this is composed of spikelets, containing individual flowers. Each flower plus the outer bract around the kernel (lemna) and inner bract around the kernel (palea) make up a floret. In awned varieties of barley and wheat, the lemna tip has an awn or needle like extension. Except for rye, all small grains are naturally self pollinating. Pollen grains are sensitive to high temperatures. In self pollinated crops, high temperatures may sterilize pollen grains within the floret resulting in no seed set. Hot dry winds may also cause a poor seed set – especially with cross pollinated rye. Long awns, as in barley, not only perform photosynthesis like a leaf but in dry hot weather tend to provide a cooling effect to the pollen and developing seed.

Flowering lasts only three to four days, most of it occurring at night. At our latitudes, flowering of barley takes place in the boot stage. The period from flowering to maturity of small grains requires about one month. Wheat, oats, barley and rye are called cool-season, long-day nitro-negative cereals. Flowering can be delayed if they are grown in a soil rich in nitrogen where the carbon-nitrogen ratio is kept lower (See Soil Improvement – Soil Management).

Earlier varieties can reach maturity in 90-95 days in the south and in 100-105 days in northern areas. During the YCDP trials (1988-1990), cereal plots matured in 96-103 days of growth with 87-103 frost free days and an accumulation of 796-1020 Growing Degree Days. (See Crop Response to Growing Season Climate – Agricultural Capability )

## CEREAL CROP RESEARCH

The types of cereals grown in the Yukon and discussed here include barley, oats, wheat and rye. The varieties grown during the YCDP trials (1988-1990) and the NCDP trials (1985-1987) are described.

**A study of cereals between 1952-1959 produced at 6 sites (Beaverlodge and Fort Fermillion, Alberta, Fort Simpson, NWT, Palmer and Fairbanks, Alaska, and Mile 1019, Haines Junction, YT) revealed:**

"The seed produced was usually viable. Even at Mile 1019, with an average growing period of only 54 days, when wheat did not mature properly its ability to germinate was only moderately reduced."

"Wheat and oats required longer to ripen at Beaverlodge than at other Canadian Sites. These differences appear to be related to the acceleration in development normally associated with increase in day length. However, if day length were the main influence, the maturation of barley would not have been delayed at Mile 1019, there would have been more rapid development at Palmer and Fairbanks and the annual differences in maturation at all sites would have been much less."

- Source: *Growth of Spring Cereals in Northwestern Canada and Alaska*, 1965, Canada Department of Agriculture Publication 1220.

### *Barley*

Barley is a member of the grass family and is one of the "bunch grasses". Barley stalks range in length from about 20-150cm (7.9-59 in.), terminating with a spike shaped head. There are two types of barley spikes. *Hordeum vulgare* has six rows of grain and *Hordeum distichum*, has two rows of grain. The six rowed barleys have been the most widely grown in Alaska and Yukon because they are the earliest varieties. Most 2 rowed barleys are classified as malting and pearling barleys and have a longer growing season requirement.

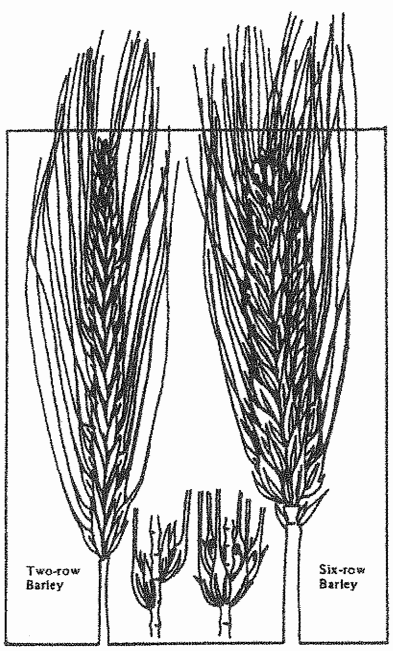



Figure 7.3 Barley

Source: *Small Scale Grain Raising*, G. Lodgson, Rodale Press Inc, 1977.

Barley is self pollinating, that is the pollen from the pistil of a flower fertilizes the stigma of the same flower. Barley responds well to soil fertility. It has a comparatively shallow root system and it absorbs large quantities of water in its early growing stages. Because of these characteristics it does best in light textured soils. It can do well in heavier soils but added fertility is required for good results. It is important that nutrients are readily available in the soil for rapid growth. Compared to oats and rye, barley uses the smallest amount of moisture to produce a crop and is more affected by excess moisture. During a wet season, if barley and oats are grown side by side, oats may do well but barley may show signs of drowning. It is superior to oats and rye in resistance to heat.

#### Barley Varieties – NCDP & YCDP Trials

The 6 rowed barleys developed in Alaska have been tested in both the NCDP and YCDP trials.

**Otal** - First developed in Palmer, Alaska, this was further developed by the Beaverlodge Research Station, and licensed in Alberta in 1981. It is a very early barley variety suitable for northern areas. This is available from Canadian growers and seed companies. This was a good producer in the NCDP and YCDP trials.

**Datal** - A 6 rowed variety developed in Palmer, Alaska in 1983. It is a cross between a 6 rowed and 2 rowed barley from Sweden and is very early maturing. It had good bushel weights in Alaskan and NCDP trials. It is subject to yield reductions from early season drought.

**Thual** - A new hulless variety developed by the USDA in Palmer Alaska. This variety has been used as a component of dog food mixes in Alaska. Bushel weights for these hulless varieties are quite similar to those for wheat, varying around 60 pounds. The hull is removed in the trashing process. In the NCDP trials this was susceptible to lodging.

**Weal** - A six rowed variety developed by the USDA in Palmer, Alaska. This is a hooded barley with no awns developed for use as a component in forage and silage mixtures. It has a strong straw and can withstand fairly strong winds but has less tolerance to drought than other varieties. In Alaska trials, bushel weights of Weal are frequently lower than other varieties. This has also been noted in the NCDP and YCDP trials. The best grain production for this variety occurred in the Whitehorse area in 1990, producing yields of 122 bu/acre.

### *Oats*

Oats are the most commonly planted cereal crop in the Yukon. Oats serve as a dual purpose crop, harvested primarily for use as a green feed at immature growth or harvested for grain at maturity. A few producers combine or thrash their oats for grain. Oats that are harvested for grain should be planted as early as possible, preferably before May 24th.


Figure 7.4 Oats

Source: *Small Scale Grain Raising*, G. Lodgson, Rodale Press Inc, 1977.

For best results, oats should be grown in regions with generally cool temperatures and adequate moisture. Hot dry weather when the crop is filling frequently results in poorly filled kernels and low yield. For good kernel development oats require more growing season moisture than any other small grain. Oats produce better when seeded in soils with good moisture holding capacity.

Oats fall between barley and wheat in time to maturity. Oats require from 85 to 110 days to mature, varying from season to season and from location to location. Oats are less tolerant of saline soils than barley or wheat, but they are more tolerant of acid soils.

Oats are very nutritious providing a well balanced source of proteins, carbohydrates, fats and fiber. Fiber is a little higher in oats than in other coarse grains, which influences digestion.

### Oat Varieties – YCDP Trials

**Cascade** - A high yielding oat variety developed at the Canada Agriculture Research Station at Lacombe, Alberta and released in 1979. It is suitable for grain and forage production with good resistance to lodging. This was a superior producer in the NCDP and YCDP trials and was a high yielder in Alaskan trials. This is a popular variety in Alberta.

**Toral** - Developed by the USDA in Palmer, Alaska this was an outstanding variety in Alaskan trials. It is very resistant to lodging and is a dual purpose variety suitable for grain and forage production. It was a good producer in NCDP and YCDP trials.

**Athabasca** - A very early maturing Canadian variety developed at the Agriculture Canada Research Station at Lacombe, Alberta in 1977. Due to its shorter height, forage yields can be expected to be less than other varieties. It has a strong straw and a resistance to lodging and shattering.

**Grizzley** - Developed at the University of Alberta in 1967, this variety is preferred for greenfeed by many producers. It is late maturing with only fair lodging resistance. It was a good green feed producer in the NCDP trials in Watson Lake in 1987. Grain was not mature (22 lbs bushel wt.) but total production was excellent.

### Companion Crop

Oats are frequently sown as a companion crop in the establishment of grasses and legumes. Oats are less competitive than barley and are therefore more suitable for this purpose. Oats should be sown at only half the normal rate when sown as a companion crop. Limit the nitrogen applied so that the total available does not exceed 30-40 lbs/ac. Higher nitrogen levels will cause excessive stress on the grass or legume being established through heavy oat growth. Harvest the oats for fodder as early as possible to assist the grasses or legume establishment.

### Oats/Field Peas

A number of Yukon producers have planted oats and field peas together as a soil improvement crop or for green feed. At the Agricultural Research Branch plots, oats/field peas were planted for soil improvement, seeded at the 225 lbs/acre (field peas) and 100 lbs/acre for oats. This provided a dense stand of organic matter for tilling into the soil.

### Yukon Crop Development Lime Trial – *Cascade* Oats

On the Mease farm near Minto Bridge in the Mayo region a newly cleared field had a pH of 5.3 with a lime requirement of 3.6 tons/acre. A lime trial was conducted between 1988-1990. Each year there was marked variation in the growth of Cascade oats with the application of lime. Four .12 acre (.05 ha) plots were set up, with a full lime plot having the rate of 1.3 tons lime applied/acre; this rate was reduced 1/2 and 1/4 for two plots, and a control plot with no lime. Each year, soil tests were taken in the fall and the recommended lime rate for the full lime trial used to determine lime rates for each plot in the spring. All plots received the recommended fertilizer rate each year. Soil tests were taken within each plot after harvesting oats in the fall of 1988, 1989 and 1990.

*I've baled oats like hay. I cut it when it is in the milk stage and let it dry longer in the windrow before I bale it.*

- Dawson Producer

Table 7.1 YCDP Lime Trial (1988-1990)

| | No Lime | 1/4 Lime | 1/2 Lime | Full Lime |
|---|---|---|---|---|
| **Treatment** | | | | |
| pH - 1988 | 5.4 | 5.8 | 6.1 | 5.9 |
| - 1989 | 5.3 | 5.6 | 5.9 | 6.4 |
| - 1990 | 5.7 | 5.6 | 6.0 | 6.9 |
| **Lime Requirement** | | | | |
| Tons/Acre - 1988 | 2.3 | 1.6 | 1.1 | 1.3 |
| - 1989 | 3.8 | 2.6 | 2.1 | 0.9 |
| - 1990 | 3.0 | 2.8 | 3.1 | None Required |
| **Soil Analysis** | | | | |
| Deficient - 1988 | N, P, K, S, B | N, P, K, B | N, P, K, B | N, P, K, Zn, B |
| - 1989 | N, S, B | N | N | N, K |
| - 1990 | N | None Deficient | P | K |
| Marginal - 1988 | Cu | S,Cu | S,Cu,Zn | S,Cu |
| - 1989 | P, K | P, K, S, B | P, K, S | P, S |
| - 1990 | P, K, S, B | N, K, S, Mg | N, K, S, Mg, Zn | N, P, S, Mg, Zn, B |

**Note:** All other nutrients were at optimum levels.

The pH was effectively altered in the full lime plot with the raise from pH 5.3 (spring 1988) to 5.9 (fall 1988) to 6.4 (fall 1989) and 6.9 in the fall 1990. No further lime was required by 1990. The balance of nutrients was improved for each plot, from deficiencies at the start to nutrients being marginal or optimal. The full lime plot was deficient only in K by the end of the trial. The full lime trial had the best growth which was uniform and mature at harvest, producing about 4.5 tons/acre (9.8 tonnes/ha) of total green matter and grain at 85 bu/acre. (The full lime trial is shown as the background shot on the front cover.)

### *Wheat*

Wheat belongs to the genus *Triticum* and two species are widely cultivated: *T. aesitivum* subspecies *vulgare* (bread wheat) and *T. durum* (macaroni wheat). The bread wheats are subdivided based on growth habit: hard red spring wheat and hard red winter wheat.

In general, wheat has a wide climatic and soil adaption range. The more humid regions produce the softer wheats with higher yields and lower protein contents, used mainly for livestock feed or for specialized pastry, biscuit and cake flours. The hard wheats with higher protein levels are grown in areas of lower rainfall which produce the most desirable bread wheat flours. In Alaska, hard red spring wheats have shown the greatest adaption while the hard winter wheats have a poor survival. Macaroni wheats require a longer growing season and yield less than hard red spring wheats in Alaska.

Hard red spring wheats have a narrower range of adaption than barley or oats. Wheat is more sensitive to cool temperatures, particularly during the maturation stages of growth. If weather conditions are warm and dry during the 30 day maturation period after pollination, wheat matures about 10 days later than barley. If weather is cool and wet, an additional 10-15 days may be required for ripening. Early planting is mandatory as late plantings may fail to mature or may result in low test or bushel weights. Seeding should be done as soon as the soil can be tilled or no later than mid-May. The best yields of wheat are usually produced on soils with a good moisture holding capacity. The kilograms of water required to produce a kg of dry matter are greater for wheat than for oats or barley. It is good practice to sow wheat on fields with the greatest moisture reserve.


Figure 7.5 Wheat

Source: *Small Scale Grain Raising*, G. Lodgson, Rodale Press, Inc, 1977.

**Excerpts from Mile 1019 Research Station Progress Reports: 1953- 1959 Report, 1966 Report:**

*" Studies on cereal crops consisted chiefly in testing new varieties of oats, barley, springwheat, winter wheat and winter rye."*

*" The important factor in recommending varieties is early maturity, as late-maturing varieties are damaged by early - fall frosts."*

*From 1953-1959: "the weather was cool and dry during April, June and July so that grains germinated irregularly and the seedlings developed slowly. Despite this adverse weather, satisfactory grain crops were harvested except for spring wheat, which matured only in 1953 and 1957."*

*" Oats is an important cereal crop in the area because they can be used as a grain and as roughage."*

*" Oats and barley escaped damage at Mile 1019 except in 1959. No soil amendments were used."*

*" Barley matures earlier than any other grain crops tested. Prolonged dry weather, which often occurs during early spring and early summer causes barley to be very short. Barley (Olli ) went through early phenological stages at an incredible rate, but kernel ripening was very slow."*

*" Spring wheat is not recommended as it is not considered a reliable grain crop for the Yukon. Its late maturity often results in the production of immature grain which is difficult to store. However wheat of an acceptable feed grade is usually produced and can be used satisfactorily in home grown mixed feeds for livestock."*

*" Biennial cereal crops, namely, winter wheat and winter rye grow satisfactorily in the area. The most critical factor in suitability of winter wheat is winter hardiness. The wheat should be sown about August 1, so that it may develop vigorous rosettes before freeze-up."*

### Wheat Varieties-YCDP Trials

**Park** - Developed in 1968 by the Canada Agriculture Research Station in Lacombe, Alberta, it is an early maturing variety. It is usually the first variety to have seedlings emerge in cold soils and the first variety to flower with fair resistance to lodging and shattering. This was the best performer for wheat in the NCDP and YCDP trials.

**Ingal** - A new spring wheat variety developed by the USDA in Palmer, Ak., this is a hybrid (Gasser x Morin), which is considered a semi-dwarf variety. Ingal is the earliest wheat tested in Fairbanks,Ak. where it is considered suitable for use as a feed grain and is satisfactory for milling and baking. This usually matured in NCDP and YCDP trials, though shattering was a problem.

**Nogal** - A new spring wheat variety developed by the USDA in Palmer, Ak. It is considered suitable as a feed grain and for home use in milling and baking. This was not as productive as Park and Ingal in NCDP and YCDP trials and was usually the least mature.

### *Rye*

Rye has the widest distribution and is the most drought resistant of all the cereal crops. Rye will do better than other cereals on relatively poor soils. Sandy soils which are unsuitable for wheat, oats and barley are frequently sown to rye. Rye is a cool weather plant, not as well adapted to either dry or moist heat as oats and barley. Rye is cross pollinated, largely by the wind. It is somewhat sour and difficult for animals to chew and, as a result, it is often necessary to feed it in a mixture with other grains. Rye lends itself favorably as a pasture grass in the fall or early spring.

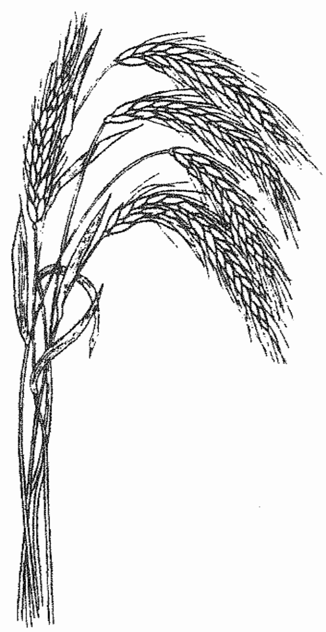


Figure 7.6 Rye

Source: *Fall Rye Reference Manual*, Agriculture Canada,Prairie Pools,Inc. Rye Committee, Agdex 117/20, 1992.

Rye is seeded in early fall, with grain produced the following summer. The variety Kodiak has been grown in the Yukon.

Because of its early establishment and early growth in the spring, it tends to overcome competition from annual weeds, often maturing in the advance of them. Seeding in stubble without any previous preparation is accepted practice in the prairies, seeding in late August or at a rate of 47-94 kg/ha.

> *I've seeded fall rye in mid August, with a tractor drawn broadcaster at the rate of 100 lbs/acre. By late fall there are clumps of 6-8" growth and some seed heads growing. I mow these off. I harvest the following year in the late part of July or early August, with large mature heads. Then I pasture my horses on it.*
>
> \- Dawson Producer

### *Determining Grain Yield*

For determining your cereal yields for green feed production see Determining Your Yields – Crop Production. The measure most commonly used by farmers to express yields of grain crops is bushel per acre bu/acre. One bushel is equal in volume to 2150.42 cubic inches or 8 gallons. The standard bushel weights for small grains are:

Barley - 48 pounds per bushel
Oats - 34 pounds per bushel
Wheat - 60 pounds per bushel
Rye - 58 pounds per bushel

Test weights or bushel weights are taken to ascertain grain quality. A test weight or bushel weight lower than the standard weight can reflect the characteristics of a variety, the presence of foreign material, lack of maturity, disease, excessive nitrogen fertilization, or subjection of the crops to severe drought or high temperatures during critical stages of growth.

Bushel weights are best determined by a feed testing laboratory, and can be done at the same time as the grain analysis for crude protein and energy content (TDN., DE. etc.) (See Feed Quality – Forage Production).

Determine the grain weight by thrashing your total whole plant grain sample (1 sq metre). Convert this by using the conversion figure, 4048 to lbs/acre. (See Determining Your Yields – Crop Management). The bushel weight (determined at the lab) is then divided by the lbs/acre to determine the bushel/acre yield of the crop. In lieu of the lab determined bushel weight, the bushel/acre can be determined by dividing the lbs/acre figure by the standard bushel weight of each crop type.

**Example:** Cascade oats – Grain Yield = .71 lbs per 1 $m^2$ sample
Grain Wt= .71 x 4048 (Conversion Figure) = 2874 lbs/acre
Grain bu/acre = 2874 divided by 34 (standard bu wt)= 85 bushels/acre (bu/acre).

### *Yields of Cereals – Yukon research Trials*

**NCDP Trials**

The yields of the 1987 NCDP cereal trials in bushels/acre and bushel weights from laboratory analysis were:

Table 7.2 Yield of Cereals - NCDP Trials

| Crop | Watson Lake | | Whitehorse | | Pelly | | Mayo | | Dawson* | |
|---|---|---|---|---|---|---|---|---|---|---|
| | bu /acre | bu wt. | bu /acre | bu wt. | bu /acre | bu wt. | bu /acre | bu wt. | bu /acre | bu wt. |
| **Barley:** | | | | | | | | | | |
| Weal | 45 | 33 | 103 | 47 | 32 | 42 | 41 | 50 | 74 | 43 |
| Otal | 32 | – | 81 | 55 | 57 | 53 | 29 | 50 | 59 | 55 |
| Datal | 61 | 43 | 79 | 55 | 89 | 52 | 27 | 52 | 100 | 51 |
| Thual | 32 | – | 86 | 65 | 57 | 64 | 30 | 64 | 78 | 63 |
| **Oats:** | | | | | | | | | | |
| Toral | 59 | 27 | 100 | 37 | 170 | 44 | 51 | 40 | 156 | 41 |
| Athabasca | 61 | 26 | 118 | 37 | 142 | 42 | 39 | 42 | 173 | 42 |
| Cascade | 54 | 23 | 154 | 33 | 178 | 37 | 64 | 37 | 196 | 43 |
| **Wheat:** | | | | | | | | | | |
| Park | 16 | 44 | 61 | 61 | 46 | 66 | 26 | 59 | 66 | 67 |
| Nogal | 9 | 32 | 39 | 51 | 50 | 63 | 19 | 54 | 62 | 64 |
| Ingal | 27 | 46 | 65 | 60 | 35 | 63 | 21 | 58 | 62 | 64 |

*Results from Sunnydale site in Dawson.
Results from Dawson-Henderson's Corner not listed.

For barley production, the highest yield was in the Whitehorse area. This was also the only irrigated site. For grain production, these barley varieties can be ranked as follows: Datal, Thual, Weal, and Otal. As indicated by the bushel weights, grain was mature at all sites except Watson Lake. Weal barley had lower bushel weights than 48 (the standard bushel weight for barley), though it was mature, which has also occurred in Alaska. Thual, when mature, has a bushel weight close to that of wheat.

> *" Some remarkably high yields were obtained from the test plots at Swede creek; wheat 60 bushels/acre (bu/acre), oats 134 bu/acre, barley 66 bu/acre."*
>
> - *Yukon Agriculture: A Policy Proposal*, R.W. Peake, 1975

The best trial site in Dawson was at Sunnydale, on a south facing slope not subject to frosts which produced the highest wheat and oat grain yields. This was located near the site of the Dominion Experimental farm at Swede Creek, which operated from 1917-1925.

For the oats grain production, ranking was Cascade, Toral and Athabasca. Oats were not mature in Watson Lake, with low bushel weights. Highest production was at Sunnydale at 196 bu/acre for Cascade.

Park wheat was the highest yielder at the Sunnydale site near Dawson at 66 bu/acre. Wheat production was Park, Ingal and Nogal. Grain was mature at all sites except Watson Lake.

Grain production and maturity for the NCDP trials can be ranked by region as:

1. Dawson-Sunnydale
2. Whitehorse
3. Pelly Farm
4. Mayo
5. Dawson-Henderson's Corner
6. Watson Lake

**YCDP Trials**

The yields of the different cereal crops tested in the YCDP trials from 1988-1990 are indicated in bushels/acre (bu/acre).

Table 7.3 Yields of Cereals - YCDP Trials

| YCDP Trials | | Whitehorse bu/acre | Pelly bu/acre | Mayo bu/acre | Dawson bu/acre |
|---|---|---|---|---|---|
| **Barley:** | | | | | |
| Weal | -1988 | 3 | – | – | 9 |
| | -1989 | – | 23 | 18 | – |
| | -1990 | 122 | 6 | 24 | 51 |
| **Oats:** | | | | | |
| Cascade | -1988 | 13 | – | 49 | – |
| | -1989 | – | 60 | 51 | – |
| | -1990 | 123 | 75 | 50 | 45 |
| Toral | -1988 | 15 | – | 39 | 14 |
| | -1989 | – | 104 | 54 | – |
| | -1990 | 170 | 70 | 36 | 21 |
| Athabasca | -1989 | – | 56 | 65 | – |
| | -1990 | 118 | 70 | 57 | 27 |
| Grizzley | -1989 | – | 60 | 51 | 28 |
| | -1990 | 129 | 46 | 61 | 43 |
| **Wheat:** | | | | | |
| Ingal | -1990 | 66 | 41 | 22 | 11 |
| Nogal | -1990 | 47 | 31 | 32 | 2 |

The best cereal growth occurred in the Whitehorse area in 1990, where a combination of adequate soil moisture and good weather conditions provided for an excellent yields of barley, oats and wheat. Grain was fully formed and mature by harvest. In general, cereals grown in Whitehorse were usually not as mature as in the Pelly Farm and Mayo areas. The site in Dawson, near Henderson's Corner, usually had cooler conditions with frosts occurring each month of the growing season, providing for lower grain yields than the NCDP trial site in Sunnydale. Cereals were consistently mature with fairly good yields at Pelly Farm and Mayo. The Mayo site often had drier conditions causing lower yields than Pelly.

Ranking by region for grain production during the YCDP trials

1. Whitehorse
2. Pelly
3. Mayo
4. Dawson-Henderson's Corner

### *Alaska Trials*

In cereal trials located in Fairbanks and Delta Junction between 1971-81, the following yields in bushels/acre were noted:

Table 7.4 Yields of Cereals - Alaska Trials

| Crop | Fairbanks | | Delta Junction | |
|---|---|---|---|---|
| | Average Yield | Range of Yields | Average Yield | Range of Yields |
| Weal barley | 77 | 43-125 | 61 | 31-83 |
| Toral oats | 134 | 67-179 | 122 | 52-179 |
| Park wheat | 57 | 25-74 | 33 | 16-55 |

Cascade oats tested in Delta Junction in 1981 were the highest yielding, producing 174 bu/acre.

Source: *Performance of Cereal Crops in the Tanana River Valley of Alaska 1981*, Alaska Experiment Station, AES Circular No.42, 1982.

## CEREAL CROP ESTABLISHMENT

Cereal varieties only express their full potential and high yields when they are planted at proper seeding times, seeding depth, and seeding rates with adequate fertility and moisture.

A successful grain crop requires sound management decisions, including:

- what variety and grade of seed to sow
- what rotation or crop sequence to follow
- when to start working on the land in the spring
- how much tillage to give the soil
- date, rate and depth of planting
- soil analysis and rate of fertilizer to use
- what to do for weed, insect and pest control
- when to harvest and how
- safe storage techniques
- after harvest field maintenance

### *Seedbed Preparation*

The preparation of a proper seedbed does not vary for cereal crops. It will depend on location, soil type, season, soil moisture, trash cover, weed history and topography. With fall tillage, the important thing is to leave enough trash cover on the surface to minimize water or wind erosion. Surface or tillage with a disc or heavy cultivator will usually do a good job. The land should be worked across the slope if possible, to minimize erosion from water. Leaving the stubble in the fall will act as a snow trap, conserving soil moisture. However, unworked soil with standing stubble may be slower to warm up and dry in the spring, to be able to work it.

### *Planting Dates*

Crops should be seeded as early as possible in the spring, as soil conditions and temperatures permit, in early-mid May. The temperature of the soil in early May is a guide to when to seed with minimum soil temperatures of 3-5°C (37-41°F). (See Soil Temperatures for Germination – Crop Management). A preferred soil temperature for germination is 20 °C (68 °F). Freezing temperatures in May may affect seedlings, however oats can withstand a low temperature while still in the vegetative stage. A temperature of –6 °C is required to kill the leaves of seedlings.

### *Seeding Rates*

Thin seeding results in heavy tillering, large heads and seeds. Thick seeding results in reduced tillering, smaller heads and seeds. Heavier seeding promotes earlier maturity but may also contribute to lodging. A number of studies have shown that when density exceeds a certain level, although total dry matter production remains constant, the amount of grain produced decreases. This is because each plant competes with others for air, water and nutritive elements. Sowing densities can vary greatly without modifying final yield. An interaction occurs between sowing density and the assimilation of nitrogenous fertilizer: with low fertilizer levels, increased sowing density usually causes a slight increase in yield, whereas with high levels of nitrogen best results are more often obtained with light sowings. It is known that a lighter seeding rate will produce a crop that requires a little more time to mature, has more resistance to lodging and is a bit taller, than if it were sown at a heavier seeding rate.

