YUKON AGRICULTURE
RESEARCH AND DEMONSTRATION

2006 PROGRESS REPORT

Yukon
Energy, Mines and Resources

Yukon Agriculture Research & Demonstration Report

2006

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Executive Summary

A number of trials continued into 2006 with a couple of new trials implemented. The climate monitoring trials continued in a number of areas showing that the season was cool but without frosts for the latter part of the summer allowing for a extended growing season.

Other trials and demonstrations for 2006 included soil moisture and temperature monitoring, nutrient fluctuations in hay stands, oilseeds production, raspberry production, nitrogen fixation from alfalfa, and a forage demonstration.

Some of the highlights of the 2006 season include the production of up to 800 kg/ha of oil from oilseeds and over 90 kg/ha of nitrogen fixed from alfalfa production.

We gained a better understanding of the moisture level under irrigated and dryland conditions and the nutrient flux in bromegrass hay stands.

With soil temperature probes installed at 10 and 20 cm depth we learned that the temperatures in the plow layer reach upwards of 20^{o}C at shallow depths and provide adequate temperatures for microbes and for nitrogen fixation.

Raspberry production was at an all time high with 100 kg of raspberries produced from 300 linear meters, this crop was still being harvested when heavy frosts hit the berries and ended the season. Techniques to extend the season will be examined this year.

From the work completed in 2006 we were able to prove that oilseeds can be grown in the Yukon and that an experimental seed from Agriculture Canada, *Camelina sativa*, showed the best yields. The results show that 769-800 kg of oil can be produced per hectare from this seed. Unfortunately, the site in the central Yukon failed, so data from this region was not available. This trial will continue into the next year with some new seed selections and locations throughout the Yukon.

A study examining the nitrogen fixation of alfalfa in mixed grass and monoculture stands was completed. Yield and nitrogen production varied throughout the different treatments. Overall, the highest level of nitrogen fixation was achieved by a mixed alfalfa and timothy stand with no nitrogen fertilizer. This treatment achieved nitrogen fixing rates over 90 kg/ha. Alfalfa yield in this crop was over 3000 kg/ha.

In monoculture, alfalfa production achieved similar yields, with over 3000 kg/ha and between 65-75 kg/ha nitrogen fixation. Important observations from these trials were that late season harvesting of alfalfa reduced the second year forage yield by up to half and that even in low fertilizer situations, alfalfa is not suited to coexist with the bromegrass.

Most of these trials will continue into the next year, the focus being to improve the economics of production.

Preface

This document is a record of agricultural trials, experiments, and studies conducted in the Yukon. This is a yearly testimony of new and accumulated data and information set out to assist growers and researchers with future endeavors related to northern agriculture.

The target audience for this document is commercial agriculture producers, growers, and those interested in northern agronomic research.

Acknowledgments

The Yukon Agriculture Branch would like to thank all agricultural producers who participated and contributed with site locations, data collection, and field monitoring and observations. Recognition is also extended to the Forest Management Branch of the Department of Energy, Mines and Resources, as well as Environment Canada for contributing valuable climate data. In addition, the Agriculture Branch would also like to thank the following individuals and companies:
Art Bomke (UBC), Denis Lacroix, Sean MacDonald, Kevin Falk and Richard Gugel (AAFC, Saskatoon Research Centre), Scott Horner (HyTech Production Ltd.), George Green and the Golden Age Society, Gary Kruger (Western Ag Labs), Philom Bios, and Norwest Labs.

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Introduction

The Yukon Agriculture Branch conducts a variety of research and demonstration work to enhance the knowledge base of agriculture North of 60^{o}. Agriculture research has been taking place in the Yukon for almost one-hundred years and is an important aspect of the development of the industry.

As thousands of people entered the Yukon during the Klondike Gold Rush there was a necessity for people to produce their own food. In 1915, the Dominion Department of Agriculture began conducting co-operative research with interested producers in the Yukon. In 1917, the Department established an experimental sub-station at Swede Creek near Dawson City. The results of the research carried out at the station confirmed that a variety of crops could be grown successfully at a latitude of 64^{o} north, with yields and quality of produce comparing favourably with those obtained in agricultural areas a thousand miles to the south. The Swede Creek station closed in 1925.