Seeding rates may have to be modified according to the viability (germination percentage) of the seed, soil and environmental conditions. Seeding rates should be increased depending on the degree to which the following conditions are present: a) weeds, b) abundant moisture reserves, c) the need to hasten maturity of the crop, d) germination below 90 percent, e) size of seed, f) rough land preparation, and g) deep seeding.

Good quality certified seed should be planted to ensure a better crop performance and less weed seeds. Research has shown that large kernels will produce healthier more vigorous plants than small kernels; therefore it is essential that seed be well cleaned to remove the small kernels.

Table 7.5 Normal Rates of Seeding Cereal Crops

| Type of Crop | Rate of Seeding | |
|---|---|---|
| | kg/ha | lbs/acre |
| Wheat | 67-134 | 60-120 |
| Oats | 57-114 | 50-100 |
| Barley | 80-134 | 70-120 |
| Rye | 47-94 | 42-84 |

**Note:** kilograms/hectare (kg/ha) x 0.89 = pounds/acre (lbs/acre)

Source: *Principles and Practices of Commercial Farming*, University of Manitoba, 1977.

These rates are for a drill seeder and should be increased for broadcasting. Field Crop Guides (Alberta) indicate increasing the drill seeding rate by about 1/2. Additional soil and environmental factors may require a higher rate.

### *Seeding Rates*

#### Alberta

Experiments have shown that approximately 20 plants per square foot, or 215 plants per square metre, is a good plant density for most cereal crops. Seeding rate must also take into account expected plant survival. This term 'expected survival' is the per cent of germination, less expected seedling mortality which is usually two to three per cent and sometimes higher under adverse conditions. For this method:

1. Count out 1,000 seeds and obtain the weight in grams(g);
2. Seeding rate (lbs/ac) = $\frac{\text{weight of 1,000 seeds in grams} \times 2}{\text{\% expected survival}}$

**Example:** Weight of 1,000 seeds of barley = 40 grams

Germination = 93%

Expected seeding mortality = 3%

Seeding rate (lb/ac) = $\frac{40 \times 2}{(93-3)\%} = \frac{80}{0.9} = 89$ lb/ac

For Seed Drill Calibration:

1. Fill drill
2. Measure a 100 ft. distance
3. Collect out put from one drill run over the 100 feet
4. Weight of sample collected in grams = half calculated rate (lb/ac)

**Example:** Calculated seeding rate = 90 lb/ac

Sample collected should = $\frac{90}{2}$ = 45g/100ft of row 6" spacing

For 9" spacing the amount collected should be 45 x 1.5 = 67 grams.

#### YCDP Trials

Most of the cereal trials were seeded with a hand "Cyclone" broadcaster, as it was easier to apply the right amount of seed to a smaller area and a seed drill was not available at most sites. For larger areas, fertilizer was separately applied with a tractor drawn broadcast spreader and the seeds applied afterwards at the recommended rate for each cereal plot. For smaller areas, fertilizer and seed were mixed together to facilitate good coverage. A seed drill was used at the Pelly Farm trial site.

The seeding recommendations (Alberta, Alaska) for using a drill seeder were roughly doubled for broadcast seeding.

Table 7.6 Seeding Rates - YCDP Trials

| Cereals Tested | Seeding Rates (lbs/acre) | | |
|---|---|---|---|
| | 1988 | 1989 | 1990 |
| Barley-WFeal | 80 | 80 | 125 |
| Oat-Cascade | 100 | 118 | 125 |
| Oat-Toral | 100 | 118 | 125 |
| Oat-Athabasco | – | 118 | 125 |
| Oat-Grizzley | – | 118 | 125 |
| Wheat-Ingal | – | – | 125 |
| Wheat-Nogal | – | – | 125 |

The seeding rate of the Weal barley was increased in 1990 as this was older seed and germination % was reduced. The oat varieties were increased from 100 to 125 lbs/acre. This was found to be a good rate for broadcasting oats. These cereals were not irrigated and moisture conditions sometimes were very dry. In areas of newly cleared fields, seedbed conditions were not always optimum. In 1990, the wheat varieties were seeded at a heavier rate, as the indicated germination % was less than 85%.

### *Depth of Seeding*

Seed should not be placed deeper than necessary to assure contact with moist soil. Although 5 cm (2") is an average satisfactory depth for cereals, the depth of soil moisture and the firmness of the seed bed must be considered. Seeding deeper than necessary may reduce germination and produce weaker plants. In general, the moisture level is lower in lighter soils and deeper seeding is often necessary.

Shallow seeding into a firm moist seedbed assures a short subcrown internode and promotes the growth of healthy young plants. The length of this internode is determined by sowing depth. The crown root system is responsible for supplying most of the plant's moisture and nutrient requirements. During unusually dry seasons, few or no tillers and crown roots form, so the primary roots must supply all nutrients to the main stem. When this happens, yields are low even when the soil moisture is adequate when the heads are filling.

Barley should be seeded into moist soil as shallowly as possible and normally not more than 5cm (2") deep. Barley is more sensitive to deep seeding than wheat or oats. High yields of barley are produced from rows spaced 15-20cm (6-8") apart.

## MANAGEMENT METHODS

### *Nutrients Used By Cereal Crops*

The amount of plant nutrients removed from the soil by cereal crops depends on the yield of the crop. The greater the yield the greater the amount of nutrients removed. Whole plants of oats, wheat and barley remove similar combined quantities of N, P, K, and S (sulphur) from the soil. Wheat requires the most nitrogen. If the straw is left on the field, oats remove less nitrogen and potassium but more sulphur than barley or wheat.

Table 7.7 Nutrients Used by Cereal Crops (kg/ha)

| Crop | Yield | Crop Part | N | $P_2O5$ | $K_2O$ | S |
|---|---|---|---|---|---|---|
| Wheat | 48 bu/acre | Seed | 79 | 32 | 21 | 5 |
| | | Straw | 32 | 7 | 64 | 8 |
| | | Total | 111 | 39 | 85 | 13 |
| Barley | 60 bu/acre | Seed | 65 | 24 | 22 | 5 |
| | | Straw | 34 | 9 | 73 | 8 |
| | | Total | 99 | 33 | 95 | 13 |

Table 7.7 Cont.

| Crop | Yield | Crop Part | N | $P_2O5$ | $K_2O$ | S |
|---|---|---|---|---|---|---|
| Oats | 84 bu/acre | Seed | 58 | 24 | 17 | 8 |
| | | Straw | 40 | 15 | 70 | 10 |
| | | Total | 98 | 39 | 87 | 8 |

(To convert kg/ha to lbs/acre, multiply by 0.89)

Source: *Oat Production in Alberta*, Alberta Agriculture Agdex 113/20-2, 1986.

Table 7.8 Nutrients Used by Cereal Crops (lbs/acre)

| Crop | Yield | | Pounds Removed from Soil/Acre | | | |
|---|---|---|---|---|---|---|
| | Bu/Acre | (Lb/Acre) | Nitrogen | Phosphate | Potash | Sulphur |
| Wheat | 40 | 2400 | 85 | 27 | 56 | 8 |
| Barley | 60 | 2880 | 90 | 25 | 55 | 8 |
| Oats | 80 | 2720 | 100 | 20 | 77 | 13 |

(To convert lbs/acre to kg/ha, multiply by 1.12)

Source: Forage Seed Notes - Alberta Forage Seed Council

**Fertilizer**

Soil fertility should be determined by a soil test before planting and fertilizing a cereal crop. Soil samples should be taken from the field in the fall before freeze up, after the soil temperature has dropped below 7 °C (45 °F), and tested to determine the fertilizer requirements for the crop the next year. If the soil test indicates that nitrogen is required, this can be done in the fall, after the soil temperature has dropped below 7 °C (45 °F ), or early spring. The available nitrogen content of the soil can change rapidly, therefore, the nitrogen test is only valid for one cropping season.

**Micronutrients**

Boron deficiencies in cereals are usually rare despite low soil boron levels. Wheat will form a normal head but will not flower. Barley does not form heads, while oats do not develop full pollen grains. All cereals will show thickened stems with a tendency for leaves to curl.

Barley has the highest sensitivity to boron toxicity followed by wheat then oats. Toxicity symptoms are most pronounced on barley. Symptoms start on the older leaves (bottom) with severe brown spotting and burning of older leaf tips and progress to the leaves or middle portion. In wheat, toxic symptoms appear as light browning of older leaf tips, converging into light greenish blue spots; on oats the leaf tips may be a light yellow.

### *Plow Down Research-Alberta Experience*

Research indicates that a cereal crop will perform much better after a legume plowdown. In Alberta, 50 years of research has shown that the best yield of grain was obtained following the heaviest crops of legumes. Research has indicated that cereal crops were the most consistent in producing profitable increases after clover crops. Yields were significantly higher over a longer period of years, but with the wheat the quality shown by higher protein content and higher baking quality proved consistently superior. Plowdowns are done early with a whole winter season separating the seeding from the green manuring.

*If soil fertility is not known and cannot be determined before planting time a guestimate for fertility requirements for a cereal crop in the Whitehorse area is: 100 lbs/acre N, 35 lbs/acre P, 50 lbs/acre K, and no Sulphur.*

- Whitehorse Producer

### *Cereal Crop Problems*

**Lodging**

Lodging occurs when a cereal crop lies flat. This is often caused directly by wind and rain that flatten the standing crop. High soil moisture and high nitrogen content both

### *Haines Junction Mile 1019 Research Highlights 1957-58*

**Barley:** To hasten maturity and increase the yield of barley it is recommended that 100 pounds per acre of ammonium phosphate (11-48-0, 11-55-0, 11-51-0) be applied at the time of seeding. After early spring frost damage, plant which had received the phosphorous fertilizers recovered rapidly; those not treated with phosphorous made a very slow recovery. This had a great effect on the rate of maturity of the barley plants. Stimulus to recovery from frost damage together with a general acceleration of plant maturity resulting from the phosphorous treatments caused this barley to mature 7 days earlier than normal.

**Oats:** The effect of fertilizer and manure on oat plots was studied. The application of manure (10 tons/acre rate) gave a greater increase than did any of the four commercial fertilizers used: 11-48-0, 0-0-60 and 16-20-0. The residual effect of the manure treatment the second year after application was significantly greater than any other treatment. The addition of the manure to the soil increased the soil moisture holding capacity and the level of plant nutrients available to the oats.

contribute to the frequency and severity of lodging. Lodging usually occurs after heading. This makes the crop difficult to harvest and results in reduced yields and quality of grain.

**Diseases**

*Loose Smut:* Loosesmut, a mycelium, causes damage by destroying the kernels of the infected plants. Loose smut of barley and wheat is worldwide in distribution. Loose smut generally does not produce any symptoms until the plant is headed. Smutted plants as a rule head earlier than the healthy ones, and smutted heads are elevated above the healthy plants. In infected heads, each spikelet is entirely transformed into a smut mass consisting of olive green spores. This is at first covered by a delicate greyish membrane which soon bursts and sets the powdery spores free.

Loose smut has been found in small quantities in plots seeded with Alaskan cereals of Weal barley and Nogal wheat during the YCDP trials. These infected seed heads should be removed from the field if possible. The best means of controlling loose smut is through the use of certified smut-free seed.

*Stem Rust:* Symptoms on cereals, wheat, barley and rye appear as a long narrow elliptical blisters parallel with the long axis of the stem, leaf, sheath of seedlings or of plants at any stage of growth. Stem rust causes losses by reducing yield and quality of grain. Infected plants usually produce fewer tillers, set fewer seeds per head, the kernels are smaller in size, generally shriveled and of poor milling quality and food value. The best control is to grow resistant varieties.

**Irrigation**

It takes 4 inches (20cm) of water to produce a crop and every one inch or 2.5cm of precipitation above that increase production by about four bushels per acre for most cereals. Most cereals require 14-18 inches of water for maximum production.

Irrigation should be curtailed when there is sufficient available moisture in the soil to mature a crop without moisture stress. As a rule of thumb if 75mm (3") of soil moisture are available irrigation can cease when cereals are in the early dough stage.

Too much moisture can lead to lodging of cereal crops and reduced grain yields.

> ***Haines Junction Mile 1019 1957-1958 Research Report***
>
> *"Generally oats and barley can be successfully grown at the Farm (Mile 1019 Alaska Highway). Sometimes the freshly threshed grain contains too much moisture to be stored immediately thus requiring some special care in drying. It is not difficult however to consistently raise oats and barley of good feed grade quality."*

***Harvesting***

Oats are subject to shattering and therefore should be swathed and picked up, rather than straight combined. Oats may be swathed for green feed when the kernel moisture content is about 35 per cent without loss in yield or protein content. Kernels with 35 % moisture will be in the soft dough stage. In this stage, if you remove the hull, they can be flattened by squeezing between the thumbnail and forefinger, but no free moisture or "milk" will be force out. If the kernel has a permanent crease left from squeezing but is not cut through, then there is a moisture content of about 31 per cent. Harvesting oats too early will result in some loss in grain yield and quality, but this will be compensated by having a more palatable straw for roughage. Leaving the crop stand too long will likely result in shattering losses.

> ***Haines Junction Mile 1019 1953-1959 Research Report***
>
> *"Oats, barley and wheat were tested and harvested at various stages of growth. Results to date indicated that oats were the most satisfactory. Cutting at the boot stage appeared most to be the best for quality and yield of forage from oats."*

## FEED QUALITY

***NCDP Trials***

Green Feed (GF) and grain analysis was completed on each cereal variety. Separate samples were taken for green feed and another for grain. The sample for grain analysis was thrashed with a small portable thrasher and a grain weight taken for yield determination. Samples in 1987 were tested by the Manitoba Feed Testing Laboratory.

Table 7.9 Protein Levels for Green Feed (GF) & Grain-NCDP Trials

| Crop | Watson Lake | | Whitehorse | | Pelly | | Mayo | | Dawson* | |
|---|---|---|---|---|---|---|---|---|---|---|
| | GF | Grain | GF | Grain | GF | Grain | GF | Grain | GF | Grain |
| **Barley:** | | | | | | | | | | |
| Weal | 7.5 | 9.7 | 8.4 | 12.6 | 10.0 | 16.5 | 11.7 | 16.5 | 8.5 | 14.3 |
| Otal | - | - | 7.8 | 12.5 | 10.4 | 16.1 | - | - | 8.9 | 13.6 |
| Datal | 5.8 | 9.8 | 8.1 | 13.1 | 9.7 | 14.1 | - | 15.4 | 8.5 | 13.4 |
| Thual | 5.6 | - | 7.0 | 13.5 | 9.2 | 16.6 | 10.0 | 15.7 | 8.8 | 16.3 |
| **Oats:** | | | | | | | | | | |
| Toral | 6.8 | 15.3 | 8.8 | 17.4 | 13.5 | 21.5 | 13.5 | 21.5 | 8.0 | 14.0 |
| Athabasca | 8.3 | 16.7 | 7.6 | 14.0 | - | - | - | - | 8.6 | 14.0 |
| Cascade | 8.9 | 20.5 | 8.3 | 15.0 | 13.2 | 20.1 | 13.2 | 20.1 | 8.0 | 12.0 |
| **Wheat:** | | | | | | | | | | |
| Park | - | 18.2 | 8.0 | 16.3 | 12.3 | 19.5 | - | 21.0 | 8.4 | 15.2 |
| Nogal | - | - | - | 20.3 | 11.7 | 22.0 | - | - | - | 17.3 |
| Ingal | - | - | - | 14.3 | 11.6 | 20.0 | - | 23.0 | - | 16.8 |

* Results from Sunnydale site in Dawson.
Results from Dawson-Henderson's Corner not listed.

The range of protein for barley green feed was 7-11% and 12-16% for grain. For oats the range of protein % was 12-22% for grain and 6-13% for green feed. The highest protein content of grain occurred at the Mayo site at 23.0% for Ingal wheat. Protein for wheat (range of 15-23%) was retested at the lab as it was so high for protein content. In the prairies, protein content for wheat grain is usually between 12-15%. The lab technician attributed this possibly to the effect of the long days or photoperiod, increasing protein content.

### *YCDP Trials*

The range of protein levels found in the cereal crops during the 1989 and 1990 YCDP trials are indicated in Table 7.10.

Tables 7.10 Protein Levels for Green Feed and Grain - YCDP Trials

| | | Grain Protein | Green Feed Protein |
|---|---|---|---|
| **Barley:** | | | |
| Weal | -1989 | 15.4 - 17.5% | 6.0 - 9.9% |
| | -1990 | 12.5 - 14.9% | 8.5 - 9.8% |
| **Oats:** | | | |
| Cascade | -1989 | 12.5 - 16.1% | 8.5 - 9.4% |
| | -1990 | 15.0 - 21.5% | 7.9 - 13.3% |
| Toral | -1989 | 15.6 - 18.4% | 7.5 - 9.6% |
| | -1990 | 16.2 - 24.0% | 9.9 - 11.3% |
| Athabasca | -1989 | 14.1 - 17.3% | 6.3 - 7.9% |
| | -1990 | 17.8 - 18.8% | 7.5 - 12.5% |
| Grizzley | -1989 | 9.2 - 13.3% | 9.2 - 9.4% |
| | -1990 | 15.2 - 18.4% | 8.0 - 12.8% |
| **Wheat:** | | | |
| Ingal | -1990 | 18.2 - 24.0% | 5.6 - 11.3% |
| Nogal | -1990 | 17.8% | 10.6% |

Range of protein for oats: green feed was 6.3-13.3 % and 9.2-24.0 % for grain. Weal Barley usually had lower green feed protein and grain protein than oats. Wheat had grain protein from 17.8 % to 24.0%.

### *Agriculture Branch Protein Results*

Nineteen samples of oats were tallied for protein content with a range of 1.3-23.2 % protein. The average protein was 11.56 %.

### *Nitrates in Frozen Crops*

Care should be taken when feeding frost damaged cereal crops which may contain nitrates. The risk is increased if the soil is high in plant available nitrogen, if the crop has been grown under extreme drought stress, or if a frost or hail has occurred before harvest. The frost causes an accumulation of nitrates which normally would have been used for plant growth. Cereals harvested immediately after a frost should be tested for nitrate levels to ensure no damage prior to feeding to livestock. Crops with a level of 0.5 percent nitrate in a feed is potentially dangerous, 0.75 per cent will reduce milk production and 1.5 percent can be lethal. Animals showing signs of restlessness, frequent urination and watery eyes should be watched for potential poisoning. A veterinarian can treat for poisoning if acted on quickly. Acute poisoning causes shortness of breath, blue discolouration of eyes and mouth and in extreme cases, death. Crops with nitrate levels should be mixed with other feed sources with low nitrate levels.

# VEGETABLE PRODUCTION

The production of vegetables has been an important part of the agricultural industry in the Yukon, ranging from small backyard gardens supplying the family with vegetables, to large market gardens supplying wholesalers and the Farmer's Market.

In this section, the selection of hardy varieties capable of adapting to the environment, seedbed preparation, planting and management methods are covered. Potato production is presented in detail. The raising of vegetables in the north requires more care and specific management practices than other, less sensitive crops.

## VARIETY SELECTION

There are a number of varieties which have proven successful in the Yukon for each vegetable crop type, from root crops to cabbages, the list is a long one. Lists of suitable varieties are available from the Yukon Agriculture Branch. Most local seed suppliers stock the most suitable varieties for this area. Seed catalogues usually list the number of days to maturity and growth characteristics of each variety. The Yukon Garden Handbook, published by the Yukon Agriculture Branch, is a helpful document for determining what will grow and how to do it. Also, talk to other gardeners and find out what has been successful for them.

> ***Haines Junction Mile 1019***
> ***1957-1958 Research Highlights***
>
> *" Successful vegetable gardening in the Yukon depends chiefly upon the selection and use of varieties that are adaptable to the location. Most common garden vegetables can be grown by one of the following cultural methods:*
>
> *1. garden sown*
> *2. greenhouse sown in beds or flats and later transplanted to the garden*
> *3. greenhouse sown in beds or flats and later transplanted to cold frames*
> *4. greenhouse sown in beds for retention in the greenhouse."*

### NCDP and YCDP Trials

Demonstration trials were done with several garden vegetables testing a number of different varieties including, potatoes, carrots, cabbage, head lettuce and beets. See the 1985-1990, Yukon Crop Development Program Reports available at the Agriculture Branch.

## SITE LOCATION

Choose your garden location, where it will have maximum sunlight. If possible select a site sloping towards the afternoon sun. Do not put the garden in a low area which may be subject to poor air drainage and mid season frosts. The garden should be sheltered from prevailing winds (usually from the south in the Whitehorse area). If no tree are available slotted fences can provide shelter from the wind. The garden should not be shaded by the wind barriers or shelterbelts.

> *If your garden is located on a slope make sure that you clear trees so that there is an outlet so you can provide for proper air drainage and let cool air escape down the slope.*
>
> \- Whitehorse Producer

## GARDEN LAYOUT

Crops should be grouped according to growth habits and time of maturity. A separate area should be selected for berries, and rhubarb etc. and herbs which will not be tilled each year. Early and late vegetables should be grouped together. Most garden crops require a 3 to 5 year rotation for the purpose of controlling soil borne diseases and insect pests. Orientation of the rows should be north to south to maximize sunlight. However, some producers prefer an east-west orientation. See what works best for your site.

## SEEDBED PREPARATION

The garden area should be prepared by rototilling or shoveling to make a loose friable seedbed to the rooting depth of the crops you intend to grow. For root crops, a good seedbed is more important than above ground crops.

The depth of rooting of vegetables is influenced by the soil profile. The normal depth of rooting, noted in Table 8.1, is not possible when there is a clay pan, hard pan, compacted layer, or other dense formation.

### *Raised Beds*

A number of vegetable producers prefer to make raised beds for better production. This is when a mound of soil is created, higher than the surrounding soil level. This can be done by hand shoveling, plowing or by specially made "bed-makers". Raised bed gardening can help overcome the problems of wet, cold and poorly drained soils. Benefits of raised beds are:

- Plant growth is enhanced through soil warming which results from an increased drainage capability and an increase in the exposure of the soil surface to the direct rays of the sun.
- Productive growing areas can be developed in locations where conventional gardening techniques are not possible.

Table 8.1 Characteristic Rooting Depths of Various Vegetables

| Shallow (18–24 in.) | Moderately Deep (36–48 in.) | Deep (More than 48 in.) |
|---|---|---|
| Broccoli | Bean, bush | Artichoke |
| Brussels sprouts | Bean, pole | Asparagus |
| Cabbage | Beet | Bean, Lima |
| Cauliflower | Carrot | Parsnip |
| Celery | Chard | Pumpkin |
| Chinese cabbage | Cucumber | Squash, winter |
| Corn | Eggplant | Sweet potato |
| Endive | Muskmelon | Tomato |
| Garlic | Mustard | Watermelon |
| Leek | Pea | |
| Lettuce | Pepper | |
| Onion | Rutabaga | |
| Parsley | Squash, summer | |
| Potato | Turnip | |
| Radish | | |
| Spinach | | |
| Strawberry | | |

Source: *Knot's Handbook for Vegetable Growers*, O. Lorenz & D. Maynard, John Wiley & Sons, 1988, pg 169.

A raised garden can be a simple mound of soil or boxed in with a framework of wood -like a bottomless box. Raised beds are good for intensive growing areas, for small gardens, as well as for large fields for vegetable, berry or flower crops. Raised beds work well if plastic mulches or row covers are to be used.

**"Bedmaker"- YCDP Trials**

During the YCDP vegetable trials, where plastic mulches and row covers were tested, raised beds were made with a "bedmaker". This was designed by local producers for horticultural trials, made out of steel for use on a tractor power-take-off (PTO). This implement was dragged over recently tilled ground which formed the soil into a bed 32 inches wide with a depth of approximately 6 inches. It was necessary to provide additional weight to keep the implement from bouncing and creating uneven beds. A heavy rock or person was used to weigh down the bedmaker. This equipment belongs to the Yukon Agricultural Association (YAA) and is located in Whitehorse.

**Tractor-Plowed Raised Beds**

Raised beds can also be made using a tractor plowing technique. This is to make a raised bed 32" wide. Needed is a three bottom plow and remove the middle plow. Run your rows in a east-west orientation. Figure 8.2 shows this process.

1. *Plowed Field* - Using a typical 3 bottom plow, after plowing the field there is a series of 3 ridges formed.
2. *(1A East)* - With centre shear removed, on your first pass going east, the two outer plow shears open up 2 furrows, with a portion unplowed between them in the centre.
3. *(1B West)* - On your return pass going west, the unplowed centre is moved up against the outside furrow of the previous pass and the second furrow of the previous pass is eradicated.

   You now have a row with two furrows up against each other and a row of a single furrow separated by a centre space from the other two. This completes one full plow cycle in bed making; repeat as many times as the width of your garden or field.
4. *(2A East)* - To start a second row travel east and begin pass by eradicating the single furrow and thus opening up an extra large path or space between the two rows.
5. *(2B West)* - Complete second row by repeating west pass.
6. *(Finish Pass)*- To finish bed pull a draw bar across the top of the rows thus flattening the top of the row, about 8-12" of soil is removed, forming the side of the raised beds. The path will then be the width of your tractor tire. The width of the finished bed is 32-36" wide and the walkway is usually 12-1" wide.

If fertilizers are used you can use a drop spreader on the 3

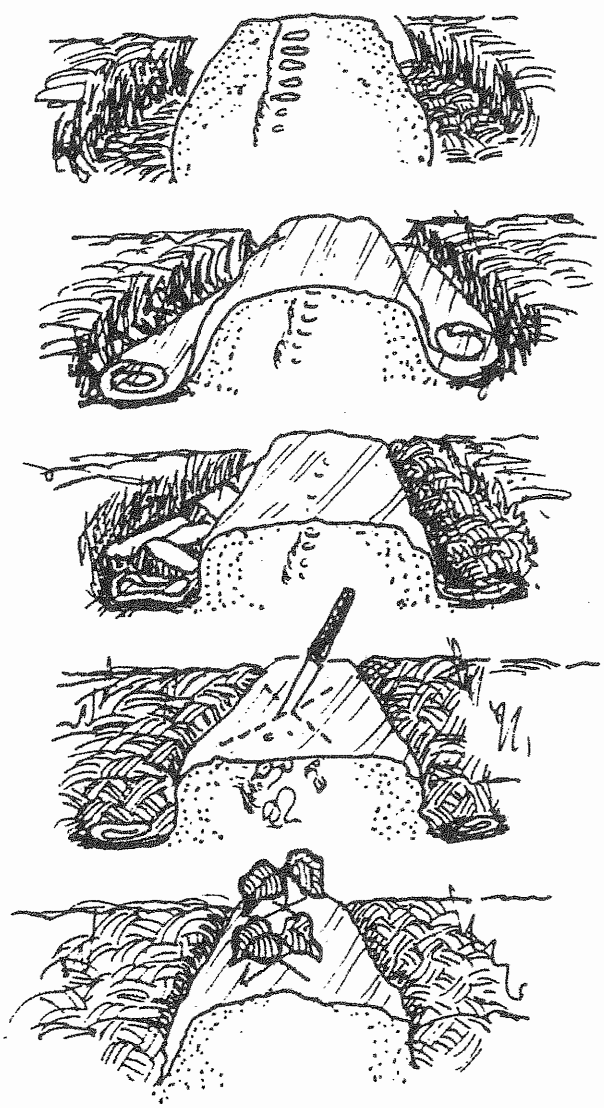


Figure 8.1 Raised Beds

Source: *16 Easy steps to Gardening*, University of Alaska Fairbanks Cooperative Extension Service, A-00134.

point hitch and pass over each bed. This is very efficient as no fertilizers is wasted in the walkways. Then do the finishing pass with the draw bar attached. This will incorporate the fertilizer and level the beds at the same time.

Source: M. & R. Girouard, Rivendell Farm - Whitehorse Producer

Whatever your row width, either as a wide row as previously described, or as a single row, the space between your rows should be according to the width of your cultivator equipment to be used. This will make maintenance alot easier for larger scale operations.

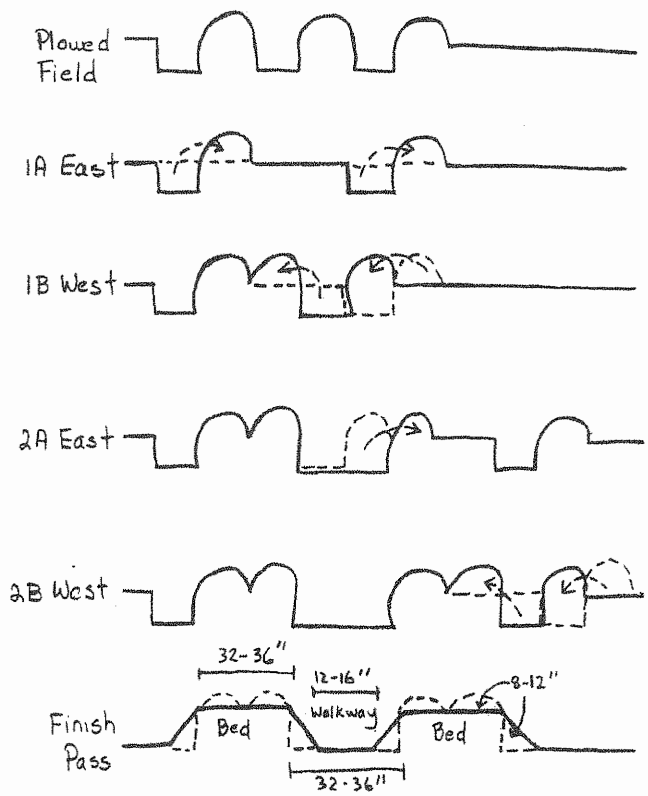



Figure 8.2 Tractor Plowed Raised Beds

## SEEDING METHODS

Generally seed your root crops directly into the garden as soon as the soil can be worked and the soil temperature is right for the particular crop (See Soil Temperature for Germination – Crop Management). The time of planting is also determined by the date at which production from the plant is desired. Some producers plant seeds (spinach, radishes) at consecutive intervals in the early spring and summer to produce a continuous supply rather than a single planting to produce the entire crop at one peak harvest. A proper seeding rate should be utilized to create the density for maximum yields. Too low a rate will reduce yields and too thick a stand will decrease size and quality. In practice it is often desirable to increase the rate of sowing to offset expected losses in the seedbed. The seedlings are thinned to a desired spacing after emergence.

*On the raised bed system, I use 3 Precision seeders (these work on a belt system with special hole plates for different seed sizes) which are attached on a draw bar and pulled behind the tractor. This way three rows of seed are accurately seeded per wide row.*

- (R. Girouard, Rivendell Farm-Whitehorse Producer)

Place seed to the correct soil depth for each vegetable type. The depth of planting depends on the size of the seed. A general rule is to plant seeds to three to four times their thickness, being sure this depth is within the moist layer of the seedbed. With too deep planting, germination may fail because the seedling is not able to emerge before the food reserves are exhausted.

Proper depth is also related to moisture supply. Too shallow planting will place the seed in the top soil layers which are subject to drying. In light sandy soils, or during periods of warm weather, deeper planting is best, whereas in heavier soils and during periods of cool, cloudy weather, shallower planting is permissible.

*" In Mayo, an avid gardener maintained that she produces better crops of cabbage and cauliflower from direct sowings in the garden, than from transplantation from the greenhouse."*

- Report on an Agricultural Survey of the Dawson City-Mayo District of the Yukon Territory, 1945.

Vegetable planting information is presented in Table 8.2. for a variety of garden and greenhouse vegetables.

It is possible to order pelleted or coated seed for a number of vegetable types. Pelleted carrot seed works well in precision seeders and provides for a more even seeding rate at higher speeds (seed does not bounce).

*I plant my garden with a small push type precision seeder. For carrots, I mix the seed with sand to create a seeding rate which is a good density and requires less thinning later on.*

-Whitehorse Producer

## Table 8.2 Vegetable Planting Information

| Kind | Approximate* seeds per ounce | Approximate seeds per 100 grams | Seed Required: For 100 feet row, seeded direct | Seed Required: For 10 meter row, seeded direct | Seed Required: Per Acre: Transplanted | Seed Required: Per Acre: Direct seeded | Seed Required: Per Hectare: Transplanted | Seed Required: Per Hectare: Direct seeded | Planting Distance: Apart in row after thinning (in.) | Planting Distance: Between rows (in.) | Planting Distance: Apart in row after thinning (metric) | Planting Distance: Between rows (metric) | Depth of planting (in.) | Depth of planting (cm.) | Days to germination |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Asparagus** | 750 | 2,600 | 1 oz. | 9.3g | 1 lb. | 6 lbs. | 1.1kg | 6.6kg | 18-36 in. | 24-48 in. | 45-90cm | 60-120cm | 1 | 2.5 | 21 |
| **Bean, Bush** | 100 | 350 | 1½ lb. | 200g | | 85 lbs. | | 95kg | 2-4 in. | 18-24 in. | 5-10cm | 45-60cm | 1-2 | 2.5-5 | 6 |
| **Bean, Pole** | 115 | 400 | ½ lb. | 74g | | 30 lbs. | | 34kg | 6-8 in. | 36-48 in. | 15-20cm | 90-120cm | 1-2 | 2.5-5 | 6 |
| **Beet and Swiss Chard** | 1,600 | 5,600 | 1 oz. | 9.3g | | 10-16 lbs. | | 10.8-17.9kg | 1-4 in. | 18-24 in. | 2-10cm | 45-60cm | ¾-1 | 2-2.5 | 8 |
| **Broccoli** | 8,900 | 31,400 | ¼ oz. | 2.3g | 4 oz. | 2 lbs. | 275g | 2.2kg | 18-24 in. | 24-40 in. | 45-60cm | 60-100cm | ½ | 1.2 | 10 |
| **Cabbage** | 8,900 | 31,400 | ¼ oz. | 2.3g | 4 oz. | 2 lbs. | 275g | 2.2kg | 12-24 in. | 24-36 in. | 30-60cm | 60-90cm | ½ | 1.2 | 10 |
| **Cantaloupe and Melon** | 1,200 | 4,200 | ½ oz. | 4.6g | | 3 lbs. | | 3.4kg | 2-3 ft. | 6-8 ft. | 60-90cm | 2-2.5m | 1-2 | 2.5-5 | 7 |
| **Carrot** | 23,000 | 81,200 | ½ oz. | 4.6g | | 3 lbs. | | 3.4kg | 1-3 in. | 18-24 in. | 2-7cm | 45-60cm | ½ | 1.2 | 8 |
| **Cauliflower** | 8,900 | 31,400 | ¼ oz. | 2.3g | 4 oz. | 2 lbs. | 275g | 2.2kg | 18-24 in. | 24-30 in. | 45-60cm | 60-75cm | ½ | 1.2 | 10 |
| **Celery** | 71,000 | 250,600 | ¼ oz. | 2.3g | 4 oz. | 1 lb. | 275g | 1.1kg | 4-8 in. | 20-48 in. | 10-20cm | 50-120cm | ⅛ | .3 | 21 |
| **Corn, Sweet** | 125-150 | 450-550 | ¼ lb. | 2.3g | | 10 lbs. | | 10.8kg | 4-6 in. | 30-48 in. | 10-15 cm | 75-120cm | 1-2 | 2.5-5 | 7 |
| **Cucumber** | 1,000 | 3,500 | ½ oz. | 4.6g | | 3 lbs. | | 3.4kg | 1-3 ft. | 3-6 ft. | 30-90cm | 1-2m | 1-2 | 2.5-5 | 7 |
| **Dill** | 22,700 | 80,100 | ¼ oz. | 2.3g | | 5 lbs. | | 5.4kg | 4-8 in. | 18-36 in. | 10-20cm | 45-90cm | ½ | 1.2 | 21 |
| **Eggplant** | 6,400 | 22,600 | ⅛ oz. | 1.2g | 4 oz. | 2 lbs. | 275g | 2.2kg | 18-24 in. | 24-30 in. | 45-60cm | 60-75cm | ¼-½ | .6-1.2 | 10 |
| **Endive** | 26,600 | 93,900 | 1 oz. | 9.3g | 1 lb. | 4 lbs. | 1.1kg | 4.5kg | 8-12 in. | 18-24 in. | 20-30cm | 45-60cm | ½ | 1.2 | 10 |
| **Lettuce** | 25,000 | 88,300 | ½ oz. | 4.6g | 1 oz. | 1 lb. | 70g | 1.1kg | 4-14 in. | 12-18 in. | 10-35cm | 30-45cm | ½ | 1.2 | 7 |
| **Mustard** | 17,600 | 62,100 | ¼ oz. | 2.3g | | 4 lbs. | | 4.5kg | 4-8 in. | 12-24 in. | 10-20cm | 30-60cm | ¼ | .6 | 10 |
| **Okra** | 500 | 1,800 | 2 oz. | 19g | | 8 lbs. | | 9kg | 12-24 in. | 24-36 in. | 30-60cm | 60-90cm | 1 | 2.5 | 14 |
| **Onion** | 8,500 | 30,000 | 1 oz. | 9.3g | | 4 lbs. | | 4.5kg | 2-4 in. | 18-30 in. | 5-10cm | 45-75cm | ½-1 | 1.2-2.5 | 10 |
| **Parsley** | 18,000 | 63,500 | ¼ oz. | 2.3g | | 3 lbs. | | 3.4kg | 4-8 in. | 12-18 in. | 10-20cm | 30-45cm | ⅛ | .3 | 21 |
| **Peas, Garden** | 85 | 300 | 1 lb. | 148g | | 80-120 lbs. | | 90-135kg | 1-3 in. | 24-36 in. | 2-7cm | 60-90cm | 1-2 | 2.5-5 | 8 |
| **Pepper** | 4,700 | 16,660 | ⅛ oz. | 1.2g | 4 oz. | 2 lbs. | 275g | 2.2kg | 15-18 in. | 18-30 in. | 40-45cm | 45-75cm | ¼-½ | .6-1.2 | 10 |
| **Pumpkin** | 120 | 420 | ½ oz. | 4.6g | | 4 lbs. | | 4.5kg | 3-4 ft. | 8-12 ft. | 90-120cm | 2.5-3.5m | 1-2 | 2.5-5 | 7 |
| **Radish** | 2,100 | 7,400 | 1 oz. | 9.3g | | 10 lbs. | | 10.8kg | 1 in. | 12-18 in. | 2-5cm | 30-45cm | ¼-½ | .6-1.2 | 7 |
| **Spinach** | 2,800 | 9,900 | 1 oz. | 9.3g | | 15 lbs. | | 17kg | 3-6 in. | 12-18 in. | 7-14cm | 30-45cm | ½-1 | 1.2-2.5 | 8 |
| **Squash, Summer** | 250 | 900 | ½ oz. | 4.6g | | 4 lbs. | | 4.5kg | 3-4 ft. | 3-4 ft. | 90-120cm | 90-120cm | 1-2 | 2.5-5 | 7 |
| **Squash, Winter** | 130 | 460 | ½ oz. | 4.6g | | 1 lb. | | 1.1kg | 3-4 ft. | 6-9 ft. | 90-120cm | 2-3m | 1-2 | 2.5-5 | 7 |
| **Tomato** | 11,000 | 38,900 | ⅛ oz. | 1.2g | 2 oz. | 2 lbs. | 140g | 2.2kg | 9-18 in. | 12-24 in. | 20-45cm | 30-60cm | ¼-½ | .6-1.2 | 8 |
| **Turnip** | 15,200 | 53,700 | ½ oz. | 4.6g | | 2 lbs. | | 2.2kg | 3-4 in. | 12-24 in. | 7-10cm | 30-60cm | ¼-½ | .6-1.2 | 7 |
| **Watermelon** | 300 | 1,100 | 1 oz. | 9.3g | | 3 lbs. | | 3.4kg | 2-3 ft. | 6-8 ft. | 60-90cm | 2-2.5m | 1-2 | 2.5-5 | 8 |

Source: Ferry Morse Seed Company Seed Catalogue, P.O.Box 4938, Modesto, CA, U.S.A.

## MANAGEMENT METHODS

### *Bio-dynamic Vegetable Garden*

This type of garden is managed by following certain definite principles of plant symbiosis such as the use of a well planned crop rotation, companionate plantings, juxtaposition of deep rooted plants with shallow rooted plants, and the generous use of summer flowering shrubs and aromatic herbs all through the garden whether it be large or small. Beneficial crop rotations and companion plants make it possible to get maximum benefits from limited garden space. Plants having complementary physical demands are well suited to each other. A plant which needs plenty of light maybe a good companion to one which needs partial shade.

Plants needing plenty of moisture get along with ones which need less moisture. Heavy feeders should be followed by light feeders, or by plants that make the soil rich again such as legumes.

Heavy feeders include: all the cabbage family, cauliflower, broccoli, etc, all leaf vegetables (chard, head lettuce, endive, spinach, celery, cucumbers, squash and sweet corn); tomatoes and rhubarb.

Light feeders include: bulbs and all root vegetables such as carrots, beets, radishes, parsnips, turnips and rutabagas.

All vegetables are aided by aromatic herbs such as borage, sage, parsley, chervil, tarragon, chives, thyme, marjoram, oregano, dill, and camomille. Yarrow increases the aromatic quality of all herbs which grow nearby and is a good companion for medicinal herbs. Herbs help build and maintain good gardens by controlling biologically, both insect pests and plant diseases. Marjoram and Oregano have a very beneficial affect on surrounding plants. Horseradish aids potatoes if restricted to the borders of the potato plot.

Usually the more variation the better, whether in general landscape development, a farm unit or a garden. Not only individual plants but whole landscapes become diseased through monocultural practices, since nature left to herself, never produces acre after acre of only one kind of a plant.

### Companion Planting

Plants are chemically affected by: aroma, exudations from the leaves and roots, by the roots of other plants,and by soil micro-organisms. It is best to plant compatible plants together and not plant together those that are not compatible. In Table 8.3 is a list of plants with their likes and dislikes.

Lettuce, radishes and carrots make a strong team together. Lettuce is aided by the presence of carrots and makes radishes tender in the summer. Radishes aid other vegetables. Peas and radishes are mutually helpful. Leeks and carrots grow well together as the leek is aided by the carrots and in turn the leek helps to repel the carrot fly from the carrots. Peas are inhibited by onions, garlic and potatoes. Potatoes grow well with cabbage and beans.

Marigolds excrete a substance from its roots which kills soil nematodes. Marigolds benefit most crops, especially cabbage family, curcurbits, fruit trees,radish and tomato. Tomatoes grow better and bear more fruit with marigolds than without them.

Table 8.3 Companion Planting

| Vegetables | Likes | Dislikes |
|---|---|---|
| Beans | Potatoes, carrots, cucumbers cauliflower, cabbage, beets, corn, most vegetables & herbs | Onions, garlic shallots |
| Pole Beans | Summer savory, corn | Onions, beets, kohlrabi, sunflower |
| Bush Beans | Potatoes ,cucumbers, celery strawberries, summer savory cabbages, corn | Onions,fennel |
| Beets | Onions, kohlrabi, bush beans | Pole beans |
| Cabbage or Brassica Family (brocolli etc) | Aromatic plants, potatoes celery,dill,camomile,sage mint,beets,onions,rosemary kohlrabi nasturtiums | Strawberries, tomatoes, Pole beans |
| Carrots | Peas ,leaf lettuce, chives, onions leeks, rosemary, sage, tomatoes | Dill |
| Celery | Leeks, tomatoes, bush beans, cauliflower, cabbage | – |
| Chives | Carrots | Peas, Beans |
| Corn | Potatoes ,peas, beans, cucumbers, pumpkin, squash | |
| Cucumbers | Beans,corn, peas, radishes, sunflowers, kohlrabi, lettuce early savoy cabbage | Potatoes, aromatic herbs |
| Tomato | Chives, onion, parsley, basil marigold, nasturtium, carrot, borage | kohlrabi, potato, fennel, cabbage |
| Peas | Carrots,turnips,radishes, cucumbers,beans, corn, most vegetables and herbs | Onions,garlic,potato |
| Squash | Nasturtium, corn | – |
| Onion | Beets, strawberries, tomato lettuce, summer savory, camomille | Peas, beans |
| Leeks | Onions,carrots,celery | – |
| Lettuce | Carrots,radishes,strawberries, cucumbers | – |
| Radish | Peas, Nasturtium, lettuce, chervil, cucumbers | – |
| Parsley | Tomato | – |
| Potato | Beans, corn, cabbage, horseradish marigold, peas, cucumber, tomato, raspberries | Pumpkin,squash |
| Pumpkin | Corn | Potato |
| Spinach | Strawberries | – |
| Sunflower | Cucumbers | Potato |
| Turnip | Peas | – |

Source: *A Companionate Herbal for the Organic Garden*, Organic Gardening and Farming, February 1972.

*Companion Plants and How to Use Them*, H. Philbrick & R. Gregg, Robinnson & Watkins Books, London, England, 1967.

Morning glories are known to stimulate the germination of melon seeds. Nasturnums benefit most crops especially the cabbage family, curcurbits, radishes and tomatoes. Nasturtiums also benefit potatoes when growing nearby. Nasturtiums planted next to brocolli keep away aphids. Nasturtium in the green house combats white fly. Flavour of radishes are improved next to nasturtiums. Chervil planted near radishes will make it hotter. Summer savory helps onions when planted as a border around them.

### *Fertilizer*

Fertilizer application should be based on soil test recommendations for a specific vegetable crop type. The heavy feeders require more than the light feeders. Under unknown conditions, suggested fertilizer rates are given in Table 8.5. For individual cases, these rates may have to be adjusted.

Table 8.4 Suggested Rates Of Fertilizers For Vegetables

| Vegetable | Amount (lbs/acre) | | |
|---|---|---|---|
| | N | $P_2O_5$ | $K_2O$ |
| Potato | 200 | 200 | 200 |
| Leafy vegetables: cabbage, lettuce, spinach | 150 | 100 | 150 |
| Fruit crops: tomato, pepper | 100 | 100 | 150 |
| Root crops: carrot, beet | 150 | 100 | 150 |
| Legumes: bean, pea | 50 | 75 | 50 |

Source: *Knot's Handbook for Vegetable Growers*, O. Lorenz & D. Maynard, John Wiley & Sons, pg 150.

*For vegetables, I weigh out mix my separate N,P, and K fertilizers, combine them, and broadcast on the raised beds, prior to planting the seed. For transplants, I usually apply a quart to 2 quarts of 20-20-20 soluble fertilizer to each plant at the time of planting, to help with transplant shock and adjustments.*

- Whitehorse Producer

### Calibration of Fertilizer Drills

Set the drill or broadcast spreader at the opening estimated to give the desired rate of application. Mark the level of fertilizer in the hopper. Operate the drill or spreader for 100 feet (30m). Weigh out a pail full of fertilizer. Refill hopper to marked level, counting the pails to determine the amount of fertilizer used in the 100 ft. (30m) and thus the application rate. If it is not correct, adjust the setting of the drill or broadcast spreader and recheck.

### *Tolerance of Vegetables to Salinity*

The relative tolerance of vegetable to salt content in soils is indicated in Table 8.5.

Table 8.5 Relative Salt Tolerance of Vegetables

| High Tolerance (12 mmhos) | Medium Tolerance (10 mmhos) | Low Tolerance (4 mmhos) |
|---|---|---|
| Beet | Tomato | Radish |
| Kale | Brocolli | Celery |
| Asparagus | Cabbage | Bean |
| Spinach | Pepper | |
| | Cauliflower | |
| | Lettuce | |
| | Corn | |
| | Potato | |
| | Muskmelon | |
| | Carrot | |
| | Onion | |
| | Pea | |
| | Squash | |
| | Cucumber | |
| (10 mmhos) | (4 mmhos) | (3 mmhos) |

**Note:** The relative salt tolerance decreases down each column, e.g. tomato is more salt tolerant than cucumber.

Source: *High Salt Content in Garden Soil*, Alberta Agriculture Garden Fax, Agdex 518-6, 1980.

### *Optimum pH Range for Vegetable Crops*

There is an optimum range of pH for different vegetable crop types:

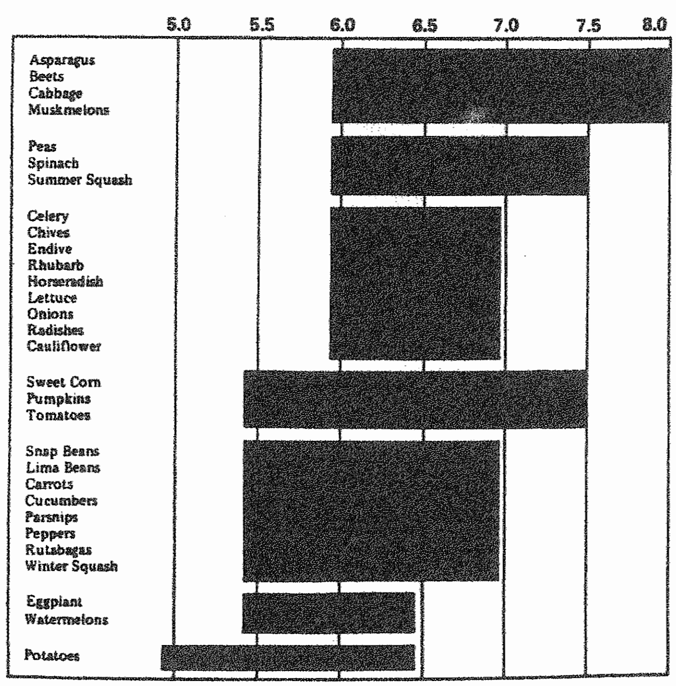



Figure 8.3 Optimum pH Range for Vegetable Crops

Source: *Down to Earth Vegetable Gardening Know How*, C. Cook, Garden Way Publishing, 1975.

### Insect Control

Making use of plant combinations which repel troublesome insects or which attract helpful insects (bees) is one part of a bio-dynamic garden. Plants which will control or repel local insects include:

Table 8.6 Plants that Control or Repel Insects

| Insect | Plant Antagonist |
|---|---|
| Ants | Spearmint, Tansy, Pennyroyal, |
| Aphids | Nasturtium, Spearmint, Garlic, Chives |
| Cabbage Butterfly/ Caterpillar | Sage,Rosemary,Hyssop,Thyme, Mint (Peppermint,Spearmint) |
| Fleabeetles | Mint, Catnip |
| Flies,mosquitoes | Basil, Rue, Tansy |

Source: *Companion Plants and How to Use Them*, H. Philbrick & R. Gregg, Watkins Books, Ltd., 1974, pg 49.
*Companion Plants*, Professor S.B. Hill, MacDonald College, Ste-Anne de Bellevue, Quebec.

Spearmint and other mints repel ants, aphids, black flea beetles, and white cabbage butterfly/caterpillar on nearby vegetation.

Sage will repel the cabbage butterfly and will make the cabbage plants more tender and digestible. It aids other vegetable in general. A sage tea can be made and should not be applied to young plants but to older plants after the blooming stage.

Thyme helps repel cabbage root fly and by its aromatic qualities enlivens nearby plants.

Tansy repels flies and ants. Tanacetin Oil from Tansy, distilled, has been used as a fly and insect repellent. Tansy also concentrates plenty of potassium and therefore is good to use in the compost heap.

**Herb tea for controlling insects:**

To make a herb tea to use as a spray: cover the herb with water in a pot, bring just to a boiling point and take off the fire. This infusion should be diluted with four parts water. It is recommended that the fluid be stirred for ten minutes and should then be used immediately.

**Horsetail Tea for controlling fungus:**

Horsetail (Equisetum arvense) bear a high percentage of silica which has a controlling affect on fungus diseases,including powdery mildew. This grows in moist areas along riverbanks etc. Put 1.5 ounces of dried Horsetail in 1 gallon of cold water. Bring to a boil and let it boil for 20 minutes but no longer. Allow to cool gradually. Strain. Spray on all plants which have their true leaves developed. Dilute the decoction more each time it is used in the same place.

### Rotations

Spinach is rich in saponin and helps to maintain the soil microlife and moisture. It is good to plant after cabbage.

Legumes benefit a garden and most all plants benefit by association with beans and peas. These can be rotated in the garden after the heavy feeder crops.

Lupines are often used as pioneer on poor soils, which they prefer. Lupines fix nitrogen and have been used for reclaiming sandy soils. In Alaska, lupines were found to be the first to revegetate in volcanic soils. Local farmers have found them on their cleared fields. In Alaska, white lupine has been seeded to determine soil improvement and was found to fix about 64 lbs acre of nitrogen. Vetches also fix nitrogen and should be encouraged to invade borders of fields etc.

### Thinning Seedlings

Thinning is a necessary practice to allow for maximum growth. Root crops like carrots, beets, radishes, turnips and rutabagas must be thinned otherwise they will grow luxuriant tops and no bottoms. Figure 8.4 shows the effect of thinning on carrots, the ones on the left have sufficient space and are well developed, the ones on the right are too crowded, providing thin carrots which are intertwined.

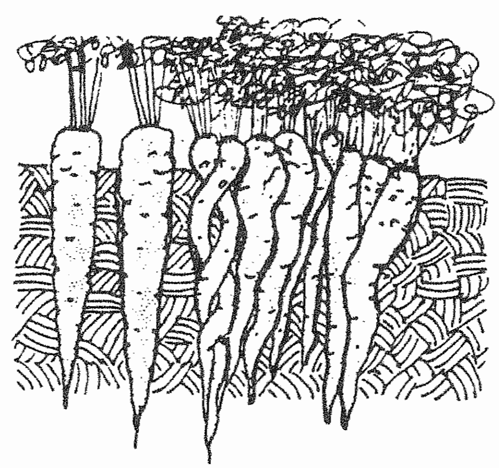


Figure 8.4 Thinning Seedlings

Crowded plants are also more susceptible to bolting. Thinning should be a gradual process, shortly after the first seedlings appear. The young seedlings should be thinned so their leaves do not overlap. As the plants continue to grow, the thinnings of lettuce make good salads and beets make good greens. By the last thinning plants of the root crops should be at least 4 in.(10cm) apart.

## PLASTIC MULCHES & ROW COVERS

The use of plastic mulches and row covers for production of vegetables is highly recommended as this cultural practice can extend your growing season, produce larger vegetables and help prevent insect and rodent predation.

### YCDP Trials

During the 1988-1990 crop trials, a winter storage cabbage Quick Green Storage was grown under a variety of commercially available plastic mulches and row covers.

Figure 8.5 Winter Cabbage

Raised beds were used made by the "bedmaker" or by hand shoveling 32" wide. In 1988, the trickle system was not available and most plots depended on rainfall. In the 1989 and 1990 seasons, a trickle irrigation system was used which consisted of: Lines from the water source, attached to a filter, then attached to a 1" plastic tubing used as a header or main-line with inserted 1/2" plastic tubing for laterals. Katif low pressure emitters were used and inserted every 2 ft along the lateral. The lateral was laid in the centre of each raised bed.