In 1944, after the completion of the Alaska Highway, the Government of Canada conducted soil surveys in the Yukon and established a new experimental farm at Mile 1019 of the Alaska Highway near Haines Junction. A variety of vegetables and forages were grown without difficulty, along with the raising of livestock. The station closed in 1968.

Key studies were undertaken in the 1970s to determine the climate classification and soil capability. A large scale soil mapping exercise was completed in 1977.

The Yukon Government began conducting it's own research through the 1980s. A number of studies and reports were published through the 80s and 90s examining fertilizer rates, soil organisms, forage varieties and management techniques. In 1988 the Yukon Government established a small research site at the Gunnar Nilsson and Mickey Lammers Research Forest. The multitude of research projects conducted at this site have since lead to a number of variety and management practice recommendations.

The mandate of the extension and research arm of the Agriculture Branch is to provide advice to farmers in all aspects of farm management, production, marketing, conservation techniques, new farm technology, and farm financing.

It is with this mandate that we move forward and look at new crops and techniques that can advance Yukon agriculture.

The 2006 field season was cooler than the previous few years, but still above average compared to the 30 year climate normals.

A number of experiments were conducted throughout the south and central Yukon to understand the range of crops that can be produce North of 60^{o}.

Climate data was collected in various locations to better understand the fluctuations in different river valleys. Soil temperature and moisture levels were also recorded.

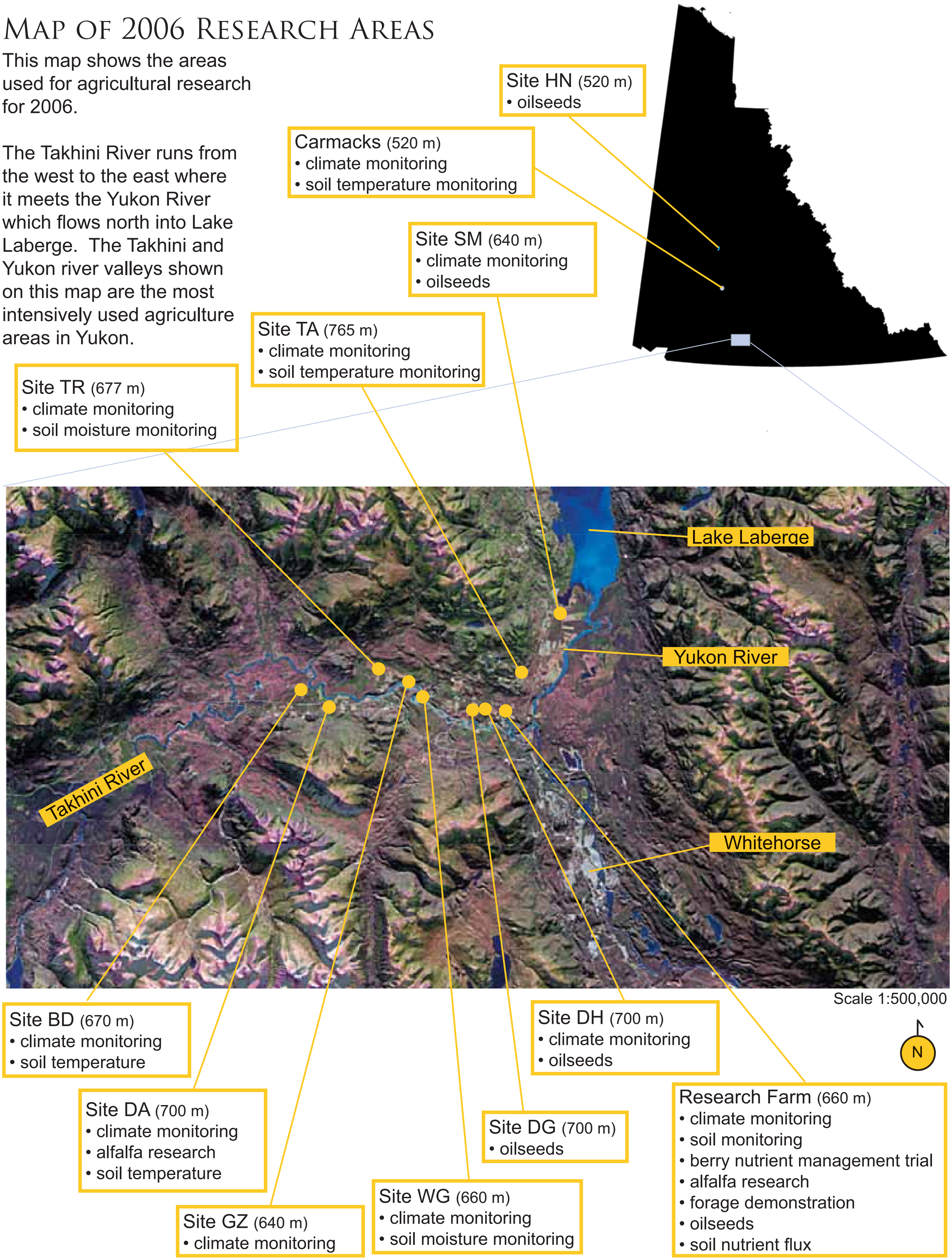
Crops grown in 2006 include canolas, false flax, flander's flax, alfalfa, a variety of grasses, and raspberries.