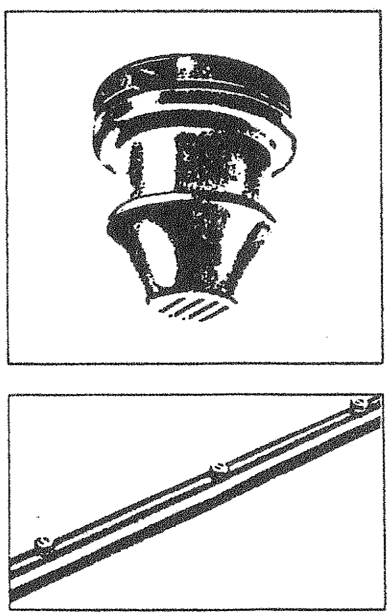


Figure 8.6 Low Pressure Emitters and Lateral

For those treatments with plastic mulch this was then applied. In the Whitehorse area the commercial mulch layer, bought as part of the project was used. This required a number of adjustments to operate correctly. In the other plots, a rod was inserted into the roll of mulch and using one person on each end of a bar was carried and unrolled over the raised bed. The mulch was held firm by piling on soil on either side. Slits were made in the plastic for the cabbage transplants. Cabbages were transplanted 2 ft. apart in the row. A solution of 20-20-20 soluble fertilizer was mixed and each plant received about a quart immediately after transplanting.

Hoops made out of #9 galvanized wire (cut into 7 ft. lengths) were placed every 4 ft at 2 ft height above the bed and then the row covers applied. A rod was inserted into the row cover, held over the row by 2 people and walked the full length of the row or test area. Soil, placed on both sides of the cover, as well as, stakes and wire "pins" were used to hold down the covers.

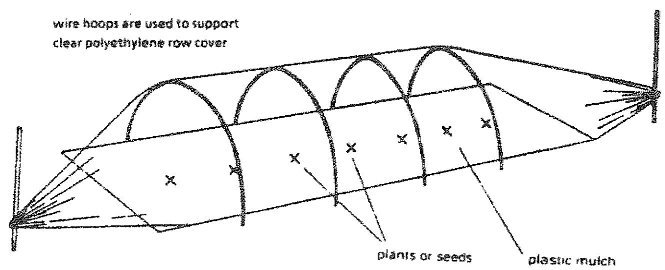



Figure 8.7 Row Cover Set up

The main trial (1988-1990) consisted of eight treatments using Black Plastic Mulch (BPM) or without; a control with no cover and three row covers; Reemay, Agronet and Slitted Poly. In a separate demonstration trial a different row cover/mulch combination was tested for comparison. In 1989, Visqueen cover and Visqueen mulch were tried,and in 1990 Lutrasil and Visqueen mulch were tested.

The various plastic mulches and row covers tested included:

**Mulches**

**Black Plastic Mulch (BPM)** - This is a black plastic 1.5mm thick and 4 ft wide. As this plastic is thin it can be stretched over the raised bed to pull it tight before holding it down with soil.

**Visqueen Mulch (VQM)** - This is a 1.25 mm thick and 4 ft wide embossed plastic, white on one side and black on the other. It is manufactured by Visqueen Film Products. The black side absorbs heat to promote healthier, faster plant growth and provide weed control. The white side reflects light to protect plants from overheating. Embossing in the film keeps bedding soil in place when it rains.

**Row Covers**

**Lutrasil** - This is a spun bonded polyester material manufactured in Germany. The fibres are bonded together in three directions making it stronger. It is also wider than the other covers used in this trial at 6.2 ft. This was tested only in the 1990 demonstration trials and was the best performer. It out performed Remay for production and was stronger. The larger width is also useful, making it easier to weigh down with soil and providing additional growing space.

**Reemay** - This is a lightweight spun bonded polyester material manufactured by Dupont. It can be purchased in 5'6" wide rolls or in larger sizes for a floating cover for field applications. It can be used with or without hoops. In the 1988 trials Remay with BPM provided the best production. Remay without BPM, was best in 1989 and 4th of the eight treatments in 1990.

**Agronet** - This is a U.V. resistant film/net of polypropylene and polymide weighing 0.05 ounces per square yard, manufactured by Kayersberg. Product information indicates that Agronet provides frost protection to -2.7 degrees Celsius. It can be purchased in 6' rolls or in larger sizes for field applications. In combination with BPM it was 4th in 1988, and 3rd in 1989. In 1990 it was the best producer, without BPM.

**Slitted Poly** - This is a 1.5 mm clear polyethylene cover with two strips of 5" (13cm) slits spaced at .75" (2cm) to provide ventilation. Plants are visible and accessible. In conjunction with BPM, it was 3rd for production in 1988, and without BPM, it was 4th in 1989 and second in 1990. With BPM, Slitted Poly was only slightly better than the control plot in 1989 and 1990. It appeared that high temperatures were a problem with this combination.

**Visqueen - White Seed Bed Cover** - This is a white plastic material with tiny holes perforated throughout. It diffuses light, providing more shading and a cooler more moist environment for plant growth. As it is not clear it has to be removed to see plant growth. It is manufactured by Visqueen Film Products and can be purchased in 6' wide rolls. It is recommended for propagation cuttings and the germination of bedding plants. Generally, it provided too much shade for cabbage growth and cabbages were smaller.

**Results - YCDP Trials**

Results were different each year of the Main Trial:

Table 8.7 YCDP Plastic Mulch & Row Cover Trials

**Main Trial**

| | | |
|---|---|---|
| 1988 | 1.BPM + Reemay | 5. Slitted Poly |
| | 2. Reemay | 6. Agronet |
| | 3. BPM + Slitted Poly | 7. BPM Control |
| | 4. BPM + Agronet | 8. Control |
| 1989 | 1. Reemay | 5. Agronet |
| | 2. BPM + Reemay | 6. BPM + Slitted Poly |
| | 3. BPM + Agronet | 7. BPM Control |
| | 4. Slitted Poly | 8. Control |
| 1990 | 1. Agronet | 5. BPM + Reemay |
| | 2. Slitted Poly | 6. BPM + Slitted Poly |
| | 3. BPM + Agronet | 7. BPM Control |
| | 4. Reemay 8. Control | |

The addition of the trickle irrigation for 1989-90, had an positive affect on growth results compared to 1988, without irrigation. In 1988, cabbages were planted in late June and weights ranged from .5 -3 lbs. In 1989 and 1990 cabbages were planted in early June and sizes ranged from 2-10 lbs (.90-4.5kg). Each year the control plots, with no mulch or row cover produced the smallest cabbages averaging 2 lbs or less. In 1990, Agronet without BPM was the best overall treatment and produced cabbages averaging 3.6 lbs (1.6kg) while the control was the least productive cabbages averaging 2.2 lbs (1kg).

(The cabbage picture on the back cover is an 8.9 lb (4.03kg) cabbage raised near Whitehorse in 1989, under the slitted poly row cover with no BPM.)

**Demonstration Trial**

In 1989, the Visqueen Row Cover produced the poorest of the row cover treatments. This cover provided too much shade. The VisQueen Mulch performed the best with slitted poly, then Agronet and Remay. In 1990, the Lutrisil cover had the best production first with the VisQueen mulch, second with BPM and third with no mulch. Agronet and Slitted poly with VQM did better than Remay. The worst treatment was the Visqueen cover with BPM. The Lutrasil cover in combination with the Visqueen Mulch or BPM, produced the best yields of all the treatments with cabbages averaging 4 lbs (1.8kg).

*For my garden I've used a trickle irrigation system with black plastic mulch and Lutrisil row cover over hoops. I've had excellent production with cabbages, broccoli and cauliflower. I also use the Lutrasil cover as a floating cover for improving germination of my carrots, beets, spinach, peas, radishes and onions, etc.*

- Whitehorse Producer

During the 1988 YCDP trials, ten carrot varieties were tested as part of the vegetable trial which were not irrigated. A remay floating cover was used to cover a portion of each raised bed to improve germination. There was a remarkable difference in growth in 2 weeks between the covered and uncovered carrot bed. The cover kept the soil from drying out too rapidly after rainfalls and kept soil temperatures moderated.

In 1990, as part of the YCDP vegetable trial, six varieties of head lettuce was grown using black plastic mulch (BPM) and Remay, set up like the main cabbage trial. Initially, lettuce growth was very good in this environment and by the end of July, lettuce heads were formed. As the covers were left on continuously, hot weather in early August created too high temperatures under the covers, with not enough ventilation. Rains tended to pool on the mulch and cause decay on the base of the plants. It appeared that this treatment would probably be best to give the lettuce crop a good start and then removed later in the summer when temperatures increase.

## IRRIGATION FOR FROST PROTECTION

Potato producers in Dawson and Watson Lake have used a sprinkler system for frost protection and found it to be very successful for potato production to protect them from mid season frosts.

> **_Haines Junction Mile 1019_**
> **_1945-1952 Research Report_**
>
> *In 1951 and 1952, rotating type of sprinklers were used to determine frost protection potential on a potato crop. A signal was activated at 32° Farenheit (0°C) the sprinklers commenced spraying the potato vines. The sprinklers continues to function until a frost free temperature was registered. This occurred a number of times each season. The vines were encased in ice. Later as the morning sun became effective the icicles fell away and subsequent observation during the day revealed no injury to the potato vines.*

### *Soil Moisture/Frost Protection Project*

Funded by Green Plan, a study was completed on a garden site near Dawson, YT. (Henderson's Corner) to determine the minimum amount of water which is required for frost protection using a sprinkler irrigation system. Two different nozzle sizes (15/64 and 1/4 inch) were used providing 3 different zones of water applications at .14"/hr, and .18"/hr, and where sprinklers overlapped, .32"/hr. Eight plots were set up, where frost sensitive vegetable crops, peas, beans, tomatoes, zucchini, and potatoes were planted. These plots were representative of the different water application rates. One of these was a control plot with no irrigation.

Soil moisture levels were monitored by soil irrometers (See Irrigation Practices – Crop Management) and by using a soil auger nd soil moisture evaluation by the "feel method". (See Soil Characteristics and Irrigation – Soil Management). From July 27th - August 12th, the quantity of water applied for each scheduled irrigation was determined. During the frosts on August 13, 14, 15, 18 and 23, the length of time the frost protection system was on and the amount of water applied was determined, as well as, the minimum temperature of each frost. On August 23rd, a frost of -6.7 °C (-20 °F) required 580 minutes (9.6 hours) of operation. Soils in Zone 2 were over-saturated on August 24th, and the decision was made to stop frost protection. Tomatoes and zucchini were able to ripen in the test plots when all neighboring gardens had already been killed by the consecutive frosts.

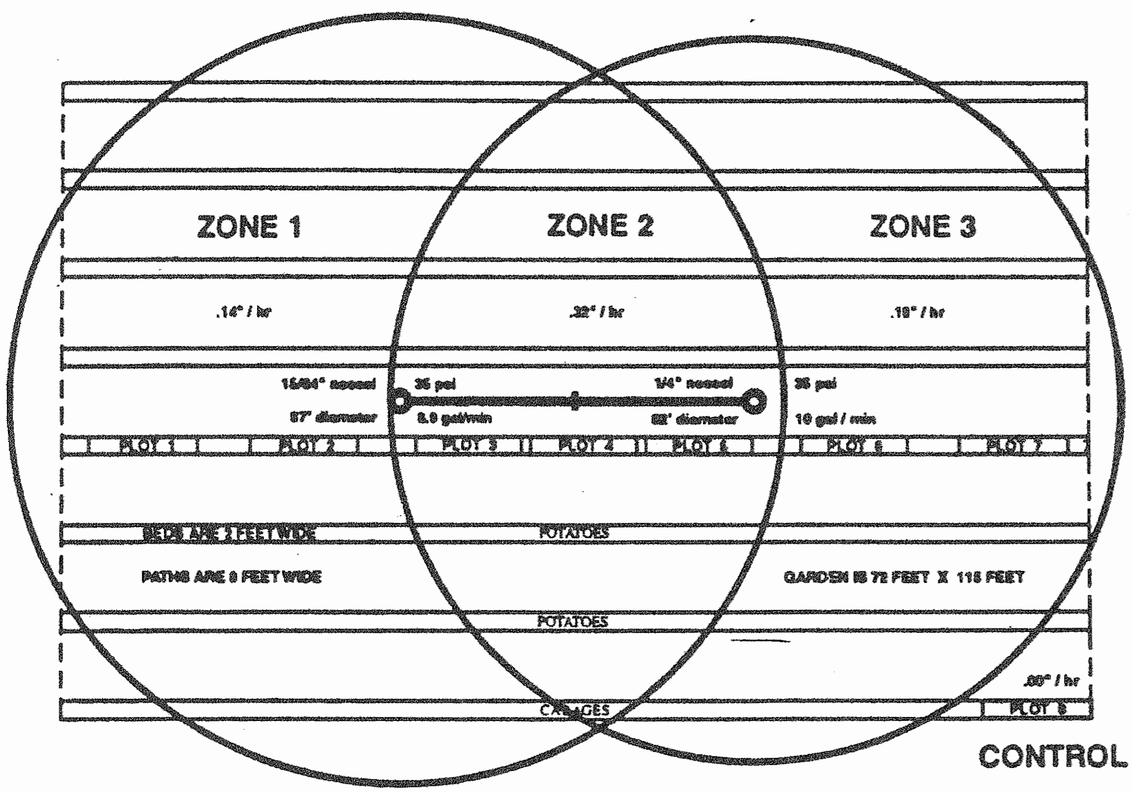



Figure 8.8 Garden Plan/Irrigation System.

- We were able to protect all test vegetables including tomatoes and zucchini down to -5.0 °C and to protect potatoes down to
- 6.7 °C, with a water application rate of .14"/hr in Zone 1.
- We were able to protect all test vegetables, including tomatoes and zucchini down to -6.7 °C with a water application rate of .18"/hr in Zone 3. This rate was the most suitable for the intended purpose.

Recommendations include:

1. Use an overhead sprinkler system that has the proper application rate for the crop, for the temperatures you expect to encounter.
2. Use a thermostat to turn the system on and off when a frost occurs. A timer is also useful to record the length of each irrigation to determine application rates.
3. Apply water for normal irrigations when it is most likely for a frost to occur (one hour before dawn). That way a normal irrigation may also serve as frost protection.
4. A minimum water application rate should be used to protect against frost while avoiding both excessive ice build up and waterlogging of the soil.
5. During frost protection the irrigation system should not be turned off until any ice that may have formed is completely melted from the plants.
6. When long periods of frost protection are required and the soil becomes over-saturated, a decision must be made whether or not to continue frost protection.

Source: *Soil Moisture/Frost Protection Research 1994*, K. Bisset & Associates, for Green Plan, Whitehorse, Yukon, 1994.

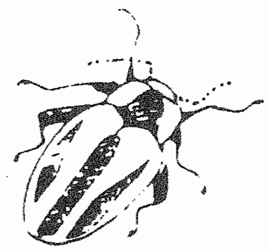
## INSECT PESTS

### Red Turnip Beetle

This leaf feeding beetle of the family *Chrysomelidae* has the scientific name *Entomoscelis americana* Brown. The adult red turnip beetle is a bright red with three black stripes down the back, and a black patch behind the head.

The eggs are brown-orange, 1/8 by 1/16 inch, laid on the ground in loose clusters sheltered by debris and soil lumps. Larvae are rough-skinned, yellowish underneath and dark brown above, with a few short hairs. The beetles pupate on or just below the soil surface. The pupa is predominantly orange and the same size as the adult. The larvae and adults feed on members of the mustard family (turnips, cabbage, cauliflower, radishes etc.); indeed the insect appears to be entirely restricted to this group of plants. It is a serious pest of canola in the prairie provinces. Weeds such as tansy mustards and shepards purse are fed upon by the larval stage of the beetles in the spring. The brightly colored adults are first noted in late June or early July. After several weeks of feeding, the bulk of the population usually disappears. The beetles are still there but they have dug into the soil several inches and become inactive in a condition known as aestivation or summer hibernation. In a few weeks the beetles may reappear from the resting sites and begin feeding on crops again. Mating and egg laying occurs in late August. The frost eventually kills the adults. Fortunately the red turnip beetle is easily controlled by application of diazinon or malathion, insecticides also used against aphids and root maggots. Rotenone, and diatomaceous earth, natural insecticides can also be used. (See Insect Control – Crop Management).

> **Haines Junction Mile 1019 1945-1952 Research Report**
>
> *"Red Turnip Beetle as a rule is seasonally encountered. Turnips, and radishes suffer the most from this pest."*



In the YCDP row cover trials, the cabbages were affected by the red turnip beetle at the younger transplant stage. Diazinon and rotenone were used for control. It appeared that dry weather was necessary for populations to build up to become harmful. The row covers prevented feeding from this pest and the control treatments with no covers were most affected.

> *"All of the people interviewed reported that their gardens were seriously damaged by the red turnip beetle only during years in which tansy mustard was abundant."*
>
> - Source: *Red Turnip Beetle*, R. Washburn, Agroborealis, June 1975.

### Root Maggots

When root maggot larvae feed on tubers of root crops such as turnip, rutabaga and radish they leave surface scars and feeding tunnels. That attack all varieties of crucifers, of the mustard family (Cruciferae).

At one YCDP plastic mulch and row cover trial site near Whitehorse, there was a problem with root maggots. There appeared to be less effects from root maggots on the treatments with black plastic mulch than without. In soils where these are present, perhaps the use of plastic mulch can reduce this problem.

> **Haines Junction Mile 1019 1945-1952 Research Report**
>
> *"Cabbage root maggot is seasonally present, yet seldom in devastating numbers".*
>
> *"Radishes are perfectly adaptable up to three periodic sowings. Root maggots can attack a percentage in later sowings."*

## POTATO PRODUCTION

Potatoes are a successful crop for the north. Many factors affect growth and quality including variety, size of seed tubers, temperature (frost), moisture, nutrition, planting and harvest date.

For simplicity sake, one main stem is shown on the diagram of a potato plant in Figure 8.9.

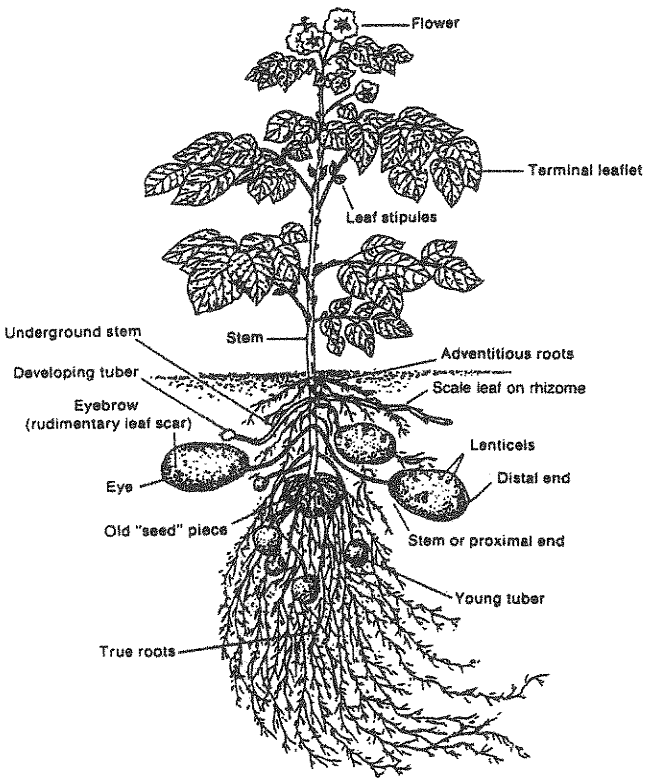



Figure 8.9 Potato Plant

Source: *Potato Production Guide for Commercial Producers*, Alberta Agriculture, Agdex 258/20-8, 1992.

### *Varieties*

A number of varieties have been tested in the NCDP trials and are grown by local producers. It is essential to purchase high quality seed, preferably certified disease free. Certified, Foundation, Elite 4 or 3 seed is used to produce commercial potatoes in Canada. The importance of selecting disease-free seed lots with few, if any tubers greater than 8 oz cannot be overemphasized. Smaller, uniformly sized tubers provide better planter performance.

> ***Haines Junction Mile 1019 1945-1952 Research Report***
>
> *"Site, soil and altitude are extremely important to the potato culturalist. At this latitude the warm sandy loams appear more desirable for potato culture than do the heavier clay loams."*

Locally grown potato varieties have included:

**White Skinned**

*Yukon Gold* - A mid season variety with oval tubers and a yellowish fine skin. This variety has good baking and french frying qualities.

*Norgold Russet* - An early mid-season variety with oblong tubers and a tan russeted skin. It has good boiling and baking qualities.

*Carleton* - An early maturing variety with oval white skinned tubers. Good baking qualities. This was susceptible to scab in the YCDP trials.

*Warba* - An early maturing variety with whiteskinned round to oval tubers with deep eyes that are pink in colour.

*Bintje* - This is a long shaped whiteskinned tuber variety originally from Holland.

*Kennebec* - A late maturing, high yielding variety. It is suitable for chipping and boiling.

*Gemseg* - A very early variety with oblong tubers and a tan skin. This was most affected by scab in the 1985 NCDP trials. It has good cooking qualities.

**Red Skinned**

*Norland* - An early variety with oblong tubers and a smooth red skin. It has good boiling and chipping qualites.

*Viking* - An early variety with round tubers and good cooking qualities.

*Pontiac* - An early variety with round tubers.

**Purple Skinned**

*Purple Survivor* - An early hardy variety with bright purple skin and fair cooking qualities.

### *Seedcutting*

Before cutting seed should be warmed to about 15 °C for 10 days unless sprouts have already appeared. This warming process helps to break the dormancy during cold storage and will speed up emergence.

The importance of proper seed cutting cannot be over emphasized because the cut seed lot has a direct bearing on plant stand, vigor and yield. Seed piece factors affect both yield and uniformity of a potato crop and include seed piece weight, type of seed pieces and the age of the seed tubers.

> **In 1993 legislation** was passed in Alberta requiring that anyone planting potatoes with the intent of selling them (no matter how small the area) will be required to plant certified classes of seed. Exemption permits, allowing a grower to plant other than certified seed for special uses are available.

### *Alberta Research*

In Alberta, researchers have found that the productivity of the seed decreased as the number of cut surfaces increased. Also, they found that variation in growth was directly related by different seed piece weights. The number of cut surfaces and the weight of the whole potato is indicated in Figure 8.10.

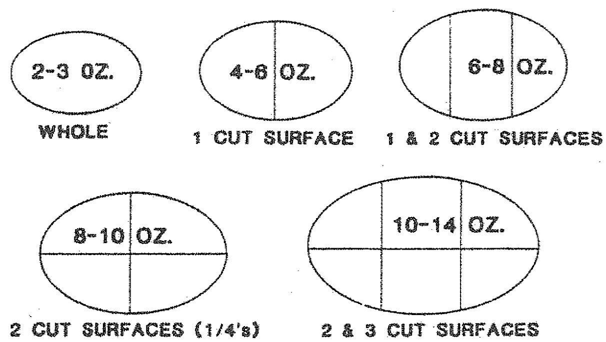



Figure 8.10 Potato Seed-Piece Types

Source: *Smaller Seed Tubers Key to Increased Yields*, Research Notes, Alberta Special Crops and Horticultural Research Center, Brooks, Alberta, 1988.

Production was compared between the different seed pieces: pieces with 2-3 cut surfaces produced less than whole tubers or halves. Seed pieces cut from large mother tubers were not as productive as pieces of the same weight cut from smaller tubers. Pieces from larger tubers can have fewer "eyes" and produce plants of varying productivity. The eyes that form on the tubers are similar to buds that form on branches- buds from which next season's growth will sprout. A piece should have at least two eyes to ensure sprouting.

The best sized tuber is 1.5 -3 ounces and used whole. Small seed pieces less than 1.5 ounce produce weak, unproductive plants and seed pieces greater than 3 ounces are not appreciably more productive than 2 ounce seed pieces, yet they cost more. The small tubers or end pieces/cuts less than 1.5 ounce should be discarded. A 2 ounce half-tuber seed piece cut from a 4-5 ounce tuber is more productive than a 2 ounce centre or stem-end piece cut from a 12 ounce large tuber. Uniform lots of small whole tubers ranging in size from 2-2.5 ounces (60-70g) will produce plants with high vigor, stem counts, high tuber set and high yield of uniform tubers.

*"Growers should avoid cutting seed from tubers greater than 8 ounces."*

*"Growers should adjust the cutting to give the highest proportion of pieces with the fewest number of cuts."*

Most potato growers plant within one day of cutting. Precutting seed earlier can reduce the rush at planting time but only if they can be maintained at 15-20 °C with high humidity and good air movement for about five days (for the cuts to heal), called suberization. If cut pieces are to be stored after suberization is complete they should be cooled down. If these conditions are not attainable growers are advised to cut just before planting.

Sulphur may also be applied to the flesh side of the cut pieces to speed drying of the flesh. Potatoes may also be planted directly after applying sulphur; the sulphur protects pieces from rotting if soil conditions are moist at planting time. During and after cutting and at planting time ensure the pieces are not exposed to drying conditions and direct sun.

### *Planting*

Soil temperatures should be at least 5 °C before potatoes are planted. Seed pieces planted into too cool a soil may decay.

The optimum soil temperature for initiating tubers is 16-19 °C. Sprout elongation maximizes at about 18 °C. Tuber development is reduced above 20 °C and practically stops above 30 °C. The number of tubers is greater at lower temperatures, whereas higher temperatures favour development of large tubers, with less produced per plant.

Potato plants that have emerged and then frozen to the ground will regrow rapidly and within a few days appear to be unaffected. However, when compared to later planted crops that are not frozen, they will mature later and quality may be reduced.

*I plant my potatoes as soon as the soil can be worked, in early May. I may loose emerging leaves to frosts, but I find that the plants recover and yields are better than if I planted in late May.*

- Haines Junction Producer

### *Fertilizing*

Fertilizing should be done according to soil test recommendations. Depending on soil fertility and the inherent amounts of nitrogen, phosphorous and potassium already available in your soil, the following lbs/acre can be applied for potatoes. (Alberta Agriculture recommendations). The range indicated is fairly wide, depending on low-high amounts in your soil:

| lbs/acre | N lbs/acre $P_20_5$ | lbs/acre $K_20$ |
|---|---|---|
| 100-150 | 100-200 | 100-300 |

If the soil recommendations are not known a suggested rate is 200 lbs/acre N, $P_20_5$, and $K_2O$. (See Table 8.4)

### *Spacing*

Growers in Alberta are planting from 1500-2000 lbs of seed per acre, 8-15" (20-38cm) apart in the row, depending on irrigation. Rows are usually planted 36" (90cm) apart. Spacing recommendations under irrigated conditions are usually less than dry land. Average spacing is 8-12' (20-30cm) in the row for irrigated potatoes and for dry land 11-15" (28-38cm) in the row. Crop uniformity is improved, the incidence of oversizing and "hollow heart" is reduced. Yield per plant goes down at close spacing, but the marketable yield per acre increases as spacing decreases. Plant seed 1-3" (3-8cm) below field level or about 4-6" (10-15cm) below the crest of the planter hill. Shallow planting may result in uneven emergence if seed pieces are planted into dry soil. However, deep planting into cold soil can delay emergence and reduce vigor.

### *Hilling*

Potatoes are hilled to protect tubers near the soil surface from greening and frost damage. Hilling should be done before plants are 8" (20cm) tall and should be high enough to cover tubers by about 4" (10cm) of soil. Hilling too late may cause excessive root damage and spread of diseases from plant to plant.

### *Irrigation*

High tuber set is obtained with high moisture at tuber setting time compared with low moisture. Potato plants initiate tubers when the plants are about 8-10" (20-25cm) high, well before the flowers appear, and they have a high moisture need at that time.

A uniform supply of moisture (above 60-70 per cent of available moisture capacity ) generally increases tuber set and yield, and reduced the number of deformities.

Irrigation and management practices have increased yields in Alberta from about 4.5 tons/acre in the 1950's to about 12 tons/acre in the late 1980's.

### *Vine Killing*

Potato vines are chemically dried or mechanically removed by Alberta growers. This is done to remove vine growth that interferes with mechanical harvest and to mature the tubers and set the skin thus reducing skinning, bruising and storage shrinkage. Diquat (Reglone) is used to desiccate the vines. Growers should allow a minimum of 10 days between top killing and harvest. Vine killing is also naturally done by fall frosts. A few frosts will help to mature the tubers. Growers should avoid harvesting potatoes when tuber temperatures are below 5 °C (41 °F). At low temperatures the tubers are very brittle and subject to bruising and shattering.

### *Diseases*

A few of the potato diseases seen in the Yukon include:

**Common Scab** - Common scab is a bacterial disease caused by Streptomyces scabies where it occurs naturally in the soil where it lives on plant debris. Severely infected tubers are unsightly with deep scabs or lesions. Scab is worse when soil moisture is low and after applying barnyard manure. Scab is more prevalent on soils with a pH higher than 5.2 and appears to worsen on more alkaline soils as pH increases.

**Hollow Heart** - This is when a cavity in the center of the tuber is formed, walls of the cavity are white to light brown. This is caused by rapid tuber growth. This is not detectable on the outside of the tuber. This can be controlled by closer plant spacings and maintaining uniform soil moisture.

**Fusarium and Verticulum Wilts** - Wilt diseases are caused by soil born fungi, Fusarium spp. and Verticulum spp. Individual leaves turn pale green or yellow, leaves on affected stems then wilt and finally the entire plant dies prematurely. This fungi, once established can live for long periods in the soil even if a potato crop has not been planted for many years. The disease can become established through the use of infected seed.

> ***Haines Junction Mile 1019 1945-1952 Research Report***
>
> *"Common scab on the potato is becoming somewhat of a problem in older garden sites, particularly in soils with neutral or slightly alkaline reactions. Infections may be described as light scab."*

### *Rotation*

Potatoes must be rotated with other crops to prevent a build up of diseases. Some diseases are quite adequately controlled in a one or two year rotation, however other require longer periods.Wilt diseases require at least a four year rotation to reduce populations to tolerable levels.

### *NCDP Trials*

Potato varieties tested in the NCDP trials in 1986-87 had a range of yields of 5-18 Tons/acre. Norland at a site in Sunnydale, west of Dawson, produced 18 tons/acre. Carlton, the best producer, produced up to 14 Tons/acre.

> **This season:** Weigh seed pieces, check for eye distribution on seed pieces, count stands, count stems and compare tubers from vigorous plants with those of runts. Why are there misses in your stand? Do the bigger plants come from bigger seed pieces? Which seed pieces emerged first?

# BERRY PRODUCTION

The production of berries has been undertaken by several Yukon producers on a commercial scale. Local experience with berry production has been primarily with raspberries, strawberries, saskatoons and black currants.

This section covers the production and management of raspberries, strawberries, saskatoons, the Northern Black Currant and commercial black currant.

## RASPBERRIES

Raspberries have been the most commonly grown as a field crop in the Yukon, consisting of commercially available varieties. Gardeners have also had success with raspberry plants transplanted from the wild.

Figure 9.1 Raspberries

Source: *Commercial Raspberry Production on the Prairies*; A Grower's Guide, S. Williams, University of Saskatoon, University Extension Press, 1993.

The raspberry is a member of the rose family (Rosaceae) and the genus Rubus, known as "bramble fruits". While red, yellow, black and purple fruited raspberries exist, only red and yellow (a variant of red) are reliably hardy. There are two types of raspberries, summer bearing or fall bearing. Almost all commercial plantings in the prairies are of summer bearing raspberries. Fall bearing raspberries, which produce two crops per season, fruit too late in the prairies, and thus, are not suitable for Yukon Conditions.

### *Summer-bearing Canes or "Floricane" Types*

Most hardy varieties have a biennial growth habit and are referred to as "floricane" types. First year or "primocane " growth is rapid and vegetative (leafy), taking place during spring and early summer. As the new canes develop, axillary buds are produced at the base of the leaves. Axillary buds break or grow in the first year, so primocanes are mostly unbranched. In the fall with shorter days and cooler temperatures, growth ceases and primordial flowers develop within axillary buds. Once the canes are at least 20 nodes tall and low temperatures, between 4.4-10°C (40-50°F), are the critical factors for flower bud initiation. Floral differentiation advances from the top of the stem downward. Buds near the base of the cane remain vegetative, with those below soil level becoming next year's primocanes. The plant then enters dormancy or a winter rest stage. During their second year, the axillary buds on the "floricanes" develop into fruiting shoots, with several leaves and flower clusters. The greater the diameter and vigour of the floricanes, the greater their production. Buds in the middle portion of the cane are the most fruitful. Canes do not increase in height during their second year, and after fruiting, the canes die. New primocanes are being produced to replace them in the next season.

In the prairies, 'Boyne' is the most popular variety of summer bearing raspberries. It is the hardiest and most consistently productive cultivar for the prairies and in all colder regions of Canada. Canes are medium in height, thick erect, and stocky, with many lateral branches. Fruit is medium sized, dark red, firm, juicy and tart. It has good dessert quality, good frozen quality, and is excellent for processing and canning. Other varieties include 'Chief', 'Killarney', 'Festival', 'Nova', and 'Redbrook'.

### *Site Selection*

A gentle slope to the north or east is preferred as this permits excess water and cold air to drain. Avoid "frost pockets" or depressions where cold or freezing air collects. North and east facing slopes thaw, dry, and warm up more slowly in the spring which tends to delay bloom for one or two weeks, further avoiding the danger of frost damage. Good soil drainage and moisture holding capacity are essential. The roots of raspberries are sensitive to oxygen depletion and intolerant of soil that is waterlogged for more than 24 hours. Avoid sites with heavy clay or very sandy soils. A deep friable loam with at least 3% organic matter is preferred. If the soil does not contain sufficient organic matter incorporate 2-3" (5-8cm) of well rotted manure into the soil a year prior to planting. Four to eight tons of poultry manure or 14-18 tons of barnyard manure, per acre, may be added. Green manure crops may also be used as a pre-plant soil amendment. Peas, oats, buckwheat, rye and fababeans have been used as green manures preceding raspberries.

A pH range from 5.5-7.0 is recommended, although raspberries have done well with a pH as high as 7.5. Avoid alkaline soils as raspberries are highly susceptible to an iron deficiency (iron chlorosis) caused by soils with a high pH, which makes iron unavailable to plants. This causes raspberries to be more prone to winter injury and the planting weakens over time. Zinc and manganese deficiencies may also be found on soils with high pH. Because of the possible presence of verticillium disease, avoid sites where alfalfa, eggplant, potatoes, strawberries, sunflowers or tomatoes have been grown within the last five years. Keep raspberries away from potatoes because the latter are more susceptible to blight.

Shelterbelts are very important as raspberries are very susceptible to wind damage. Shelterbelts against the prevailing wind reduce wind damage in the winter while encouraging snow cover.

*Plant raspberries in an open field and at least 100 ft. away from the base of a south facing slope. I planted at the base of a south facing slope and solar gains in the winter caused thawing of the canes resulting in a total loss of my raspberry crop in the first year.*

- Whitehorse Producer

### Planting

Rows planted on a north-south orientation favour a more uniform distribution of light, air and water drainage which are probably more important considerations. Plant spacing within the row is recommended at 1m (3ft). Rows should be spaced 2.7-3.7m (9-12ft) apart depending on the type of machinery used for weeding, pruning and harvesting and whether alternate row cropping is practiced. A spacing of 1m in the row with rows 3 m (9ft) apart would require about 1450 plants per acre.

Early spring planting is preferred to fall planting. This allows plants to establish a better root system during the first season and results in a much higher survival rate. Obtain one year old plants that are certified free of virus and root rot. They should have well formed root systems. Digging and transplanting suckers from local plantings is not recommended for the establishment of commercial plantings. Roots should not be allowed to dry out. Plants should be stored at 0°C (32°F) or "heeled in" by burying the lower two thirds of the dormant plants in trenches in a shaded area protected from wind.

Plough a furrow 5-6" (13-15cm) deep, setting the plants against the side of the furrow and covering the roots with soil. If possible, plant when the weather is cool, cloudy,and calm. Plants should be set at the same depth or up to 2" (5cm) deeper than they were previously planted. This level can be determined by the soil lines on the canes. If set too shallow or inadequately firmed they will dry out. If planted too deeply new shoots may not emerge. Immediately after planting, irrigate young plants beyond the depth of their root system and into the soil below. Using a starter solution of 10-52-10 during transplanting has been beneficial. Cut canes back to about 8" (20cm) if they have not already been cut. This reduces the water loss through the foliage, compensates for transplanting shock, and eliminates most of the potential fruit production which would otherwise reduce root establishment and sucker production. No further pruning should be needed until the third year.

### Irrigation

For consistently high yields, irrigation is essential, particularly during periods of fruit enlargement or during dry weather. Raspberries absorb most of their required moisture from the upper 1-2 ft (0.3-0.6m) of soils. They should be watered to this depth whenever 50% of the available soil moisture has been used. Soil moisture should be maintained above 50 percent capacity for maximum growth. Critical periods for irrigation of raspberries are during their year of establishment, and seasonally, from bud development through to fruiting. For maximum berry size, irrigation is particularly essential during the final swell or enlargement of fruit. This usually occurs three weeks after the first bloom. After August, it is important to allow plants to harden up for winter and irrigation should be less. Once raspberries have entered dormancy, apply one final irrigation prior to freeze-up.

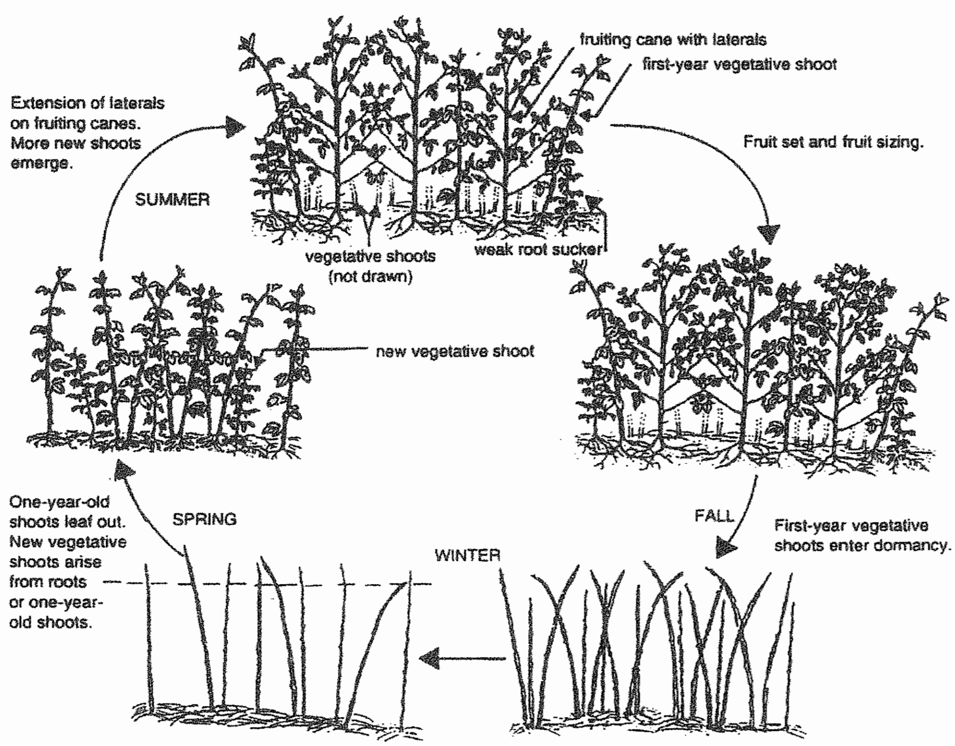



Figure 9.2 Biennial Life Cycle of Raspberry Plants

Source: *Commercial Raspberry Production on the Prairies; A Grower's Guide*, S. Williams, Univ. of Saskatoon.

Water tests are recommended to ensure irrigation water is non-saline and has a pH range of 5.5 to 8.0.

Most growers use either an overhead sprinkler or a trickle irrigation system. Surface flooding or furrow irrigation is not recommended as raspberries are sensitive to standing water.

### Fertilizer

Generally raspberries require approximately 60 lbs/acre of nitrogen, 60 lbs/acre of phosphate ($P_2O_5$),and 80 lbs/acre of potassium ($K_2O$) applied in the spring. A soil test is required to determine the exact rate for your specific soils. On irrigated, loam soils, the nitrogen requirement of summer bearing raspberries will increase from approximately 30 lbs/acre during the first year to 50 lbs/acre in the second year and 60-80 lbs/acre in the third year and thereafter. Nitrogen should not be applied closer than 6" (15cm) from new plants. Ammonium nitrate is the preferred form of nitrogen. Plants with a nitrogen deficiency will exhibit small, yellowish green foliage and may appear stunted. On soils with a pH higher than 7, applying a sulphur containing fertilizer such as 21-0-0-(24) or 16-20-0-(14) should be considered. A phosphorous deficiency is usually indicated by a purplish or dark cast to the older leaves or premature leaf drop. A potassium deficiency includes small leaves and the scorching of margins.

### Cultivation

A cultivation depth of 2-3 inches (5-8cm) is recommended to avoid root injury as raspberries are shallow rooted.

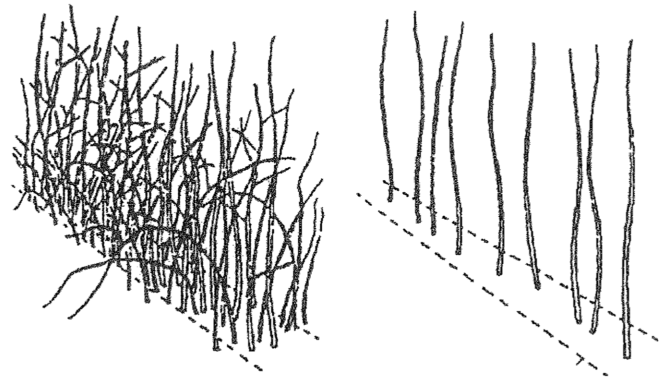
### Mulching

It is recommended that new raspberry plantings have one season's growth prior to the application of mulch; that nitrogen be incorporated into the top few inches of the soil at the rate of 1-1.5 percent of the weight of the mulch used and that the mulch be applied in the fall (after the plants have entered dormancy) or in the spring when the soil is moist. Once mulching has been initiated it should be continued for the duration of the planting. Top dressing of the mulch layer will be needed approximately every third year.

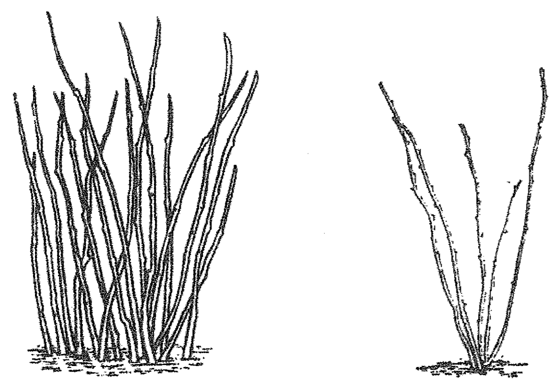
### Pruning

Raspberries are pruned to 1) maintain a desired row width; 2) limit cane density; 3) tip or remove the top portion of the cane; 4) remove spent fruiting canes; and 5) remove weak, damaged and diseased canes. Pruning is critical to the longevity and productivity of the stand.

Hedgerow width should be restricted to a maximum base of 12-18" (30-46cm) through pruning, mowing, and cultivation from the third year onward. Canes should be thinned by removing smaller, weaker and late developing canes so that four to five canes of .5 inches diameter per linear foot of row remain. Thinning is done in spring when winter breakage and injury can be assessed. Ideally thinning can be done repeatedly over the season. Thinning reduces competition among the remaining floricanes for moisture, nutrients, and light, thus improving berry size, yield and quality. Tipping is done to remove the upper portion of the canes that have



*a) Limiting cane density: raspberries before and after thinning.*



*b) Left: Red raspberry plant before thinning and pruning.*
*Right: The same plant after thinning and pruning.*

Figure 9.3 Pruning of Raspberries

Sources: a) *Commercial Raspberry Production on the Prairies; A Grower's Guide*, S. Williams, University of Saskatoon, Extension Press, 1993.

b) *Growing Raspberries*, Farmer's Bulleting No. 2165, U.S. Department of Agriculture, Washington, D.C., 1975.

been tip killed during the winter. Tipping down to a final height of 1.7m (5.5ft) makes picking easier and reduces the extent to which canes bend with the weight of the fruit. Floricanes that have fruited should be removed and burned immediately following harvest. The earlier they are removed the less they will interfere and compete with the new primocanes for light, nutrients and water. Weak damaged and diseased canes should be removed as they are noticed, to prevent the buildup and spread of disease in the stand.

An alternative management practice is to mow down all the first year canes in the spring following planting. This stimulates greater sucker production during the second summer (by eliminating competition for nutrients between floricanes and primocanes within the plant), ensuring a substantial crop in the third summer.

Most raspberry plantings are productive for 10-20 years. A well managed planting, where weed and pest management, pruning and rouging of diseased material is carried out on an annual basis, should seldom need a major renewal. Lower productivity is usually due to the presence of weeds, disease, or woody, crowded roots which are no longer able to produce vigorous new suckers. Viruses can be spread from diseased to healthy plants by sucking insects (primarily aphids) or by bees during pollination.

## STRAWBERRIES

Strawberries have been planted on a commercial scale by several producers in the Whitehorse area. Most home gardens have a small patch of strawberries.

Strawberries are divided into two basic types:

*June Bearing* - single crop, normally ripening in June or July

*Everbearing* - produce their primary crop early in the summer and another small crop again in the fall, plus a few berries all summer. Most producers prefer the June bearing type but a mix of both is desirable.

Figure 9.4 Strawberries

Source: *Food from your Garden, All you need to know to grow,cook and preserve your own fruit and vegetables*, Reader's Digest Association Ltd., Montreal, 1977.

### *Site Location*

Choose a site that is well drained and that has good air movement. A slightly inclined 3-4 degree south facing site is often ideal. Raised beds are a good solution for poorly drained sites. Avoid low lying frost pockets where cold air is likely to collect and try to locate your strawberry bed near the upper part of the slope rather than at the bottom. Strawberries are susceptible to many of the same diseases which affect garden-variety fruits or vegetables like tomatoes, peppers, eggplant and potatoes. Therefore it is generally best not to locate a strawberry bed where these crops have recently been grown. To avoid white grubs or cut worms locate your strawberries in an area which has been cultivated or cover cropped for at least one year prior to planting. Strawberries like a rich soil. Depending on its condition, most strawberry experts agree that you should start improving your soil between one and three years before planting. This can be done by adding animal manure or by planting green manure crops. As many weeds as possible should be destroyed prior to planting. Strawberries like a moderately acid soil with a pH 5.5 to 6.5.

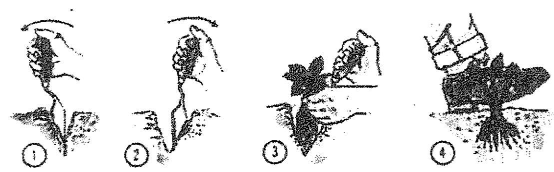
Soil should be worked sufficiently one or two days before planting to prepare a deep and reasonably loose planting bed. Raised beds can also be made. (See Raised Beds – Vegetable production.) It is not desirable to have the soil excessively loose, ie. from deep rototilling. When preparing the bed, it is a good time to fertilize the area with a commercial fertilizer: 5-10-10 is suitable at the rate of 30 lbs/1000 square feet or 137 lbs/acre. To cut down on costs, fertilize the row areas only.

### *Planting*

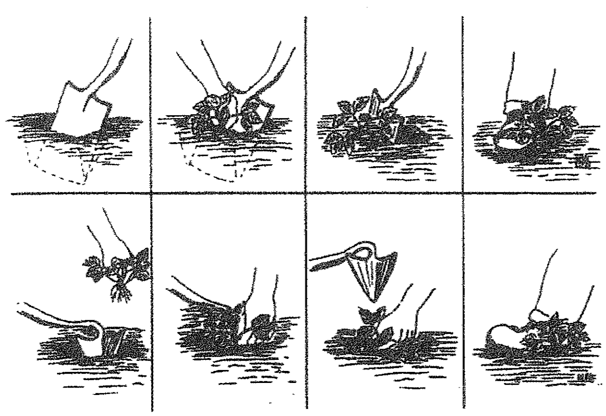
Ideally, the time to plant your strawberries is immediately after they arrive in the spring. If they have to be held for planting you can:

1. Store them in the refrigerator or cool place and check moisture levels.
2. "Heel them in" - Dig a 5 inch deep trench in a cool, shaded, not overly moist spot, with a trowel or shovel, laying the plants on one side of the trench and covering the roots with soil.

For planting, use a trowel, shovel or spade to make the hole, put in the plant at the correct depth, and pack around the base of the plant using your hands or feet. The usual procedure is to strip off the outer leaves, leaving 2 to 4 of the central ones at planting time. Do not allow the roots to dry out at any time during planting.



*a) Trowel Method*



*b) Shovel/Spade Method*

Figure 9.5 Planting Strawberry Plants

Source: a) *The Troy Built Way of Growing Strawberries*, W. Lockwood, Garden Way Manufacturing, Troy, N.Y, 1976.
b) *Small Fruit Culture*, Fourth Edition, J.S. Shoemaker, The Avi Publishing Company, Inc.,Westport, Connecticut, 1975.

Strawberries must be planted at the same depth at which they were growing before being transplanted. Set the plants so that the midpoint of the crown or centre section of the plant is just slightly above the surface of the soil, as shown in Figure 9.6. If they are set too deep, runnering is delayed and reduced and the crown and tops of roots may dry out. If possible set the plants out during cloudy weather, taking care to protect the roots from drying out, from exposure to wind or sun.

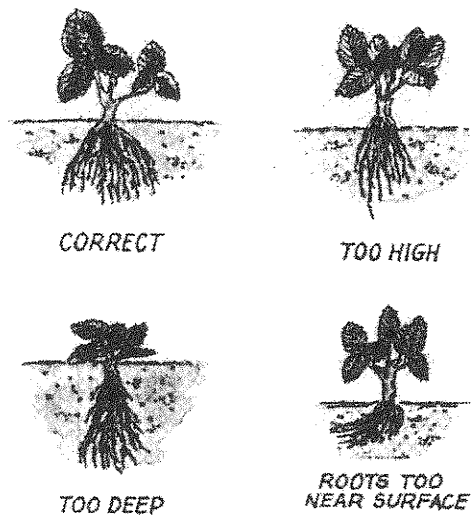



Figure 9.6 Proper Planting Depth of Strawberries

Source: *The Troy Built Way of Growing Strawberries*, W. M. Lockwood, Garden Way Manufacturing, Troy, N.Y, 1976.

### *Systems of Training*

There are several systems of training strawberry plants including matted rows, hedgerows, spaced beds and hill rows as shown in Figure 9.7.

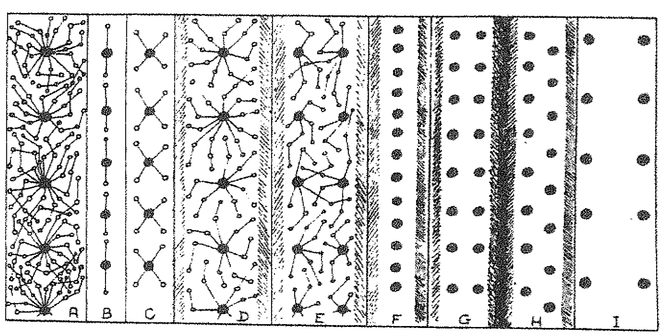



Figure 9.7: Systems of Planting and Training Strawberries A–matted row; B–Single hedgerow; C–Double hedgerow; D–Spaced row (planted in centre of raised bed); E–Spaced row (planted near edges of raised bed); F–Single row hills, G–Double row hills (opposite); Double row hills (alternate); I–Stool hills.

Source: *Small Fruit Culture*, Fourth Edition, J.S. Shoemaker, The Avi Publishing Company,Inc., Westport, Connecticut, 1975, pg 125.

The matted row system is most used in northern regions. Spacing is commonly 3.5-4 ft (1-1.2m) between rows and 1.5-2 ft (.45-.60m) in the rows. Rows closer than 3 ft (.90m) are seldom suitable commercially. In small plantings, setting plants 12-15" (30-38cm) apart in the rows is suggested. A row width of 1.5 to 2 ft (.45-.60m) wide is preferable to a wider or narrower one as they are easier to harvest. A point in favour of wide matted rows is that runners can space themselves better. In northern regions, aim for a full stand of plants by early fall. This system gives more berries with less work and special care than any other technique.

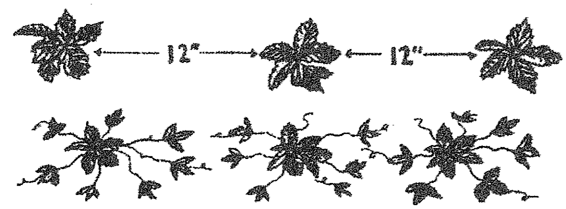



Figure 9.8 Matted Row System

Source: *The Troy Built Way of Growing Strawberries*, W. M. Lockwood, Garden Way Manufacturing, Troy, N.Y, 1976.

Allow the runners to fill the space 1-2 ft (.30-.60m) to either side of the original row and arrange the runners by hand so that they are an average 5-6" (13-15cm) apart. Do not cut off early-formed runners as these are the most productive ones. Do not sever the new plant from its parent until it is well rooted - after four to six weeks. Once it is growing strongly in its own roots, sever the runner and set it in its new position.

To ensure strong fruitful plants, remove all flower clusters on a weekly basis the first year as this will direct all food energy into the development of strong vigorous plants. You won't get any berries the first year, but the better you care for your plot the better will be your crop next spring.

Cultivation for weeds should be very shallow throughout the plot. Recheck for planting depth. Make sure that the plot does not dry out in the first couple of weeks of establishment.

> *Plant strawberries close together in a wide bed. This can help to protect roots from winter injury.*
>
> - Whitehorse Producer

### *Fertilization*

Proper timing of fertilizing is important. Increased yield and higher earlier pickings may result from nitrogen applied a month after planting, and near the start of fruit-bud formation. Yield is influenced by the number of flower clusters and numbers of flowers that form fruit. Nitrogen will stimulate fruit-bud formation and increase top and root growth.

### *Irrigation*

This is important for crop establishment and may also be used for frost protection to protect the blossoms. However, excessive water during fruit development may cause softer fruit. Do not apply water faster than the soil can absorb it.