Photo: A klondike garden, July 1903, YA#4705 (photographer H.C. Barley)

Map of 2006 Research Areas

This map shows the areas used for agricultural research for 2006.

The Takhini River runs from the west to the east where it meets the Yukon River which flows north into Lake Laberge. The Takhini and Yukon river valleys shown on this map are the most intensively used agriculture areas in Yukon.



Site Descriptions

HN Farm Site (Heiko Nyland)
Research conducted: Oilseeds Research

The site is located in the central Yukon and therefore is influence by the warmer continental climate. It is located west of Pelly Crossing along the Pelly River near Crosby Creek. The site is on a north bench of the Pelly River, with good sun exposure.

The soil survey for this area:

Soil Association:	Fort Selkirk
Dominant Soil:	Orthic Eutric Brunisol
Texture:	Sand loam to loamy sand over gravel sand
Landform:	Nearly level fluvial deposits on terrace of the Pelly & Yukon Rivers

Carmacks/LSCFN Farm Site (LSCFN Community Garden)
Research conducted: Climate and Soil Temperature Monitoring

The site is located in the central Yukon and is also influenced by the continental climate resulting in warmer growing conditions. This location is home to the field garden for the Little Salmon Carmacks First Nation (LSCFN). The garden is located within a small 1.5 hectare cleared area, on a slight east facing aspect of the lower edge of the Yukon River.

The soil survey for this area:

Soil Association:	Carmacks
Dominant Soil:	Orthic Regosol
Texture:	Fine sandy loam to silt loam over loamy sand
Landform:	Nearly level alluvial deposits of the Yukon river.
pH & Conductivity	pH is around 7.3 and electrical conductivity below 0.5 dS/m

SM Farm Site (Steve and Bonnie Mackenzie-Grieve)
Research conducted: Oilseeds Research and Climate Monitoring

SM site is located in the Yukon River valley, near the south tip of Lake Laberge. The weather station and field experiment were located on the northwest corner of a large 50 ha clearing. The site is on a slightly sloping east aspect on an alluvial terrace next to the Yukon River. This is an irrigated site with oats as the previous crop.

The soil survey for this area:

Soil Association	Yukon
Dominant Soil	Orthic Eutric Brunisol
Texture	Medium to coarse loamy sand to sand
Drainage	Moderately well to rapidly drained
Landform	Fluvial. Undulating
pH & Conductivity	pH is 7.2, Electric Conductivity is below 1 dS/m
Organic Matter	Organic Matter approximately 2-3%

TA Farm Site (Tulio Albertini)
Research conducted: Climate and Soil Temperature Monitoring

The site is located in the Yukon River valley, 20 km north of Whitehorse. The climate and soil monitoring was setup on a south-east facing slope on an upper terrace, on the edge of a dryland hay field.