### *Mulching*

Many producers like to mulch their strawberries, to reduce weed growth and conserve moisture. Organic materials such as straw, leaves, wood shavings, pine needles, grass clippings or a strawy manure can be used, as well as, newspaper or black plastic mulch. Do not use organic materials (hay) that contain seeds as these may sprout as well as attract mice. Late fall is the time for winter mulching the strawberry bed. In the north, this helps to reduce repeated freezing and thawing in the top inches of the soil. This should be applied before the ground is frozen, before a "hard" freeze with a temperature of 6.6°C (20°F) or below occurs. Subsequent resistance to cold depends on previous exposures to frost at above 6.6°C (20°F). At 6.6C (20°F), there may be damage to the crown. Thus, timing of the fall mulch is important to protect plants; too early mulching may be as harmful as too late.

> *"Strawberries like compost containing pine needles and straw and they also appreciate a mulch of pine needles or spruce needles.*
>
> *A mulch of pine needles increases the vigor, flavour,and stem strength of strawberries. It is said that pine needles make the berries taste more like wild strawberries. A special compost for strawberries is made of straw, pine needles, with green plant material. Sawdust placed around the plants also helps."*
>
> - Source: *Companion Plants and How to Use Them*, R. Gregg & H. Philbrick, Watkins Books Ltd., London, 1967.

## SASKATOONS

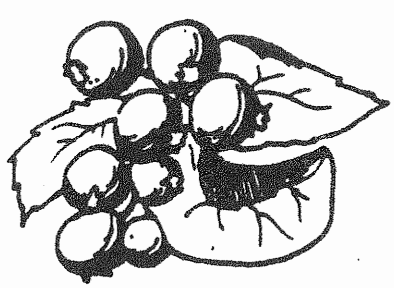


Figure 9.9 Saskatoon

Source: *Commercial Saskatoon Berry Production on the Prairies*, S. Williams, University of Saskatchewan, University Extension Press, 1994.

The saskatoon is derived from the Indian word "mis-sask-quah-toomin" meaning "tree of much wood" because of its suckering habit. It has an extensive range from Alaska and Yukon east to Hudson Bay in the north, south to Washington and east to Ohio in the northern states. The biggest and sweetest berries come from northern Alberta (Peace River Region). In southern Yukon, saskatoons are found generally on dry, grassy slopes as far north as the Dawson area. This is a shrubby plant growing to two feet but occasionally under good conditions to 10 ft (3m) or more. It is extremely adaptable and will grow under a wide range of climatic conditions and in all types of soils. They have been transplanted into gardens locally and grow into beautiful small trees producing bountiful berries. The fruit is borne in clusters of six to twelve, but do not ripen all at the same time. The berries are usually blue-purple, but colours of creamy white through red, to almost black are not uncommon.

Saskatoons may be grown from seed, or from root sprouts (suckers), root cuttings, or softwood cuttings. As soon as the fruit is ripe seed should be collected and cleaned. Squash the fruit on paper toweling, pushing the seeds to one side and discarding the skins. Allow to dry and pick out the seeds. Seeds should be stored in the refrigerator for for 90-120 days before setting out in nursery rows.

Suckers should be dug in early spring; getting as much of the roots as possible. Cut off the stems about 2" (5cm) above roots and plant in the final location. Keep moist until well established and do not let the fine roots dry out.

Take root cuttings in the early spring while they are actively growing. They should be 3-6" (7.6-15cm) long and of pencil thickness. Plant in rows with stem end up and about 1/4" (.63cm) below ground surface. Place them in an intermittent mist propagating bed. Rooting hormone will improve root development. Keep moist and shaded from the sun. Leave in the bed through the winter and then set them out in the spring.

Most producers prefer to purchase plants from commercial nurseries, where 2-3 year old bushes are available. For an orchard, several growers provide year old suckers or seedlings in root trainers. The latter are best obtained in the fall, after dormant, and planted immediately in the orchard.

### *Varieties*

*Smokey* is the most common in commercial saskatoon plantings. The bush is upright and spreading; reaching up to 12 ft (3.6m) in height. The berries are fleshy, round, sweet and mild flavored. Other varieties include *Honeywood*, *Thiessen*, *Northline* and *Pembina*.

### *Site Locations*

Saskatoons do not like to stand in water for any length of time. Choose a sunny location, preferably on a gentle southerly slope, which is not subject to late spring frosts as these can damage the blossoms.

*For saskatoons, I have a sandy loam soil and I have not added any organic matter - this provides for a well drained soil which is important.*

- Whitehorse Producer

### *Planting*

Orchards are normally planted in hedge rows. Set seedlings or two year old plants 3 ft (.91cm) apart in the row and have the rows 15 ft (4.6m) apart. If you plan to cultivate by hand between the rows you can then set rows at 10 ft (3m) or less.

### *Pruning*

Plants will begin to bear fruit when they are two to four years old and generally come into full production at 7-8 years. The fruit is produced on the previous year's growth. Usually young vigorous branches yield the largest and sweetest fruit. Prune in early spring, after the danger of cold weather is past and before they start to grow. Pruning promotes larger and more plentiful fruit. Remove all weak, diseased and damaged growth and keep heights below six feet. Thinning the centre growth keeps this area open and promotes fruiting.

### *Management*

It is necessary to provide some irrigation during orchard establishment and later from flowering through harvest each season to get fruit of good quality and size. Drip irrigation or soaker hoses are the preferred method. After the orchard is established many growers plant grass between the rows. Fertilizers should be added annually in a two foot band from the base of the hedge, on each side using approximately 15 lbs nitrogen, 3 lbs phosphorous and 30 lbs potassium, per acre. Birds are a problem for berry production and bird netting is recommended or some bird scare devices.

Source: *So You Want to Grow Saskatoons*, F. Dorwood, Whitehorse, 1992.

## NORTHERN BLACK CURRANT

There are six species of the genus *Ribes* growing in the Yukon. This includes plants which produce edible berries: the Northern Black currant, the Northern Gooseberry, and American Red currant. These transplant from the wild and can be cultivated in the home garden very well. It is suggested that the Black Currant could lend itself successfully to a small commercial enterprise, such as a pick your own. The Northern Black Currant is the most common and is found from the southern border as far north as Old Crow. Any stream will have this black currant growing along its bank as it prefers moist woods. In the wild where it has to compete with other growth, it is generally upright and scraggly, and only rarely produces a good crop. In more open sunny locations it can produce a heavy crop of berries. In the garden it assumes a bushy form and is loaded with fruit. Plants over three years old will produce more than an ice cream pail each. From plants collected from Swift River to Old Crow, any major differences in quality or sweetness of fruit has not been discovered.

The berries ripen all together in clusters of five or more. Fruits are 5-10mm in diameter. It is best to pick the whole cluster, pinching at the joint of the stem. The first plants ripen here in July. The berries hang on the bushes for several weeks which facilitates picking.


Figure 9.10 Northern Black Currant (*Ribes hudsonianum* Richards)

Source: *Flora of Alaska and Neighboring Territories*, A Manual of the Vascular Plants, E. Hulten, Standford University Press, 1968, pg 591.

### *Grow Currants from Seed*

Collect fully ripe berries. Place a small quantity into a household blender and cover with water. Run for 15 to 45 seconds. The seeds will sink when extra tap water is added. Then float off the extraneous material. Lay the seeds out on a paper towel to dry in a warm but not hot location. Another method is to crush each berry on paper toweling, separate the seed from the skin, dry seeds in a warm place and store in your refrigerator over the winter. Seeds may be planted in flats in very early spring. Cover lightly with soil and keep moist. By watering from below and covering with clear plastic you can avoid drying out. Set into small pots and then into the garden once they are well developed. You can set the pots out in the garden in late August to harden off and loose their leaves. Cover with straw mulch and plant in the spring. You can also plant seed directly in rows in the garden in the fall, or set out the seedlings the following spring.

### *Transplanting*

There seems to be few problems in transplanting. Just be sure to keep the soil with plants and prevent roots from drying. Planting just a bit deeper seems to help. For larger plantings, make rows about 8 ft (2.4m) apart with the plants about 3 ft (.91m) apart in the row. It is best to plant grass in between the rows and cut it once or twice a year. For smaller plantings, spacings of 5 ft(1.5m) by 5 ft (1.5m) for each plant is suitable. Transplanting is best in the spring, dig in slightly deeper than the previous soil line. Firm the soil after planting and water heavily. I have found that currants can be transplanted at any time by digging out the branch with a short section of root. Place into a pail with water and pack with moss to keep it moist until you get home. If you can't transplant immediately, rinse the roots until free of the moss and dirt and keep in water (changed every two days) until you can plant. When planting cut off the tip of the branch, leaving three or four leaves and leaf buds at the root end. Remove all but one leaf. Plant with all roots below ground and at least one leaf node below ground level. Keep well watered for 10 days or so to aid establishment.

### *Management*

A row type irrigation system, drip or trickle, would be good for a larger planting. For smaller areas, a sprinkler system for the drier periods is beneficial. Fertilizer requirements are not yet known, but a low amount of a complete fertilizer could enhance growth. Black Currants do have one draw back which is their susceptibility to powdery mildew and so will need spraying at least twice each season. A bicarbonate of soda mixture has been tried for this problem. There are chemicals also available.

Source: *Some Observations on the Domestication of the Northern Black Currant (Ribes husonianum Richards)*, F.Dorwood, in proceedings of 1st Circumpolar Agriculture Conference, 1994.

Circumpolar Logo

## COMMERCIAL BLACK CURRANTS

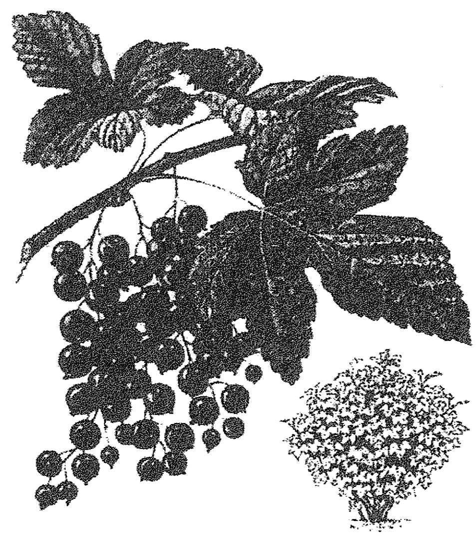


Figure 9.11 Commercial Black Currant

Source: *Food from your Garden, All you need to know to grow, cook and preserve your own fruit and vegetables*, Reader's Digest Association Ltd., Montreal, 1977.

Black Currants can be purchased from commercial nurseries. Boskoop Giant, Seabrook's Black, and Blackdown are early varieties. Wellington is a midseason variety.

### *Planting*

Plants should be planted 5-6 ft (1.5-1.8m) apart, in each direction, placed a little deeper than in the nursery. Prune the shoots to about 1 in. above ground level, cutting just above the bud. There will be no fruit yielded the first summer, but plant energy will be put into new growth for a crop the second summer after planting. Mulch the plants with a layer of compost, manure or peat. Repeat this mulch every spring at the rate of two buckets per square yard to feed the plants and conserve moisture in the soil. Water the plants regularly during dry periods.

Figure 9.12 Planting Black Currants

Source: *Food from your Garden, All you need to know to grow, cook and preserve your own fruit and vegetables*, Reader's Digest Association Ltd., Montreal, 1977.

### *Pruning*

In the first autumn after planting, cut down the weakest of the season's shoots to just above the soil. During the following autumn cut out a few of the weaker shoots to stimulate new growth. Cut down low to promote new growth from near the ground level. Aim to cut out between a quarter to one third of the old wood.

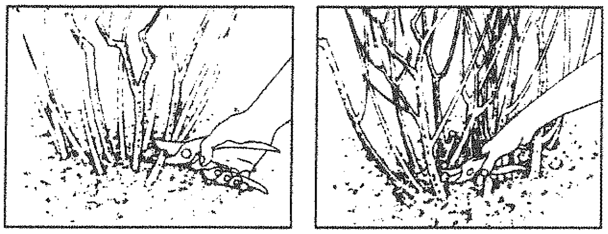


Figure 9.13 Pruning Black Currants

Source: *Food from your Garden, All you need to know to grow, cook and preserve your own fruit and vegetables*, Reader's Digest Association Ltd., Montreal, 1977.

### *Cuttings*

Black currants can be increased from cuttings. Take them from the current season's shoots that are well ripened and healthy looking. Cut off the unripened tip just above a bud, and the bottom just below a bud, to make a cutting about 8in.(20cm) long. Place cuttings in a 6" (15cm) deep trench dug with one side vertical. On the vertical side, place the cuttings 6" (15cm) apart with two buds showing above ground. Fill in the trench and firm the soil. By the following autumn they should be rooted and ready for transplanting to their permanent location, cutting them back as previously described in planting.

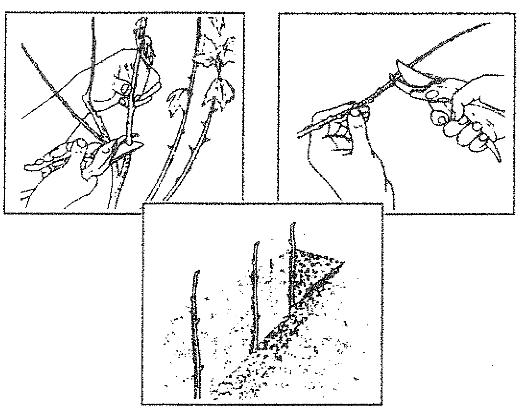


Figure 9.14 Raising New Bushes

Source: *Food from your Garden, All you need to know to grow, cook and preserve your own fruit and vegetables*, Reader's Digest Association Ltd., Montreal, 1977.

# APPENDIX A: YUKON CROP GUIDE SOURCE LIST

## SECTION 1: INTRODUCTION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# APENDIX B: ADDRESSES FOR AGRICULTURAL PUBLICATIONS

**Agriculture Branch**
**Department of Renewable Resources**
**Government of Yukon**
Tutshi Building -2131 2nd Ave.
Box 2703
Whitehorse, Yukon
Y1A 2C6

**Agriculture Canada**
Communications Branch
Sir John Carling Building
Ottawa, Ontario K1A 0C7.

**Alberta Agriculture**
Print Media Branch
J.G. O'Donoghue Building
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**School of Agricultre and Land Resources Management**
309 O'Neil Resources Building
University of Alaska Fairbanks
Fairbanks, Alaska 99775-0080

Information Office
**Cooperative Extension Service**
**University of Alaska**
Fairbanks, Alaska 99775-5200

# APPENDIX C: EQUIVALENTS OF MEASURE

Table 10.1 CONVERSION FACTORS (Imerial - Metric) (Metric - Imperial)

## LINEAR

inch x 25.4 = millimetre (mm)
milimetre (mm) x 0.039 = inch, 1mm = .039 inches
centimetre (cm) x 0.39 = inch, 1cm = .394 inches
feet x 30 = centimetre (cm)
metre (m) x 3.281 = feet, 1m = 3.281 ft.
metre x 1.09 = yard, 1m = 1.09 yards
yard x 0.91 = metre (m)
kilometre (km) x 0.62 = mile, 1 km = 0.621 miles
mile x 1.6 = kilometre (km)

## AREA

square centimetre ($cm^2$) x 0.155 = square inch
square inch x 6.5 = square centimetre ($cm^2$)
square foot x 0.09 = square metre ($m^2$)
square metre x 10.764 = square foot
square metre ($m^2$) x 1.196 = square yard
square kilometre ($km^2$) x 0.386 = square mile
square mile x 2.59 = square kilometre
Hectare (ha) x 2.471 = acres 1 ha = 2.471 acres
Acre x 0.405 = hectare 1 Acre = .405 hectares
1 acre = 43560 square feet
1 acre = 4047 square meters

## VOLUME

cubic inch x 16 = cubic centimetre ($cm^3$)
cubic centimetre ($cm^3$) x 0.061 = cubic inch
cubic yard x 0.76 = cubic metre ($m^3$)
cubic metre ($m^3$) x 1.308 = cubic yard
cubic metre ($m^3$) x 35.31 = cubic foot
cubic foot x 28 = cubic decimetre ($dm^3$)
1 cubic foot = 7.48 US gallons
1 US gallon = 3.79 litres
pint x 0.57 = litre
quart x 1.1 = litre
gallon x 4.55 = litre
litre x .22 = gallon
millilitre x .035 = fluid ounce
fluid ounce x 28 = millilitre
bushel x 0.36 = hectolitre (h)
100 L/ha = 8.9 gallons/acre

## CAPACITY

litre (L) x 0.035 = cubic feet
hectolitre (hL) x 22 = gallons
x 2.5 = bushels

## MASS/WEIGHT

ounce x 28 = gram(g)
gram (g) x 0.035 = ounces
Pound (lb) x 0.454 = kilogram (kg)
Kilogram (kg) x 2.205 = pound
1000 kg = 1.102 (short ton)
Short Ton (2000lbs) x 0.9072 = tonne (t)
tonne (t) x 1.102 = Short Ton
Tonne(metric)/hectare x 0.446 = ton/acre
Ton/acre x 2.24 = tonne/hectare
Kilogram/hectare x 0.892 = pounds/acre
Pounds/acre x 1.12 = kilogram/hectare

## AGRICULTURAL

gallons/acre x 11.23 = litres/hectare (L/ha)
litres per hectare (L/ha) x 0.089 = gallons/acre
x 0.357 = quarts/acre
quarts/acre x 2.8 = litres/hectare (L/ha)
x 0.71 = pints/acre
pints/acre x 1.4 = litres/hectares (L/ha)
fluid ounces/acre x 70 = millilitres per hectare (mL/ha)
millilitres/hectare (mL/ha) x 0.014 = fl. oz./acre
tons/acre x 2.24 = tonnes/hectare
tonnes/hectare (t/ha) x 0.45 = tons/acre
pounds/acre x 1.12 = kilograms/hectare (kg/ha)
kilograms/hectare (kg/ha) x 0.89 = pounds/acre
ounces/hectare x 70 = grams/hectare (g/ha)
grams/hectare (g/ha) x 0.014 = ounces/acre
plants/hectare (plants/ha) x 0.405 = plants/acre
plants/acre x 2.247 = plants/hectare

## TEMPERATURE

degrees Fahrenheit (F) (F-32) x 0.56 = degrees Celsius (C)
(F-32) x 5/9

## PRESSURE

pounds per square inch x 6.89 = kilopascal (kPa)
kilopascal x .145 = pounds per square inch

## POWER

horsepower x 746 = watt (W)
x 0.75 = kilowatt (kW)
kilowatt x 1.34 = horsepower

## SPEED

feet per second x 0.30 metres per second (m/s)
miles per hour x 1.6 kilometres per hour (km/h)

## IRRIGATION

**Flow Rates**

1 cubic foot/second = approx. 1.0 Acre-Inch Per Hour
= 28.3 Litres per Second
= 450 US gallons per Minute

**Pressure**

1 LBF per square inch (psi) = 2.31 Feet of Head
= 6.89 Kilopascals
= 0.70 Meters Total Dynamic Head

## FERTILIZER

$P \times 2.3 = P_2O_5$, $P_2O_5 \times 0.43 = P$
$K \times 1.2 = K_2O$, $K_2O \times 0.83 = K$

## Table 10.2 Metric Imperial Conversion Table

| Metric to Imperial | | | Imperial to Metric | | |
|---|---|---|---|---|---|
| **Metric Unit** | **Multiply by Approximate Conversion Factor** | **Imperial Unit** | **Imperial Unit** | **Multiply by Approximate Conversion Factor** | **Metric Unit** |
| **LINEAR** | | | | | |
| millimetre | .039 | inch | inch | 25.4 | millimetre |
| centimetre | .39 | inch | inch | 2.54 | centimetre |
| metre | 1.09 | yard | yard | .91 | metre |
| kilometre | .62 | mile | mile | 1.6 | kilometre |
| **WEIGHT** | | | | | |
| gram | .035 | ounce | ounce | 28 | gram |
| kilogram | 2.20 | pound | pound | .45 | kilogram |
| tonne | 1.10 | ton | ton | .91 | tonne |
| **AREA** | | | | | |
| square centimetre | .155 | square inch | square inch | 6.5 | square centimetre |
| square metre | 10.76 | square foot | square foot | .09 | square metre |
| hectare | 2.47 | acre | acre | .40 | hectare |
| square kilometre | .386 | square mile | square mile | 2.59 | square kilometre |
| **VOLUME** | | | | | |
| cubic centimetre | .06 | cubic inch | cubic inch | 16 | cubic centimetre |
| cubic metre | 1.31 | cubic yard | cubic yard | .76 | cubic metre |
| millilitre | .035 | fluid ounce | fluid ounce | 28 | millilitre |
| litre | .22 | gallon | gallon | 4.55 | litre |
| **PRESSURE** | | | | | |
| kilopascal | .145 | pounds per square inch | pounds per square inch | 6.89 | kilopascal |
| **POWER** | | | | | |
| kilowatt | 1.34 | horsepower | horsepower | .75 | kilowatt |
| **AGRICULTURAL** | | | | | |
| kilograms per hectare | .89 | pounds per acre | pounds per acre | 1.12 | kilograms per hectare |
| litres per hectare | .089 | gallons per acre | gallons per acre | 11.23 | litres per hectare |
| millilitres per hectare | .014 | fluid ounces per acre | fluid ounces per acre | 70 | millilitres per hectare |
| tonnes per hectare | .45 | tons per acre | tons per acre | 2.24 | tonnes per hectare |
| **Wheat, peas, beans, corn** kilograms per hectare | .015 | bushels per acre | bushels per acre | 67.25 | kilograms per hectare |
| **Oats**—kilograms per hectare | .026 | bushels per acre | bushels per acre | 38.11 | kilograms per hectare |
| **Barley, buckwheat** —kilograms per hectare | .019 | bushels per acre | bushels per acre | 53.80 | kilograms per hectare |
| **Canola, mustard** —kilograms per hectare | .018 | bushels per acre | bushels per acre | 56.04 | kilograms per hectare |
| **Corn, flax, rye** —kilograms per hectare | .016 | bushels per acre | bushels per acre | 62.77 | kilograms per hectare |

*Example — to convert millimetres to inches, multiply by .039; conversely, to convert inches to millimetres, multiply by 25.4

Source: *Guide to Farm Practice in Saskatchewan*, Revised 1984, University of Saskatchewan, Division of Extension & Community Relations, Saskatoon, 1984.

Table 10.3 Going Metric / Conversion Factors

## SYMBOLS

**LENGTH**

| | |
|---|---|
| mm | millimetre |
| cm | centimetre |
| m | metre |
| km | kilometre |

**WEIGHT**

| | |
|---|---|
| g | gram |
| kg | kilogram |
| t | tonne |

**PRESSURE**

| | |
|---|---|
| kPa | kilopascal |

**VOLUME**

| | |
|---|---|
| mL | millilitre |
| L | litre |
| hL | hectolitre |
| $m^3$ | cubic metre |

**AREA**

| | |
|---|---|
| $cm^2$ | square centimetre |
| $m^2$ | square metre |
| ha | hectare |
| $km^2$ | square kilometre |

**TEMPERATURE**

| | |
|---|---|
| °C | degrees Celsius |

## PREFIXES

| | | |
|---|---|---|
| mega | million | 1 000 000 |
| kilo | thousand | 1 000 |
| hecto | hundred | 100 |
| deca | ten | 10 |
| deci | tenth | 0.1 |
| centi | hundredth | 0.01 |
| milli | thousandth | 0.001 |
| micro | millionth | 0.000 001 |

## MEASURES

**LENGTH**

| | |
|---|---|
| 10 mm | 1 cm |
| 100 cm | 1 m |
| 1 000 m | 1 km |

**VOLUME**

| | |
|---|---|
| 1 000 mL | 1 L |
| 100 L | 1 hL |
| 1 000 L | 1 $m^3$ |

**WEIGHT**

| | |
|---|---|
| 1 000 g | 1 kg |
| 1 000 kg | 1 t |

**AREA**

| | |
|---|---|
| 10 000 $cm^2$ | 1 $m^2$ (100 cm x 100 cm) |
| 10 000 $m^2$ | 1 ha (100 m x 100 m) |
| 100 ha | 1 $km^2$ (1000 m x 1000 m) |

## INTER-RELATION

| Water at 4°C | Length | Volume | Weight |
|---|---|---|---|
| 1,000 $cm^3$ | 1,000 cc | 1 L | 1 kg |
| 1 $cm^3$ | 1 cc | 1 mL | 1 g |

# CONVERSION FACTORS

| Imperial Units × | Conversion Factor = | Metric Units |
|---|---|---|
| **LENGTH** | | |
| inches | 2.5 | centimetres |
| feet | 30 | centimetres |
| feet | 0.3 | metres |
| yards | 0.9 | metres |
| miles | 1.6 | kilometres |
| **AREA** | | |
| square inches | 6.5 | square centimetres |
| square feet | 0.09 | square metres |
| acres | 0.40 | hectares |
| **VOLUME** | | |
| cubic inches | 16 | cubic centimetres |
| cubic feet | 0.03 | cubic metres |
| cubic yards | 0.8 | cubic metres |
| fluid ounces | 28 | millilitres |
| pints | 0.57 | litres |
| quarts | 1.1 | litres |
| gallons (Imperial) | 4.5 | litres |
| gallons (U.S.) | 3.75 | litres |
| bushels | 0.36 | hectolitres |
| **WEIGHT** | | |
| ounces | 28 | grams |
| pounds | 0.45 | kilograms |
| short tons (2,000 lb.) | 0.9 | tonnes |
| **TEMPERATURE** | | |
| degrees Fahrenheit (F-32) | 0.56 | degrees Celsius |
| **POWER** | | |
| horsepower | 750 | watts |
| | 0.75 | kilowatts |

| Imperial Units × | Conversion Factor = | Metric Units |
|---|---|---|
| oz. acre | 70 | g/ha |
| lb. acre | 1.12 | kg/ha |
| bu. acre | 0.9 | hL/ha |
| tons/acre | 2.24 | t/ha |
| fl. oz. acre | 70 | mL ha |
| pt.·acre | 1.4 | L ha |
| qt. acre | 2.8 | L ha |
| gal./acre | 11.2 | L/ha |
| gal. acre(U.S.) | 9.35 | L/ha |
| plants/acre | 2.47 | plants/ha |
| oz. gal | 6.2 | mL/L |
| lb. gal | 0.1 | kg/L |
| oz. sq.ft. | 305 | g/$m^2$ |
| lb./sq.ft. | 4.9 | kg/$m^2$ |
| oz./ft.row | 93 | g/m row |
| lb. ft. row | 1.5 | kg/m row |
| ft. sec. | 0.3 | m/s |
| m.p.h. | 1.6 | km/h |
| p.s.i. | 6.9 | kPa |

To convert from imperial to metric, **multiply by the conversion factor.**
For example:
10" x 2.5 = 25 centimetres

To convert from metric to imperial, **divide by the conversion factor.**
For example:
25 centimetres ÷ 2.5 = 10 inches

Source: 1988 *Berry Production Guide for Commercial Growers*, Province of British Columbia Ministry of Agriculture and Fisheries, Victoria, B.C., 1988.

## Table 10.4 Metric Conversion Tables / Useful Measurements

These are double conversion tables for weights and measures. The middle column can be used with either of the other two columns in each table.

For example:
100 miles = 160.936 kilometres
(or about 160 km, rounded off)
100 kilometres = 62.136 miles
(or about 62 miles, rounded off)

Add the conversion numbers to determine exact conversions.

For example:
123 miles = 160.936 km (100 miles)
+ 32.187 km (20 miles)
+ 4.828 km (3 miles)
197.951 km
(or about 198 km, rounded off)

123 km = 62.136 miles (100 km)
+ 12.427 miles (20 km)
+ 1.864 miles (3 km)
76.427miles
(or 76 miles, rounded off)

### Volume

| Litres ← |  | → Gallons |
|---|---|---|
| 4.546 | 1 | 0.220 |
| 9.092 | 2 | 0.440 |
| 13.638 | 3 | 0.660 |
| 18.184 | 4 | 0.880 |
| 22.730 | 5 | 1.100 |
| 27.276 | 6 | 1.320 |
| 31.822 | 7 | 1.540 |
| 36.368 | 8 | 1.760 |
| 40.914 | 9 | 1.980 |
| 45.460 | 10 | 2.200 |
| 90.919 | 20 | 4.399 |
| 136.379 | 30 | 6.599 |
| 181.838 | 40 | 8.799 |
| 227.298 | 50 | 10.99 |
| 272.758 | 60 | 13.198 |
| 318.217 | 70 | 15.398 |
| 363.677 | 80 | 17.598 |
| 409.136 | 90 | 19.797 |
| 454.596 | 100 | 21.997 |

| Litres ← |  | → Gallons (U.S.) |
|---|---|---|
| 3.785 | 1 | 0.264 |
| 7.571 | 2 | 0.528 |
| 11.356 | 3 | 0.793 |
| 15.141 | 4 | 1.057 |
| 18.927 | 5 | 1.321 |
| 22.712 | 6 | 1.585 |
| 26.497 | 7 | 1.849 |
| 30.282 | 8 | 2.113 |
| 34.068 | 9 | 2.378 |
| 37.853 | 10 | 2.642 |
| 75.706 | 20 | 5.284 |
| 113.559 | 30 | 7.925 |
| 151.412 | 40 | 10.567 |
| 189.265 | 50 | 13.209 |
| 227.118 | 60 | 15.851 |
| 264.971 | 70 | 18.493 |
| 302.825 | 80 | 21.134 |
| 340.678 | 90 | 23.776 |
| 387.531 | 100 | 26.418 |

### Volume (Rounded-off)

| Gallons → | Litres |
|---|---|
| 25 | 110 |
| 50 | 230 |
| 95 | 430 |
| 100 | 450 |
| 195 | 890 |
| 200 | 910 |
| 260 | 1,180 |
| 300 | 1,360 |
| 400 | 1,820 |
| 500 | 2,270 |

| U.S. Gallons | Litres |
|---|---|
| 25 | 90 |
| 50 | 190 |
| 55 | 210 |
| 100 | 380 |
| 110 | 420 |
| 125 | 470 |
| 150 | 570 |
| 200 | 760 |
| 300 | 1,140 |
| 400 | 1,510 |
| 500 | 1,890 |

### Area

| Square Metres ← |  | → Square Feet |
|---|---|---|
| 0.093 | 1 | 10.76 |
| 0.186 | 2 | 21.53 |
| 0.279 | 3 | 32.29 |
| 0.372 | 4 | 43.06 |
| 0.465 | 5 | 53.82 |
| 0.557 | 6 | 64.58 |
| 0.650 | 7 | 73.35 |
| 0.743 | 8 | 86.11 |
| 0.836 | 9 | 96.88 |
| 0.929 | 10 | 107.64 |
| 1.858 | 20 | 215.28 |
| 2.787 | 30 | 322.92 |
| 3.716 | 40 | 430.56 |
| 4.645 | 50 | 538.19 |
| 5.574 | 60 | 645.83 |
| 6.503 | 70 | 753.47 |
| 7.432 | 80 | 861.11 |
| 8.361 | 90 | 668.75 |
| 9.290 | 100 | 1,076.39 |

| Square Metres ← |  | → Square Yards |
|---|---|---|
| 0.836 | 1 | 1.196 |
| 1.672 | 2 | 2.392 |
| 2.508 | 3 | 3.588 |
| 3.345 | 4 | 4.784 |
| 4.181 | 5 | 5.980 |
| 5.017 | 6 | 7.176 |
| 5.843 | 7 | 8.372 |
| 6.689 | 8 | 9.568 |
| 7.525 | 9 | 10.764 |
| 8.361 | 10 | 11.960 |
| 16.723 | 20 | 23.920 |
| 25.084 | 30 | 35.880 |
| 33.445 | 40 | 47.840 |
| 41.806 | 50 | 59.800 |
| 50.168 | 60 | 71.759 |
| 58.529 | 70 | 83.719 |
| 66.890 | 80 | 95.679 |
| 75.251 | 90 | 107.639 |
| 83.613 | 100 | 119.599 |

| Hectares ← |  | → Acres |
|---|---|---|
| 0.405 | 1 | 2.471 |
| 0.809 | 2 | 4.942 |
| 1.214 | 3 | 7.413 |
| 1.619 | 4 | 9.884 |
| 2.023 | 5 | 12.355 |
| 2.428 | 6 | 14.826 |
| 2.833 | 7 | 17.297 |
| 3.238 | 8 | 19.768 |
| 3.642 | 9 | 22.239 |
| 4.047 | 10 | 24.711 |
| 8.094 | 20 | 49.421 |
| 12.141 | 30 | 74.132 |
| 16.187 | 40 | 98.842 |
| 20.234 | 50 | 123.553 |
| 24.281 | 60 | 148.263 |
| 28.328 | 70 | 172.974 |
| 32.275 | 80 | 197.684 |
| 36.422 | 90 | 222.395 |
| 40.469 | 100 | 247.105 |

### Weight

| Kilograms ← |  | → Pounds |
|---|---|---|
| 0.454 | 1 | 2.205 |
| 0.907 | 2 | 4.409 |
| 1.361 | 3 | 6.614 |
| 1.814 | 4 | 8.818 |
| 2.268 | 5 | 11.023 |
| 2.722 | 6 | 12.228 |
| 3.175 | 7 | 15.432 |
| 3.629 | 8 | 17.637 |
| 4.082 | 9 | 19.842 |
| 4.536 | 10 | 22.046 |
| 9.072 | 20 | 44.092 |
| 13.608 | 30 | 66.139 |
| 18.144 | 40 | 88.185 |
| 22.680 | 50 | 110.231 |
| 27.215 | 60 | 132.277 |
| 31.751 | 70 | 154.323 |
| 36.287 | 80 | 176.370 |
| 40.823 | 90 | 198.416 |
| 45.359 | 100 | 220.462 |

| Grams ← |  | → Ounces (Dry) |
|---|---|---|
| 28.350 | 1 | 0.035 |
| 56.699 | 2 | 0.071 |
| 85.049 | 3 | 0.106 |
| 113.398 | 4 | 0.141 |
| 141.748 | 5 | 0.176 |
| 170.097 | 6 | 0.212 |
| 198.447 | 7 | 0.247 |
| 226.796 | 8 | 0.282 |
| 225.146 | 9 | 0.318 |
| 283.495 | 10 | 0.353 |
| 566.990 | 20 | 0.706 |
| 850.485 | 30 | 1.058 |
| 1,133.980 | 40 | 1.411 |
| 1,417.475 | 50 | 1.764 |
| 1,700.970 | 60 | 2.116 |
| 1,984.465 | 70 | 2.469 |
| 2,267.960 | 80 | 2.822 |
| 2,551.455 | 90 | 3.175 |
| 2,834.950 | 100 | 3.527 |

### Length

| Centimetres ← |  | → Inches |
|---|---|---|
| 2.540 | 1 | 0.394 |
| 5.080 | 2 | 0.787 |
| 7.620 | 3 | 1.181 |
| 10.160 | 4 | 1.575 |
| 12.700 | 5 | 1.969 |
| 15.240 | 6 | 2.362 |
| 17.780 | 7 | 2.756 |
| 20.320 | 8 | 3.150 |
| 22.860 | 9 | 3.543 |
| 25.400 | 10 | 3.937 |
| 50.800 | 20 | 7.874 |
| 76.200 | 30 | 11.811 |
| 101.600 | 40 | 15.748 |
| 127.000 | 50 | 19.685 |
| 152.400 | 60 | 23.622 |
| 177.800 | 70 | 27.559 |
| 203.200 | 80 | 31.496 |
| 228.600 | 90 | 35.433 |
| 254.000 | 100 | 39.370 |

| Metres ← |  | → Yards |
|---|---|---|
| 0.914 | 1 | 1.094 |
| 1.829 | 2 | 2.187 |
| 2.743 | 3 | 3.281 |
| 3.658 | 4 | 4.374 |
| 4.572 | 5 | 5.468 |
| 5.486 | 6 | 6.562 |
| 6.401 | 7 | 7.655 |
| 7.315 | 8 | 8.749 |
| 8.320 | 9 | 9.843 |
| 9.144 | 10 | 10.936 |
| 18.288 | 20 | 21.872 |
| 27.432 | 30 | 32.808 |
| 36.576 | 40 | 43.745 |
| 45.720 | 50 | 54.681 |
| 54.863 | 60 | 65.617 |
| 64.007 | 70 | 76.553 |
| 73.151 | 80 | 87.489 |
| 82.295 | 90 | 98.425 |
| 91.439 | 100 | 109.361 |

| Kilometres ← |  | → Miles |
|---|---|---|
| 1.609 | 1 | 0.621 |
| 3.219 | 2 | 1.243 |
| 4.828 | 3 | 1.864 |
| 6.437 | 4 | 2.485 |
| 8.047 | 5 | 3.107 |
| 9.656 | 6 | 3.728 |
| 11.266 | 7 | 4.350 |
| 12.875 | 8 | 4.971 |
| 14.484 | 9 | 5.592 |
| 16.094 | 10 | 6.214 |
| 32.187 | 20 | 12.427 |
| 48.281 | 30 | 18.641 |
| 64.375 | 40 | 24.855 |
| 80.468 | 50 | 31.068 |
| 96.562 | 60 | 37.282 |
| 112.655 | 70 | 43.495 |
| 128.750 | 80 | 49.709 |
| 144.843 | 90 | 55.923 |
| 160.936 | 100 | 62.136 |

Table 10.4 Cont.

**Weight/Area**

| Kilograms per Square Metre | | Pounds per Square Foot |
|---|---|---|
| 0.49 | 0.1 | .02 |
| 0.98 | 0.2 | .04 |
| 1.47 | 0.3 | .06 |
| 1.97 | 0.4 | .08 |
| 2.45 | 0.5 | .102 |
| 2.93 | 0.6 | .122 |
| 3.42 | 0.7 | .143 |
| 3.91 | 0.8 | .163 |
| 4.40 | 0.9 | .184 |
| 4.89 | 1.0 | .204 |
| 9.78 | 2.0 | .408 |
| 14.67 | 3.0 | .612 |
| 19.56 | 4.0 | .816 |
| 24.45 | 5.0 | 1.02 |
| 29.34 | 6.0 | 1.224 |
| 34.23 | 7.0 | 1.428 |
| 39.12 | 8.0 | 1.632 |
| 44.01 | 9.0 | 1.836 |
| 48.90 | 10.0 | 2.04 |
| 97.80 | 20.0 | 4.08 |
| 146.77 | 30.0 | 6.12 |

| Kilograms Per Hectare | | Pounds per Acre |
|---|---|---|
| 1.121 | 1 | 0.892 |
| 2.242 | 2 | 1.784 |
| 3.363 | 3 | 2.677 |
| 4.483 | 4 | 3.569 |
| 5.604 | 5 | 4.461 |
| 6.725 | 6 | 5.353 |
| 7.846 | 7 | 6.245 |
| 8.967 | 8 | 7.137 |
| 10.088 | 9 | 8.030 |
| 11.209 | 10 | 8.922 |
| 22.417 | 20 | 17.844 |
| 33.626 | 30 | 26.765 |
| 44.834 | 40 | 35.687 |
| 56.043 | 50 | 44.609 |
| 67.251 | 60 | 53.531 |
| 78.460 | 70 | 62.453 |
| 89.668 | 80 | 71.374 |
| 100.877 | 90 | 80.296 |
| 112.085 | 100 | 89.218 |

| Tonnes per Hectare | | Tons (2,000 lbs.) per Acre |
|---|---|---|
| 2.24 | 1 | 0.446 |
| 4.48 | 2 | 0.892 |
| 6.72 | 3 | 1.338 |
| 8.96 | 4 | 1.784 |
| 11.20 | 5 | 2.230 |
| 13.44 | 6 | 2.676 |
| 15.68 | 7 | 3.122 |
| 17.92 | 8 | 3.568 |
| 20.16 | 9 | 4.014 |
| 22.40 | 10 | 4.460 |
| 44.80 | 20 | 8.920 |
| 67.20 | 30 | 13.380 |
| 89.60 | 40 | 17.840 |
| 112.00 | 50 | 22.300 |
| 134.40 | 60 | 26.760 |
| 156.80 | 70 | 31.220 |
| 179.20 | 80 | 35.680 |
| 201.60 | 90 | 40.140 |
| 224.00 | 100 | 44.600 |

**Temperature**

| Celsius | | Fahrenheit |
|---|---|---|
| −40.0 | −40 | −40.00 |
| −34.4 | −30 | −22.0 |
| −28.9 | −20 | −4.0 |
| −23.3 | −10 | +14.0 |
| −17.8 | 0 | +32.0 |
| −17.2 | 1 | +33.8 |
| −16.7 | 2 | +35.6 |
| −16.1 | 3 | +37.4 |
| −15.6 | 4 | +39.2 |
| −15.0 | 5 | +41.0 |
| −14.4 | 6 | +42.8 |
| −13.9 | 7 | +44.6 |
| −13.3 | 8 | +46.4 |
| −12.8 | 9 | +48.2 |
| −12.2 | 10 | +50.0 |
| −6.7 | 20 | +68.0 |
| −1.1 | 30 | +86.0 |
| +4.4 | 40 | +104.0 |
| +10.0 | 50 | +122.0 |
| +15.6 | 60 | +140.0 |
| +21.1 | 70 | +158.0 |
| +26.7 | 80 | +176.0 |
| +32.2 | 90 | +194.0 |
| +37.8 | 100 | +212.0 |

**Application Rates**

| Litres per Hectare | | Gallons Per Acre |
|---|---|---|
| 11.233 | 1 | 0.08902 |
| 22.466 | 2 | 0.17804 |
| 33.699 | 3 | 0.26706 |
| 44.933 | 4 | 0.35608 |
| 56.166 | 5 | 0.44510 |
| 67.399 | 6 | 0.53412 |
| 78.632 | 7 | 0.62315 |
| 89.865 | 8 | 0.71217 |
| 101.098 | 9 | 0.80119 |
| 112.332 | 10 | 0.89021 |
| 224.663 | 20 | 1.78042 |
| 336.995 | 30 | 2.67062 |
| 449.326 | 40 | 3.56083 |
| 561.658 | 50 | 4.45104 |
| 673.989 | 60 | 5.34125 |
| 786.321 | 70 | 6.23146 |
| 898.652 | 80 | 7.12166 |
| 1,010.984 | 90 | 8.01187 |
| 1,123.315 | 100 | 8.90208 |

| Grams per 100 Litres | | Ounces per 100 Gallons |
|---|---|---|
| 6.24 | 1 | 0.16 |
| 12.47 | 2 | 0.32 |
| 18.71 | 3 | 0.48 |
| 24.94 | 4 | 0.64 |
| 31.18 | 5 | 0.80 |
| 37.41 | 6 | 0.96 |
| 43.65 | 7 | 1.12 |
| 49.89 | 8 | 1.28 |
| 56.13 | 9 | 1.44 |
| 62.36 | 10 | 1.60 |
| 124.72 | 20 | 3.21 |
| 187.09 | 30 | 4.81 |
| 249.45 | 40 | 6.41 |
| 311.81 | 50 | 8.02 |
| 374.17 | 60 | 9.62 |
| 436.53 | 70 | 11.22 |
| 498.90 | 80 | 12.83 |
| 561.26 | 90 | 14.43 |
| 623.62 | 100 | 16.04 |

| Millilitres per 100 Litres | | Pints per 100 Gallons |
|---|---|---|
| 125 | 1 | 0.008 |
| 250 | 2 | 0.016 |
| 375 | 3 | 0.024 |
| 500 | 4 | 0.032 |
| 625 | 5 | 0.040 |
| 750 | 6 | 0.048 |
| 875 | 7 | 0.056 |
| 1,000 | 8 | 0.064 |
| 1,125 | 9 | 0.072 |
| 1,250 | 10 | 0.080 |
| 2,500 | 20 | 0.160 |
| 3,750 | 30 | 0.240 |
| 5,000 | 40 | 0.320 |
| 6,250 | 50 | 0.400 |
| 7,500 | 60 | 0.480 |
| 8,750 | 70 | 0.560 |
| 10,000 | 80 | 0.640 |
| 11,250 | 90 | 0.720 |
| 12,500 | 100 | 0.800 |

| Millitres per 100 Litres | | Fluid Ounces /100 Gallons |
|---|---|---|
| 6.24 | 1 | 0.16 |
| 12.47 | 2 | 0.32 |
| 18.71 | 3 | 0.48 |
| 24.94 | 4 | 0.64 |
| 31.18 | 5 | 0.80 |
| 37.41 | 6 | 0.96 |
| 43.65 | 7 | 1.12 |
| 49.89 | 8 | 1.28 |
| 56.13 | 9 | 1.44 |
| 62.36 | 10 | 1.60 |
| 124.72 | 20 | 3.21 |
| 187.09 | 30 | 4.81 |
| 249.45 | 40 | 6.41 |
| 311.81 | 50 | 8.02 |
| 374.17 | 60 | 9.62 |
| 436.53 | 70 | 11.22 |
| 498.90 | 80 | 12.83 |
| 561.26 | 90 | 14.43 |
| 623.62 | 100 | 16.04 |

# USEFUL MEASUREMENTS

1 Imperial gallon = 4 quarts = 8 pints = 160 fluid ounces
= 10 pounds of water
= approximately 1.2 U.S. gallons
1 U.S. gallon = .8345 or approximately 5/6 Imperial gallon
1 Imperial pint = 20 fluid ounces
1 U.S. pint = 16 fluid ounces
1 pound = 16 ounces
1 tablespoon = 3 teaspoons
2 tablespoons = 1 fluid ounce

1 pound in 100,000 gallons of water = 1 ppm (part per million)
1 mile = 5,280 feet = 1,760 yards
1 yard = 3 feet = 36 inches
1 foot = 12 inches
1 acre = approximately 209 by 209 feet
43,560 square feet
1 square yard = 9 square feet
1 square foot = 144 square inches
1 mile an hour = 88 feet a minute

**PARTS PER MILLION**

1 per cent = 10,000 parts per million
Imperial: 1 fl. oz./gallon = 6250 ppm.

Metric: 1 mg/litre (water) = 1 ppm.
1 g/litre (water) = 1000 ppm.
1 mL/litre = 1000 ppm.

Source: *1988 Berry Production Guide for Commercial Growers*, Province of British Columbia Ministry of Agriculture and Fisheries, Victoria, B.C., 1988.

## Table 10.5 Rapid Conversions - Lengths

HOW TO USE:

Enter the table, either from the left column or from the top, at the known dimension. Move along the line until it intersects at right angles with the desired conversion dimension. Note the number at the intersection and follow instructions in blocks A or B.

A- Preferred Method

Enter table here and **multiply** by intersecting number. E.g. to convert 90 yards into feet, multiply by 3. Answer is 270 feet. **Note:** Figures in vertical columns indicate quantity of the left side dimension that equals one unit of the top symbol. E.g. 3 feet equals 1 yard.

**B—Alternate Method**

**Enter table here and divide by intersecting number. E.g. to convert 270 feet into yards, divide by 3. Answer is 90 yards.**

| Name | SYMBOL | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | mm. | cm. | in. | dm. | ft. | yd. | m. | rd. |
| millimetres | 1 | 10 | 25.4 | 100 | 304.8 | 914.4 | 1000 | 5029.2 |
| centimetres | .1 | 1 | 2.54 | 10 | 30.48 | 91.44 | 100 | 502.9 |
| inches | .03937 | .3937 | 1 | 3.937 | 12 | 36 | 39.37 | 198 |
| decimetres | .01 | .1 | .254 | 1 | 3.048 | 9.144 | 10 | 50.29 |
| feet | .00328 | .0328 | .08333 | .32808 | 1 | 3 | 3.2808 | 16.5 |
| yards | .00109 | .01093 | .0278 | .10936 | .33333 | 1 | 1.0936 | 5.5 |
| metres | .001 | .01 | .02540 | .1 | .30480 | .91440 | 1 | 5.0292 |
| rods | 1.99x10 [illegible] | | .00505 | [illegible] | [illegible] | .18181 | [illegible] | 1 |
| chains | | | | | | | | |

## TABLE 10
## LENGTHS

| Name | SYMBOL | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mm. | cm. | in. | dm. | ft. | yd. | m. | rd. | ch. | hm. | fur. | km. | mi. | naut. mi. |
| millimetres | 1 | 10 | 25.4 | 100 | 304.8 | 914.4 | 1000 | 5029.2 | 20116.8 | 100,000 | 201,168 | 1,000,000 | 1,609,347 | 1,853,248 |
| centimetres | .1 | 1 | 2.54 | 10 | 30.48 | 91.44 | 100 | 502.9 | 2011.68 | 10,000 | 20116.8 | 100,000 | 160,935 | 185,325 |
| inches | .03937 | .3937 | 1 | 3.937 | 12 | 36 | 39.37 | 198 | 792 | 3937 | 7920 | 39,370 | 63,360 | 72,963 |
| decimetres | .01 | .1 | .254 | 1 | 3.048 | 9.144 | 10 | 50.29 | 201.17 | 1000 | 2011.7 | 10,000 | 16,093 | 18,532 |
| feet | .00328 | .0328 | .08333 | .32808 | 1 | 3 | 3.2808 | 16.5 | 66 | 328.08 | 660 | 3280.8 | 5280 | 6080.2 |
| yards | .00109 | .01093 | .0278 | .10936 | .33333 | 1 | 1.0936 | 5.5 | 22 | 109.36 | 220 | 1093.6 | 1760 | 2026.8 |
| metres | .001 | .01 | .02540 | .1 | .30480 | .91440 | 1 | 5.0292 | 20.116 | 100 | 201.17 | 1000 | 1609.3 | 1853.2 |
| rods | $1.99 \times 10^{-4}$ | .00199 | .00505 | .01988 | .0606 | .18181 | .1988 | 1 | 4 | 19.883 | 40 | 198.83 | 320 | 368.85 |
| chains | $4.97 \times 10^{-5}$ | $4.97 \times 10^{-4}$ | .00126 | .00497 | .01515 | .04545 | .04971 | .25 | 1 | 4.9708 | 10 | 49.708 | 80 | 92.23 |
| hectometres | $10^{-5}$ | $10^{-4}$ | .00025 | .001 | .00305 | .00914 | .01 | .05029 | .20117 | 1 | 2.0117 | 10 | 16.093 | 18.53 |
| furlongs | $4.97 \times 10^{-6}$ | $4.97 \times 10^{-5}$ | $1.26 \times 10^{-4}$ | $4.97 \times 10^{-4}$ | .00151 | .00454 | .00497 | .025 | .1 | .49078 | 1 | 4.9708 | 8 | 9.223 |
| kilometres | $10^{-6}$ | $10^{-5}$ | $2.54 \times 10^{-5}$ | $10^{-4}$ | $3.05 \times 10^{-4}$ | $9.15 \times 10^{-4}$ | .001 | .00503 | .02012 | .1 | .20117 | 1 | 1.6093 | 1.853 |

## Table 10.6 Equivalents of Measure

The following list of convenient equivalents of measure includes the relationship between imperial units and the International System of Units (SI).

1 inch equals 2.54 cm (centimetres)
1 foot equals 0.3048 m (metre)
1 statute mile equals 1.6093 km (kilometres)

1 cm (centimetre) equals 0.393 70 inch
1 m (metre) equals 3.2808 feet
1 km (kilometre) equals 0.621 37 mile

1 acre equals 43 560 square feet
1 acre equals 0.404 69 ha (hectare)
1 square mile equals 640 acres
1 square mile equals 2.5900 $km^2$ (square kilometres)
1 square mile equals 259.0 ha (hectares)

1 ha (hectare) equals 10 000 $m^2$ (square metres)
1 ha (hectare) equals 2.4710 acres
1 $km^2$ (square kilometre) equals 0.386 10 square mile

1 cubic foot equals 6.2288 imperial gallons
1 imperial gallon equals 4.546 09 L (litres)
1 imperial gallon equals 1.2010 U.S. gallons
1 U.S. gallon equals 0.133 68 cubic foot
1 cubic foot equals 0.028 317 $m^3$ (cubic metre)
1 $m^3$ (cubic metre) equals 35.315 cubic feet
1 $dam^3$ (cubic decametre) equals 1000 $m^3$ (cubic metres)
1 $dam^3$ (cubic decametre) equals 1 mm (millimetre) over 1 $km^2$ (square kilometre)

1 cubic foot per second for one day equals 1.9835 acre-feet
1 cubic foot per second for one day covers one square mile to a depth of 0.037 19 inch
1 acre-foot equals 1.2335 $dam^3$ (cubic decametres)
1 $m^3/s$ (cubic metre per second) for one day equals 86.4 $dam^3$ (cubic decametre)
1 $m^3/s$ (cubic metre per second) for one day covers one square kilometre to a depth of 0.0864 m (metre)

1 foot per second equals 0.6818 mile per hour
1 mile per hour equals 1.467 feet per second
1 m/s (metre per second) equals 3.6 km/h (kilometre per hour)
1 km/h (kilometre per hour) equals 0.2778 m/s (metre per second)

1 cubic foot per second equals 0.028 317 $m^3/s$ (cubic metre per second)
1 $m^3/s$ (cubic metre per second) equals 35.315 cubic feet per second

1 pound equals 0.453 59 kg (kilogram)
1 kg (kilogram) equals 2.2046 pounds

1 short ton (2000 pounds) equals 0.907 18 t (tonne)
1 t (tonne) equals 2204.6 pounds

degrees Celsius = 5/9 (degrees Fahrenheit − 32)
degrees Fahrenheit = 9/5 (degrees Celsius) + 32

Source: *Surface Water Data*, Inland Water Directorate, Water Resources Branch, Water Survey of Canada, Ottawa, 1989.