The soil survey for this area:

Soil Association	Lewes
Dominant Soil	Orthic Eutric Brumisol
Texture	Silty loam to fine loamy sand
Drainage	Moderately well to well drained
Landform	Glaciolacustrine. Nearly level undulating to occasionally pitted

TR Farm Site (Tom and Simone Rudge)
Research conducted: Climate and Soil Moisture Monitoring

The site is positioned in the Takhini Valley, on the north side of the Takhini River and the east side of Flat Creek. The climate and soil sensors were set up on the edge of a 30 hectare flat forage field on upper terrace of the Takhini River.

The soil survey for this area:

Soil Association	Champagne
Dominant Soil	Orthic Eutric Brunisol
Texture	Silty clay to clay loam
Drainage	Moderately well drained
Landform	Glaciolacustrine. Nearly level to undulating

BD Farm Site (Bill and Barbara Drury)
Research conducted: Climate and Soil Temperature Monitoring

The site is located in the Takhini Valley on an alluvial terrace adjacent to the south side of the Takhini river, just east of the Takhini River bridge along the Alaska Highway. The site has some low lying wetter areas with undulating terrain due to thawing of ice lenses (thermokarst) which spans over a large clearing of approximately 55 ha.

The soil survey for this area:

Soil Association	Klowtaton
Dominant Soil	Orthic Eutric Brunisol
Texture	Discontinuous sandy loam to sand over silty clay loam
Drainage	Moderately well to rapidly drained
Landform	Fluvial/glaciofluvial on glaciolacustrine. Undulating to hummocky
pH & Conductivity	The soil pH is between 7 – 7.5, low electrical conductivity around 1.5 dS/m.

DA Farm Site (Dave and Tracey Andrews)
Research Conducted: Alfalfa Research and Climate and Soil Temperature Monitoring

The site is located on the south side of the Takhini Valley, on a gently north facing slope. The aspect of the slope allows for the maintenance of higher moisture over the summer providing a better regime for decomposition, in turn increasing the amount of organic matter. This location has a large cleared area of approximately 80 ha.

The soil survey for this area:

Soil Association	Champagne
Dominant Soil	Orthic Eutric Brunisol
Texture	Silty clay to clay loam
Drainage	Moderately well drained
Landform	Glaciolacustrine. Nearly level to undulating
pH & Conductivity	Soil pH is around 7.7, and electrical conductivity is low at under 1 dS/m.
Organic Matter	Organic matter is high at >3%

GZ Farm Site (Gary and Pamela Zgeb)
Research conducted: Climate Monitoring

This site is located on the north side of the Takhini Valley, on an alluvial terrace next to the Takhini River, close to a raspberry orchard, on a slightly sloping, south face. This is a small area with little air movement resulting in frequent frosts.

The soil survey for this area:

Soil Association	Laberge
Dominant Soil	Gleyed Melanic Brunisol, Orthic Humic Cleysol
Texture	Silty loam to loamy sand
Drainage	Imperfectly to poor drained
Landform	Fluvial. Depressions, low terraces, creek bottoms
pH & Conductivity	Soils have an average pH of 8.2 and Electrical conductivity ranges below 1 dS/m to upward of 3.7 dS/m resulting in areas of poor growth
Organic Matter	Very high organic matter between 5 – 10%.

WG Farm Site (Wayne and Allison Grove)
Research conducted: Climate and Soil Moisture Monitoring

This is an irrigated site, located on a lower bench in the Takhini Valley, to the east of the TR site. The climate and soil moisture monitoring was set up near a south facing slope on a 33 hectare hay field with a slight south aspect.

The soil survey for this area:

Soil Association	Lewes
Dominant Soil	Orthic Eutric Brumisol
Texture	Silty loam to fine loamy sand
Drainage	Moderately well to well drained
Landform	Glaciolacustrine. Nearly level undulating to occasionally pitted

DG Farm Site (Dorine Girouard)
Research conducted: Oilseeds Research

The site is located on the north side of the Takhini valley, near the DH site. The research plot was located on a south aspect at the base of a slightly undulating slope within a cleared 16 ha field. The site is bordered to the east and south by an aspen and pine forest and the area has been managed as fallow land over the past couple years.

The soil survey for this area:

Soil Association	Lewes
Dominant Soil	Orthic Eutric Brumisol
Texture	Silty loam to fine loamy sand
Drainage	Moderately well to well drained
Landform	Glaciolacustrine. Nearly level undulating to occasionally pitted

DH Farm Site (Dan Halen)
Research conducted: Oilseeds Research and Climate Monitoring

The DH site is located on the north side of the Takhini valley. The research project and weather station were set up on the north side of a small, flat 1.6 ha field, near a strip of forest adjacent to the access road. Previous crop was sweet clover.

The soil survey for this area:

Soil Association	Lewes
Dominant Soil	Orthic Eutric Brumisol
Texture	Silty loam to fine loamy sand
Drainage	Moderately well to well drained
Landform	Glaciolacustrine. Nearly level undulating to occasionally pitted

RF Site (Research Farm)
Research conducted: Oilseeds, Alfalfa, Forage and Raspberry Research and Climate Monitoring, Soil Nutrient Flux

This site is located in the Gunnar Nilsson and Mickey Lammers Research Forest located south of the Klondike Highway and Takhini Hot springs Rd. Junction. The research is conducted on 2 hectares in the northeast corner of the Research Forest on a level field surrounded by a dominantly Lodgepole Pine forest providing shelter from winds, consequently creating a frost pocket. The soil, landscape and climatic properties of the site are typical of those encountered at many farms in the southwest region of the Yukon. The area was cleared in 1987 of willow, aspen, spruce, lodgepole pine, sheperdia spp, and bearberry and has been worked intensively for a variety of research since.

The soil survey for this area:

Soil Association	Lewes
Dominant Soil	Orthic Eutric Brumisol
Texture	Silty loam to fine loamy sand
Drainage	Moderately well to well drained
Landform	Glaciolacustrine. Nearly level undulating to occasionally pitted
pH & Conductivity	pH approximately 7.0 (neutral), trending downwards/more acidic over the years
Organic Matter	Organic mater is as low as 2%
Particle size	42% sand, 47% silt and 11% clay

1.0 Microclimate monitoring

Cooperators: Tulio Albertini, Dawn Charlie LSCFN, Dave Andrew, Bill Drury, Wayne Grove, Dan Halen, Gary Zgeb, PFRA

Location: Various Locations, YT

Funding: Yukon Government, APF Science and Innovation

Objective: To understand the variability in climate at various locations in the Yukon.

Introduction

Climate is the major limiting factor to agriculture in the Yukon due to a short frost free period and lack of heat units during the growing season. Agroclimatic capability ratings are a measure of the degree of limitation imposed by climate on agricultural production. These ratings are derived from 30-year normal data collected by the Meteorological Service of Environment Canada. They represent a measure of the amount of heat available to crops during the growing season. The agroclimatic rating is modified to account for local climate patterns, such as frost occurrences, which affect the length of the growing season. As shown in Table 1.1, agroclimatic classes range from Class 1 (no restrictions) to Class 7 (unable to be used for any agricultural purpose). The number of Growing Degree Days (GDD) are calculated beginning the fifth consecutive day of the year with daily mean temperatures above 5°C, and terminated the day of the first killing frost (-2.2°C) occurring after July 15. This killing frost temperature does not need to occur as a daily mean temperature, but rather at any moment of a day.

For example, if the daily mean temperature is 10°C, the GDD total is 5. Similarly if the daily mean temperature is 16°C, GDD equals 11. However, in the instance that a mean temperature is 5°C or lower, GDD would equal 0. The GDD is adjusted upward by 18% to account for the boost plants receive from the long hours of daylight north of 60° latitude. For example, the 785 GDD recorded at site RF, becomes 926 Effective Growing Degree Days (EGDD).