Table 10.7 Metric Conversion Tables

### General Conversions

| | |
|---|---|
| Length: | 1 mm = 0.0394 in. |
| | 1 m = 3.281 ft. |
| | 1 km = 0.621 miles |
| Area: | 1 $m^2$ = 10.76 $ft^2$ |
| | 1 ha = 2.471 acres |
| Volume: | 1 mL = 0.035 fl.oz.(Imp.) |
| | 1 L = 0.220 gal.(Imp.) |
| | 1 $m^3$ = 35.31 $ft^3$ |
| | 1 $m^3$ = 1.308 $yd^3$ |
| Mass: | 1 g = 0.035 oz. |
| | 1 kg = 2.205 lb. |
| | 1 t = 1.102 ton |
| Density: | 1 kg/$m^3$ = 0.0624 lb/$ft^3$ |
| Force: | 1 kN = 224.8 lb.force |
| Pressure: | 1 MPa = 145 lb/$in^2$(psi) |
| Fluid Flow: | 1 L/s = 2.12 $ft^3$/min.(cfm) |
| Energy: | 1 mJ = 947.9 BTU |
| Power: | 1 kW = 1.341 hp |

### Sawn Lumber Sizes

| IMPERIAL | | METRIC |
|---|---|---|
| Nominal | Actual | |
| 1" | 3/4" | 19 mm |
| 2" | 1 ½" | 38 mm |
| 3" | 2 ½" | 64 mm |
| 4" | 3 ½" | 89 mm |
| 6" | 5 ½" | 140 mm |
| 8" | 7 ¼" | 184 mm |
| 10" | 9 ¼" | 235 mm |
| 12" | 11 ¼" | 286 mm |

### Roof Loading

1 kN/$m^2$ = 20 psf (approx.)
1 kN/$m^2$ = 20.89 psf

### Modular Dimensions

| | |
|---|---|
| 1/8" = 3 mm | 12" = 300 mm |
| 1/4" = 6 mm | 16" = 400 mm |
| 3/8" = 10 mm | 19" = 480 mm |
| 1/2" = 13 mm | 24" = 600 mm |
| 5/8" = 16 mm | 32" = 800 mm |
| 3/4" = 19 mm | 48" = 1200 mm |
| 1" = 25 mm | 6 ft. = 1800 mm |
| 4" = 100 mm | 8 ft. = 2400 mm |
| 6" = 150 mm | 10 ft. = 3000 mm |
| 8" = 200 mm | 12 ft. = 3600 mm |
| 9 ½" = 240 mm | 14 ft. = 4200 mm |

16 ft. = 4800 mm

### Softwood Plywood

WIDTH = 1200 mm LENGTH = 2400 mm

THICKNESS

| Imperial (nominal) | Metric (actual) sanded | sheathing |
|---|---|---|
| 1/4" | 6 mm | – |
| 5/16" | – | 7.5 mm |
| 3/8" | 8 mm | 9.5 mm |
| 1/2" | 11 mm | 12.5 mm |
| 5/8" | 14 mm | 15.5 mm |
| 3/4" | 17 mm | 18.5 mm |

### Insulation R - Values

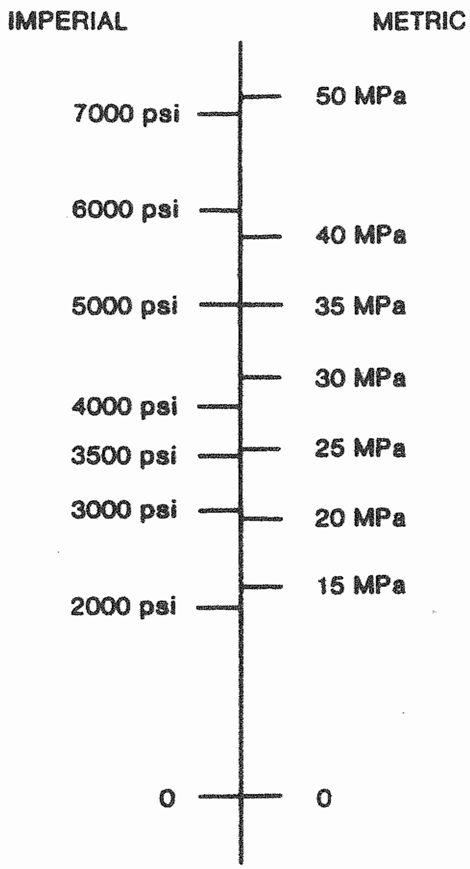
| IMPERIAL | METRIC |
|---|---|
| R8 | RSI 1.4 |
| R12 | RSI 2.1 |
| R14 | RSI 2.5 |
| R20 | RSI 3.5 |

### Vapour Barriers

| IMPERIAL | METRIC |
|---|---|
| 2 mil | 50 µm |
| 4 mil | 100 µm |
| 6 mil | 150 µm |
| 10 mil | 250 µm |

Table 10.7 Cont.

**Concrete Strength**
**(approximate)**




**Rebar Sizes**
**(approximate)**

| IMPERIAL | METRIC | AREA OF SECTION |
|---|---|---|
| 3,4 | 10M | 100 $mm^2$ |
| 5 | 15M | 200 $mm^2$ |
| 6,7 | 20M | 300 $mm^2$ |
| 8 | 25M | 500 $mm^2$ |
| 9 | 30M | 700 $mm^2$ |
| 10 | 35M | 1000 $mm^2$ |
| 14 | 45M | 1500 $mm^2$ |

**Welded Wire Fabric**

| Spacings | | Wire Size | |
|---|---|---|---|
| IMPERIAL | METRIC | IMPERIAL | METRIC |
| 2" | 50 mm | 6 | P18 |
| 3" | 75 mm | 8 | P13 |
| 4" | 100 mm | 10 | P9 |
| 6" | 150 mm | | |
| 8" | 200 mm | | |
| 12" | 300 mm | | |

eg. 6 x 6 x 6/6 = 150 x 150 x P18/P18

**Sheet Metal Thickness**

| GAUGE(USS) | METRIC |
|---|---|
| 12 | 3.0 mm |
| 14 | 2.0 mm |
| 16 | 1.6 mm |
| 18 | 1.2 mm |
| 20 | 1.0 mm |
| 22 | 0.8 mm |
| 24 | 0.6 mm |
| 26 | 0.5 mm |
| 28 | 0.4 mm |
| 30 | 0.3 mm |

**Bolt Sizes**
**(diameter)**

| IMPERIAL | METRIC |
|---|---|
| 1/4" | M6 |
| 5/16" | M8 |
| 3/8" | M10 |
| 1/2" | M12 |
| 9/16" | M14 |
| 5/8" | M16 |
| 11/16" | M18 |
| 3/4" | M20 |

**Grain Bin Capacity**

1 Tonne = 1000 kg = 2205 lb.
1 $m^3$ = 35.3 $ft^3$

| | |
|---|---|
| Wheat: | 1 Tonne = 1.33 $m^3$ = 36.7 bu. |
| Rye: | 1 Tonne = 1.43 $m^3$ = 39.4 bu. |
| Flax: | 1 Tonne = 1.43 $m^3$ = 39.4 bu. |
| Canola: | 1 Tonne = 1.60 $m^3$ = 44.1 bu. |
| Barley: | 1 Tonne = 1.67 $m^3$ = 45.9 bu. |
| Oats: | 1 Tonne = 2.35 $m^3$ = 64.8 bu. |

Table 10.8 Conversion Table for Use of Materials on Small Areas / Metric - English Conversions

| LIQUID MATERIALS | | | DRY MATERIALS | | |
|---|---|---|---|---|---|
| Rate/Acre | Rate/1000 Sq Ft | Rate/100 Sq Ft | Rate/Acre | Rate/1000 Sq Ft | Rate/100 Sq Ft |
| 1 pt | ¾ Tbsp | ¼ tsp | 1 lb | 2½ tsp | ¼ tsp |
| 1 qt | 1½ Tbsp | ½ tsp | 3 lb | 2¼ Tbsp | ¾ tsp |
| 1 gal | 6 Tbsp | 2 tsp | 4 lb | 3 Tbsp | 1 tsp |
| 25 gal | 4½ pt | 1 C | 5 lb | 4 Tbsp | 1¼ tsp |
| 50 gal | 4½ qt | 1 pt | 10 lb | ½ C | 2 tsp |
| 100 gal | 9 qt | 1 qt | 100 lb | 2¼ lb | ¼ lb |
| 200 gal | 4½ qt | 2 qt | 200 lb | 4½ lb | ½ lb |
| 300 gal | 6¾ gal | 3 qt | 300 lb | 6¾ lb | ¾ lb |
| 400 gal | 9 gal | 1 gal | 400 lb | 9 lb | 1 lb |
| 500 gal | 11¼ gal | 1¼ gal | 500 lb | 11¼ lb | 1¼ lb |

## METRIC-ENGLISH CONVERSIONS

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 centimeter | = | .3937 inches | 1 kilometer | = | 1000 meters | 1 gallon | = | 3.785 liters |
| 1 inch | = | 2.54 centimeter | 1 kilometer | = | .62137 miles | 1 gram | = | 15.43 grains |
| 1 foot | = | 30.48 centimeter | 1 sq centimeter | = | .155 sq inches | 1 ounce | = | 28.35 grams |
| 1 meter | = | 39.37 inches | 1 sq decimeter | = | 100 cu centimeters | 1 kilogram | = | 1000 grams |
| 1 meter | = | 100 centimeters | 1 cu centimeter | = | .061 cu inches | 1 kilogram | = | 2.205 pounds |
| 1 meter | = | 1.094 yards | 1 cu decimeter | = | 1000 cu centimeters | 1 pound | = | 7000 grains |
| 1 meter | = | 1000 millimeters | 1 cu meter | = | 100 liters | 1 pound | = | .4536 kilograms |
| 1 millimeter | = | .001 meter | 1 fluid ounce | = | 29.54 milliliters | 1 kilogram | = | 1000 milliliters |
| 1 yard | = | .9144 meter | 1 liter | = | 1000 cu centimeters | 1 kilogram | = | 1 liter (water) |

**MULTIPLY** ............ **TO OBTAIN**

ounces by 0.9115........ounces (Troy)
ounces by 2..........tablespoons (liq)
ounces by 6............teaspoons (liq)
ounces by 3.........tablespoons (dry)
ounces by 9...........teaspoons (dry)
ounces by 28.349527...........grams
ounces (fluid) by 1.805.......cu inches

pounds by 16.................ounces
pounds of water by 0.01602.....cu feet
pounds of water by 27.68.....cu inches
pounds of water by 0.1198......gallons

tablespoons (liq) by 0.5.........ounces
tablespoons (dry) by 0.3333.....ounces
tablespoons by 3...........teaspoons
teaspoons (liq) by 0.1666.......ounces
teaspoons (dry) by 0.1111.......ounces
teaspoons by 0.3333......tablespoons

bushels by .8..................cu feet
bushels by 4...................pecks
bushels by .04545............cu yards

**MULTIPLY** ............ **TO OBTAIN**

liters by 1000..........cu centimeters
liters by 0.03531................cu feet
liters by 61.02...............cu inches
liters by .01.................cu meters
liters by .001308.............cu yards
liters by 0.2642...............gallons
liters by 2.113...............pints (liq)
liters by 1.057..............quarts (liq)

gallons by 3785........cu centimeters
gallons by 0.1337..............cu feet
gallons by 231..............cu inches
gallons by .003785..........cu meters
gallons by .004951...........cu yards
gallons by 3.785.................liters
gallons by 8................pints (liq)
gallons by 4...............quarts (liq)
gallons water by 8.3453....lbs of water

grams by 0.03527.............ounces
grams by 0.03215........ounces (Troy)
grams by .002205.............pounds

acre by 43,560...................sq ft
hectare by 10,000...........sq meters
lb/acre by 1.12..................kg/ha
(acre is sq area 208.7 ft on each side)

**MULTIPLY** ............ **TO OBTAIN**

cu feet by .0002832.....cu centimeters
cu feet by 1728..............cu inches
cu feet by 0.02832...........cu meters
cu feet by 0.03704............cu yards
cu feet by 7.48052.............gallons
cu feet by 28.32..................liters
cu feet by 59.84.............pints (liq)
cu feet by 29.92............quarts (liq)
cu feet by 1.25...............bushels

cu meters by 35.31.............cu feet
cu meters by 61.023.........cu inches
cu meters by 1.308............cu yards
cu meters by 264.2............gallons
cu meters by 1000................liters
cu meters by 2113............pints(liq)
cu meters by 1057..........quarts (liq)

miles/hr by 44.70......centimeters/sec
miles/hr by 88................feet/min
miles/hr by 1.467.............feet/sec
miles/hr by 1.609.........kilometers/hr
miles/hr by 0.8684..............knots
miles/hr by 26.82..........meters/min

## Table 10.9 U.S. Units of Measurement

*Length*

1 foot = 12 inches
1 yard = 3 feet
1 yard = 36 inches
1 rod = 16.5 feet
1 mile = 5280 feet

*Area*

1 acre = 43,560 square feet
1 section = 640 acres
1 section = 1 square mile

*Volume*

1 liquid pint = 16 liquid ounces
1 liquid quart = 2 liquid pints
1 liquid quart = 32 liquid ounces
1 gallon = 8 liquid pints
1 gallon = 4 liquid quarts
1 gallon = 128 liquid ounces
1 peck = 16 pints (dry)
1 peck = 8 quarts (dry)
1 bushel = 4 pecks
1 bushel = 64 pints (dry)
1 bushel = 32 quarts (dry)

*Mass or Weight*

1 pound = 16 ounces
1 hundredweight = 100 pounds
1 ton = 20 hundredweight
1 ton = 2000 pounds

Source: *Knott's Handbook for Vegetable Growers*, Third Edition, O. Lorenz & D. Maynard, John Wiley & Sons, 1988, pg 398.

## Table 10.10 Conversion Factors for U.S. Units

| Multiply | By | To Obtain |
|---|---|---|
| | *Length* | |
| feet | 12. | inches |
| feet | 0.33333 | yards |
| inches | 0.08333 | feet |
| inches | 0.02778 | yards |
| miles | 5,280. | feet |
| miles | 63,360. | inches |
| miles | 1,760. | yards |
| rods | 16.5 | feet |
| yards | 3. | feet |
| yards | 36. | inches |
| yards | 0.000568 | miles |
| | *Area* | |
| acres | 43,560. | square feet |
| acres | 160. | square rods |
| acres | 4,840. | square yards |
| square feet | 144. | square inches |
| square feet | 0.11111 | square yards |
| square inches | 0.00694 | square feet |
| square miles | 640. | acres |
| square miles | 27,878,400. | square feet |
| square miles | 3,097,600. | square yards |
| square yards | 0.0002066 | acres |
| square yards | 9. | square feet |
| square yards | 1,296. | square inches |
| | *Volume* | |
| bushels | 2,150.42 | cubic inches |
| bushels | 4. | pecks |
| bushels | 64. | pints |
| bushels | 32. | quarts |
| cubic feet | 1,728. | cubic inches |
| cubic feet | 0.03704 | cubic yards |
| cubic feet | 7.4805 | gallons |
| cubic feet | 59.84 | pints (liquid) |
| cubic feet | 29.92 | quarts (liquid) |
| cubic yards | 27. | cubic feet |
| cubic yards | 46,656. | cubic inches |
| cubic yards | 202. | gallons |
| cubic yards | 1,616. | pints (liquid) |
| cubic yards | 807.9 | quarts (liquid) |
| gallons | 0.1337 | cubic feet |
| gallons | 231. | cubic inches |
| gallons | 128. | ounces (liquid) |
| gallons | 8. | pints (liquid) |
| gallons | 4. | quarts (liquid) |
| gallons of water | 8.3453 | pounds of water |
| pecks | 0.25 | bushels |
| pecks | 537.605 | cubic inches |
| pecks | 16. | pints (dry) |
| pecks | 8. | quarts (dry) |
| pints (dry) | 0.015625 | bushels |
| pints (dry) | 33.6003 | cubic inches |
| pints (dry) | 0.0625 | pecks |
| pints (dry) | 0.5 | quarts (dry) |

## Table 10.10 Cont.

| Multiply | By | To Obtain |
|---|---|---|
| | *Volume* | |
| pints (liquid) | 28.875 | cubic inches |
| pints (liquid) | 0.125 | gallons |
| pints (liquid) | 16. | ounces (liquid) |
| pints (liquid) | 0.5 | quarts (liquid) |
| quarts (dry) | 0.03125 | bushels |
| quarts (dry) | 67.20 | cubic inches |
| quarts (dry) | 2. | pints (dry) |
| quarts (liquid) | 57.75 | cubic inches |
| quarts (liquid) | 0.25 | gallons |
| quarts (liquid) | 32. | ounces (liquid) |
| quarts (liquid) | 2. | pints (liquid) |
| | *Mass or Weight* | |
| ounces (dry) | 0.0625 | pounds |
| ounces (liquid) | 1.805 | cubic inches |
| ounces (liquid) | 0.0078125 | gallons |
| ounces (liquid) | 0.0625 | pints (liquid) |
| ounces (liquid) | 0.03125 | quarts (liquid) |
| pounds | 16. | ounces |
| pounds | 0.0005 | tons |
| pounds of water | 0.01602 | cubic feet |
| pounds of water | 27.68 | cubic inches |
| pounds of water | 0.1198 | gallons |
| tons | 32,000. | ounces |
| tons | 20. | hundredweight |
| tons | 2,000. | pounds |
| | *Rate* | |
| feet per minute | 0.01667 | feet per second |
| feet per minute | 0.01136 | miles per hour |
| miles per hour | 88. | feet per minute |
| miles per hour | 1.467 | feet per second |

Source: *Knott's Handbook for Vegetable Growers*, Third Edition, O. Lorenz & D. Maynard, John Wiley & Sons, 1988, pg 399-401.

## Table 10.11 Conversion Factors For U.S. Units

*Concentration*

1 decisiemens per meter (dS/m) = 1 millimho per centimeter (mmho/cm)

1 decisiemens per meter (dS/m) = approximately 640 milligrams per liter salt

1 part per million (ppm) = 1/1,000,000

1 percent = 0.01 or 1/100

1 ppm × 10,000 = 1 percent

ppm × 0.00136 = tons per acre-foot of water

ppm = milligrams per liter

ppm = 17.12 × grains per gallon

grains per gallon = 0.0584 × ppm

ppm = 0.64 × micromohos per centimeter (in range of 100–5000 micromhos per centimeter)

ppm = 640 × millimhos per centimeter (in range of 0.1–5.0 millimhos per centimeter)

ppm = grams per cubic meter

mho = reciprocal ohm

millimho = 1000 micromhos

millimho = approximately 10 milliequivalents per liter (meq/liter)

milliequivalents per liter = equivalents per million

millimhos per centimeter = EC × $10^3$ (EC × 1000) at 25°C (EC = electrical conductivity)

micromhos per centimeter = EC × $10^6$ (EC × 1,000,000) at 25°C

millimhos per centimeter = 0.1 siemens per meter

millimhos per centimeter = (EC × $10^3$) = decisiemens per meter (dS/m)

1000 micromhos per centimeter = approximately 700 ppm

1000 micromhos per centimeter = approximately 10 milliequivalents per liter

1000 micromhos per centimeter = 1 ton of salt per acre-foot of water

milliequivalents per liter = 0.01 × (EC × $10^6$) (in range of 100–5000 micromhos per centimeter)

milliequivalents per liter = 10 × (EC × $10^3$) (in range of 0.1–5.0 millimhos per centimeter)

*Pressure and Head*

1 atmosphere at sea level = 14.7 pounds per square inch

1 atmosphere at sea level = 29.9 inches of mercury

1 atmosphere at sea level = 33.9 feet of water

1 atmosphere = 0.101 megapascal (MPa)

1 bar = 0.10 megapascal (MPa)

1 foot of water = 0.8826 inch of mercury

1 foot of water = 0.4335 pound per square inch

1 inch of mercury = 1.133 feet of water

1 inch of mercury = 0.4912 pound per square inch

1 inch of water = 0.07355 inch of mercury

1 inch of water = 0.03613 pound per square inch

1 pound per square inch = 2.307 feet of water

1 pound per square inch = 2.036 inches of mercury

1 pound per square foot = 47.9 pascals

## Table 10.11 Cont.

*Weight and Volume (U.S. Measurements)*

1 acre-foot of soil = about 4,000,000 pounds
1 acre-foot of water = 43,560 cubic feet
1 acre-foot of water = 12 acre-inches
1 acre-foot of water = about 2,722,500 pounds
1 acre-foot of water = 325,851 gallons
1 cubic foot of water = 7.4805 gallons
1 cubic foot of water at 59°F = 62.37 pounds
1 acre-inch of water = 27,154 gallons
1 gallon of water at 59°F = 8.337 pounds
1 gallon of water = 0.1337 cubic foot or 231 cubic inches

*Flow (U.S. Measurements)*

1 cubic foot per second = 448.8 gallons per minute
1 cubic foot per second = about 1 acre-inch per hour
1 cubic foot per second = 23.80 acre-inches per hour
1 cubic foot per second = 3600 cubic feet per hour
1 cubic foot per second = 3600 cubic feet per hour
1 cubic foot per second = about 7½ gallons per second
1 gallon per minute = 0.00223 cubic feet per second
1 gallon per minute = 0.053 acre-inch per 24 hours
1 gallon per minute = 1 acre-inch in 4½ hours
1000 gallons per minute = 1 acre-inch in 27 minutes
1 acre-inch per 24 hours = 18.86 gallons per minute
1 acre-foot per 24 hours = 226.3 gallons per minute
1 acre-foot per 24 hours = 0.3259 million gallons per 24 hours

*U.S.–Metric Equivalents*

1 cubic meter = 35.314 cubic feet
1 cubic meter = 1.308 cubic yards
1 cubic meter = 1000 liters
1 liter = 0.0353 cubic feet
1 liter = 0.2642 U.S. gallon
1 liter = 0.2201 British or Imperial gallon
1 cubic centimeter = 0.061 cubic inch
1 cubic foot = 0.0283 cubic meter
1 cubic foot = 28.32 liters
1 cubic foot = 7.48 U.S. gallons
1 cubic foot = 6.23 British gallons
1 cubic inch = 16.39 cubic centimeters
1 cubic yard = 0.7645 cubic meter
1 U.S. gallon = 3.7854 liters
1 U.S. gallon = 0.833 British gallon
1 British gallon = 1.201 U.S. gallons
1 British gallon = 4.5436 liters
1 acre-foot = 43,560 cubic feet
1 acre-foot = 1,233.5 cubic meters
1 acre-inch = 3,630 cubic feet
1 acre-inch = 102.8 cubic meters

## Table 10.11 Cont.

*U.S.–Metric Equivalents*

1 cubic meter per second = 35.314 cubic feet per second
1 cubic meter per hour = 0.278 liter per second
1 cubic meter per hour = 4.403 U.S. gallons per minute
1 cubic meter per hour = 3.668 British gallons per minute
1 liter per second = 0.0353 cubic feet per second
1 liter per second = 15.852 U.S. gallons per minute
1 liter per second = 13.206 British gallons per minute
1 liter per second = 3.6 cubic meters per hour
1 cubic foot per second = 0.0283 cubic meter per second
1 cubic foot per second = 28.32 liters per second
1 cubic foot per second = 448.8 U.S. gallons per minute
1 cubic foot per second = 373.8 British gallons per minute
1 cubic foot per second = 1 acre-inch per hour (approximately)
1 cubic foot per second = 2 acre-feet per day (approximately)
1 U.S. gallon per minute = 0.06309 liter per second
1 British gallon per minute = 0.07573 liter per second

*Power and Energy*

1 horsepower = 550 foot-pounds per second
1 horsepower = 33,000 foot-pounds per minute
1 horsepower = 0.7457 kilowatts
1 horsepower = 745.7 watts
1 horsepower-hour = 0.7457 kilowatt-hour
1 kilowatt = 1.341 horsepower
1 kilowatt-hour = 1.341 horsepower-hours
1 acre-foot of water lifted 1 foot = 1.372 horsepower-hours of work
1 acre-foot of water lifted 1 foot = 1.025 kilowatt-hours of work

Source: *Knott's Handbook for Vegetable Growers*, Third Edition, O. Lorenz & D. Maynard, John Wiley & Sons, 1988, pg 202-205.

## Table 10.12 Usefull Conversions for Rates of Application

**USEFUL CONVERSIONS FOR RATES OF APPLICATION**

1 ton per acre = 20.8 grams per square foot
1 ton per acre = 1 pound per 21.78 square feet
1 ton per acre furrow slice (6-inch depth) = 1 gram per 1000 grams soil
1 gram per square foot = 96 pounds per acre
1 pound per acre = 0.0104 grams per square foot
1 pound per acre = 1.12 kilograms per hectare
100 pounds per acre = 0.2296 pounds per 100 square feet
grams per square foot × 96 = pounds per acre
kilograms per 48 square feet = tons per acre
pounds per square feet × 21.78 = tons per acre

Source: *Knott's Handbook for Vegetable Growers*, Third Edition, O. Lorenz & D. Maynard, John Wiley & Sons, 1988, pg 406.

## Table 10.13 Conversion Factors for U.S. and Metric Units

| To Convert Column 1 into Column 2 Multiply by: | Column 1 | Column 2 | To Convert Column 2 into Column 1 Multiply By: |
|---|---|---|---|
| | *Length* | | |
| 0.621 | kilometer (km) | mile (mi) | 1.609 |
| 1.094 | meter (m) | yard (yd) | 0.914 |
| 0.394 | centimeter (cm) | inch (in) | 2.54 |
| | *Area* | | |
| 0.386 | square kilometer | square mile | 2.59 |
| 247.1 | square kilometer | acre | 0.00405 |
| 2.471 | hectare (ha) | acre | 0.405 |
| | *Volume* | | |
| 0.00973 | cubic meter | acre-inch | 102.8 |
| 3.532 | hectoliter (hl) | cubic foot | 0.2832 |
| 2.838 | hectoliter | bushel (bu) | 0.352 |
| 0.0284 | liter | bushel | 35.24 |
| 1.057 | liter | quart (qt) | 0.946 |
| | *Mass* | | |
| 1.102 | metric ton (MT) | ton | 0.9072 |
| 2.205 | quintal (q) | hundredweight (cwt) | 0.454 |
| 2.205 | kilogram (kg) | pound (lb) | 0.454 |
| 0.035 | gram (g) | ounce (oz) | 28.35 |
| | *Pressure* | | |
| 14.22 | kilograms per square centimeter | pounds per square inch (psi) | 0.0703 |
| 14.50 | bar | pounds per square inch | 0.06895 |
| 0.9869 | bar | atmosphere (atm) | 1.013 |
| 0.9678 | kilograms per square centimeter | atmosphere | 1.033 |
| 14.70 | atmosphere | pounds per square inch | 0.06805 |
| 0.01450 | kilopascal (KPa) | pounds per square inch | 6.895 |
| 0.00987 | kilopascal | atmosphere (atm) | 101.30 |
| 10.0 | megapascal (MPa) | atmosphere | 0.101 |
| 10.0 | megapascal | bar | 0.1 |
| | *Yield or Rate* | | |
| 0.446 | metric tons per hectare | tons per acre | 2.24 |
| 0.892 | kilograms per hectare | pounds per acre | 1.12 |
| 0.892 | quintals per hectare | hundredweight per acre (cwt/acre) | 1.12 |
| | *Temperature* | | |
| $9/5$ (°C) + 32 | Celsius | Fahrenheit | $5/9$ (°F) − 32 |
| | −17.8°C | 0°F | |
| | 0°C | 32°F | |
| | 20°C | 68°F | |
| | 100°C | 212°F | |
| | *Water Measurement* | | |
| 8.108 | hectare-meters | acre-feet | 0.1233 |
| 97.29 | hectare-meters | acre-inches | 0.01028 |
| 0.08108 | hectare-centimeters | acre-feet | 12.33 |
| 0.973 | hectare-centimeters | acre-inches | 1.028 |
| 0.00973 | cubic meters | acre-inches | 102.8 |
| 0.981 | hectare-centimeters per hour | cubic feet per second | 1.0194 |
| 440.3 | hectare-centimeters per hour | gallons per minute | 0.00227 |
| 0.00981 | cubic meters per hour | cubic feet per second | 101.9 |
| 4.403 | cubic meters per hour | gallons per minute | 0.227 |
| | *Light* | | |
| 0.0929 | lux | footcandle (ft-c) | 10.764 |

Source: *Knott's Handbook for Vegetable Growers, Third Edition*, O. Lorenz & D. Maynard, John Wiley & Sons, 1988, pg 403-405.