Historical climate data comparisons between different Yukon locations have been conducted. From this Agroclimatic data comparison there is distinguishable difference between agriculture land capabilities in the Whitehorse area vs. the central Yukon. Over the years the Research Farm and the Whitehorse airport have shown interesting contrasts between growing degree day (GDD) values. These differences are mainly attributed to site profiles; namely elevation, slope, aspect, and wind (i.e. wind drainage, entrapment by geography or forests). In 2004, the Agriculture Branch set out to record temperatures at various farm sites in the Whitehorse area, particularly in the Takhini River valley in order to assess their agroclimatic capability classification, as well as to compare and contrast microclimates of these different agricultural settings. In 2006, data loggers were deployed at other farm sites in order to expand on this comparative analysis.

Table 1.1 : Definitions and operational constraints of land capability classes for cultivated agriculture in the Yukon Territory (Tarnocai et al. 1988)

Class 1 1400-1600 GDD	These lands have no significant limitations that restrict the production of the full range of common Canadian agricultural crops (none in Yukon).
Class 2 1200-1400 GDD	These lands have slight limitations that restrict the range of some crops but still allow the production of grain and warm season vegetables (none in Yukon, based on a 30 year average).
Class 3 1050-1200 GDD	These lands have moderate limitations that restrict the range of crops to small grain cereals and vegetables (in a few localized areas in Yukon).
Class 4 900-1050 GDD	These lands have severe limitations that restrict the range of crops to forage production, marginal grain production and cold-hardy vegetables (valleys of central Yukon).
Class 5 700-900 GDD	These lands have very severe limitations that restrict the range of crops to forages, improved pastures and cold-hardy vegetables (the most common class of agricultural land in Yukon).
Class 6 <700 GDD	These lands have such severe limitations for cultivated agriculture that cropping is not feasible. These lands may be suitable for native grazing.
Class 7	These lands have no capability for cultivated agriculture or range for domestic animals.

Methodology

Data loggers were used to record ambient temperature throughout the growing season. These units were placed at six different locations in the Takhini River valley, three locations between Whitehorse and Lake Laberge, and one location in the central Yukon located near Carmacks. Data was recorded using HOBO air temperature monitors or WatchDog weather stations. The HOBO unit is a small battery operated sensor manufactured by Onset Computer Corporation. The HOBO units were fixed approximately two meters (six feet) above ground on a steel bar using Stevenson screens (plastic protective plates) for solar shielding. This height was used in order to avoid stagnant air movement at ground level, where boundary layers tend to occur. Furthermore, this height factor could adjust for non-uniform terrain common at some of the chosen sites, hence resulting in more representative air temperature samples. The WatchDog weather station from Spectrum Technologies, Inc. are remote weather stations used to record real time weather information, including temperature, wind speed and direction, relative humidity, rainfall, and solar radiation. The units were set up at the WG, TR and SM sites. The WatchDog weather stations were set up in open areas away from irrigation at 2 meters above the ground. The recording period started in early to mid May, depending on the site, and lasted until October.

Results and Discussion

Dataloggers were set up in various locations in the Yukon, including 6 locations in the Takhini Valley along with sites in the Yukon River Valley between Whitehorse and Lake Laberge, and one site in the central Yukon near Carmacks. The Carmacks site has traditionally been a warmer area in the summer due to the influence of continental weather, and the 2006 season was no exception. graph 1.1 shows the average daily temperature for Carmacks in light blue and is the only temperature that has any distinguishable difference from the other areas plotted in the graph. The trend for Carmacks is generally warmer resulting in a higher EGDD of 1192 as reported in Table 1.3. This gives Carmacks a class 3 land capability resulting in only moderate limitations that restrict the range of crops to small grain cereals and vegetables as outlined in table 1.1.

In 2006 a concentrated effort was made to monitor the Takhini Valley and Whitehorse area for micro-climate variations. In previous years there has been interesting variation from the sites in this area. For the 2006 season the sites in the Takhini Valley showed only slight difference between the locations as outlined in table 1.2. The sites ranged from 827 to 913 EGDD, having a resulting land capability range between upper class 5 and lower class 4 lands as defined in table 1.1. The lands that were class 5 in 2006 were either a result of an earlier killing frost (as with the TR site) or lower on average temperatures (sites DH & WG).

Graph 1.1 : 2006 Yukon agriculture average daily temperatures

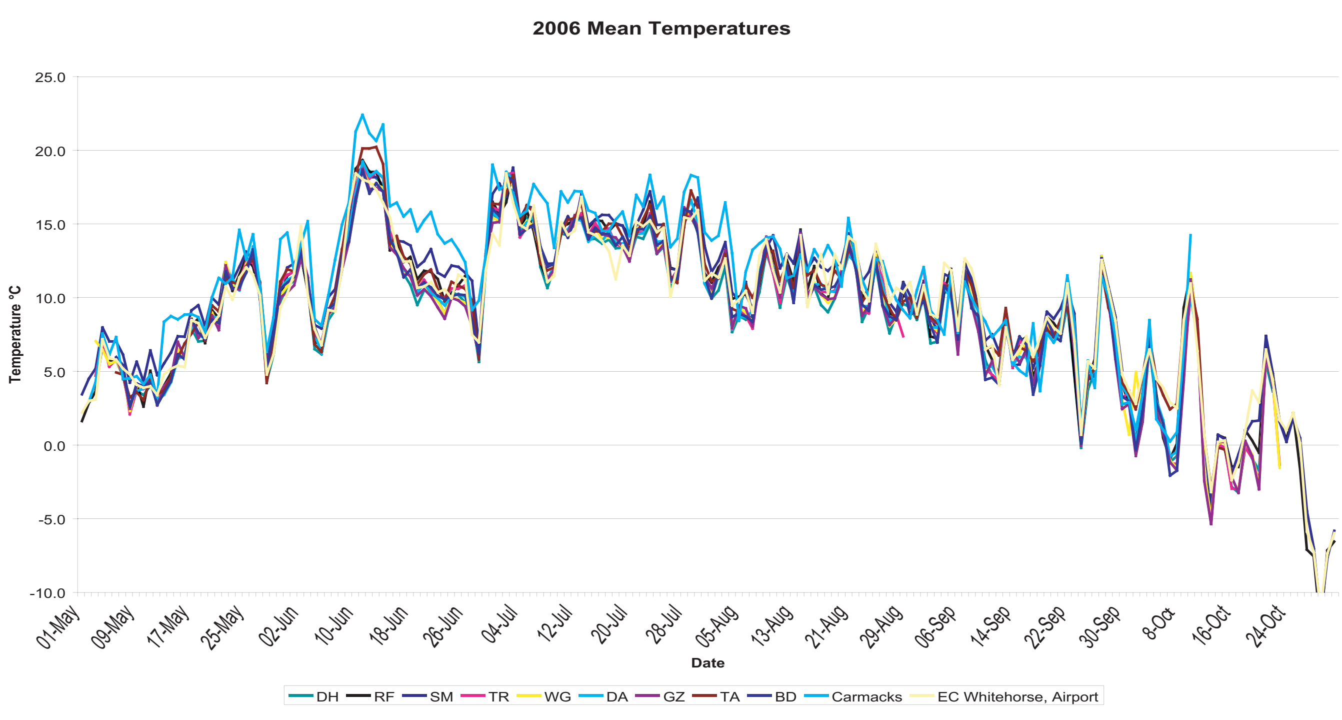


Table 1.3 compares the Takhini Valley to the remaining sites in the Whitehorse area as well as the Whitehorse airport. Again there was no significant difference. There were slight variations for the sites TA and SM resulting in higher EGDD. For the SM site, the average warmer temperatures, although not noticeable in graph 1.1, resulted in the highest seasonal EGDD for this area. Site TA had the second highest EGDD in the area, and is of special interest due to its higher elevation. One would expect that with the higher elevation the site would be cooler, which is true, but the good frost drainage offsets the cool temperature and extends the growing season. The TA site did not experience a killing frost until the middle of September, compared to the early September killing frost experienced at most other sites.

The airport experienced a longer frost free period when compared to the other sites in Table 1.3. This is a result of good frost drainage provided by the large open area at this location. It would be expected that this area would have a higher EGDD value with this long growing season, but temperatures were cooler for this site in 2006 when compared to the other sites north of the airport.

Table 1.2 : Agroclimatic data for the 2006 growing season in the Takhini Valley

Location	DH	WG	GZ	TR	DA	BD	AVERAGE
EGDD	866	883	901	828	913	910	884
Land Capability Class	5	5	4	5	4	4	4-5
Frost Free Days	35	37	35	33	60*	34	35**
Killing Frost Free Days	78	73	74	57	104*	77	72**
Precipitation (mm)	-	149.5	-	151	-	-	150
(°C) Max Temperature	31.5	29.1	30.7	30.4	28.3	28.7	29.8
Last Spring Killing Frost	24-Jun	24-Jun	27-Jun	27-Jun	29-May	24-Jun	
Fall Killing Frost	10-Sep	05-Sep	09-Sep	23-Aug	10-Sep	09-Sep	

*DA site did not experience the early August frost, or the late June killing frost, resulting in longer frost free days
**DA site not included in seasonal average

Table 1.3 : Yukon agriculture agroclimatic data for the 2006 growing season

Location	Average of Takhini Valley	RF	TA	SM	Whitehorse Airport	Carmacks
EGDD	884	926	993	1020	987	1192
Land Capability Class	4-5	4	4	4	4	3
Frost Free Days	35	33	79	43	104	84
Killing Frost Free Days	72	66	110	99	117	99
Precipitation (mm)	150	156	-	173	198	-
Max Temperature (°C)	29.8	30.2	29.1	29.1	29.4	31.1
Fall Killing Frost	9-10 Sep	01-Sep	16-Sep	05-Sep	23-Sep	13-Sep

Research Farm

During the 2006 growing season the Research Farm recorded 785 GDD. The data was collected from May 20 and ended on September 1 with the first killing frost. The 785 GDD is adjusted to 926 EGDD, therefore the Research Farm agroclimatic rating for 2006 was a Class 4 (900-1050 GDD), which is up a class from 2005. The land capability in this area has ranged from Class 6 to as high as Class 2 (occurring in 2004) as outlined in Table 1.5. Eliminating the extremes, it can be generalized that this area is Class 4 to 5, therefore the land is classified as having severe limitations that restrict the range of crops to forage production, marginal short season grain and cold hardy vegetables. Looking further at the 2006 Research Farm data, summarized in Table 1.4, a killing frost of -2.4°C occurred June 28, this frost would not factor into GDD as a killing frost (only killing frosts after July 15 are used in the calculation). There was no significant damage observed to the plants following the recorded killing frost, which suggests that during this stage of plant growth the crop at the Research Farm was frost tolerant. This late June frost greatly affect the number of frost free days and also killing frost free days resulting in totals of 33 frost free days (FFD) and 66 killing frost free days (KFFD). These FFD & KFFD are just below the 12 year average for the Research Farm of 36 FFD and 69 KFFD as summarized in Table 1.5.

When looking at the RF site, one could argue that the site should be grouped into the Takhini Valley group due to its location. Upon evaluation of the data in Table 1.3, the EGDD at the RF site is slightly higher than that of the Takhini Valley sites, and with the high incidence of frost at this site (shortening the growing season), the higher EGDD becomes more significant. For the 2006 season the RF site is more characterized by the warmer weather experience in the Yukon Valley than by the Takhini Valley.

Table 1.4 : Agroclimatic data for the 2006 growing season at the Research Farm

Date	April	May	June	July	August	September	Totals
Mean Temp °C	-	6.9	12.5	14.7	11.3	7.8	10.6
Max Temp °C	-	20.0	30.2	26.5	20.6	19.4	
Min Temp °C	-	-9.2	-4.5	-0.9	-1.6	-7.1	
Total Precip mm	-	16.7	48.7	12.9	39.8	15.4	156.2
Calculated GDD	-	60.4	224.8	299.5	194.0	6.0	784.6
Calculated Effective GDD	-	71.3	265.3	353.4	228.9	7.0	925.9
Frost Free Days (FFD)	-	11	21	30	26	15	
FFD Period			28-Jun	30-Jul			33
Killing Frost Free Days (KFFD	-	16	24	31	31	21	
KFFD Period			28-Jun			01-Sep	66

Table 1.5 : Growing season weather data summary for the Research Farm (1995-2006)

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
EGDD	859	595	901	972	957	784	838	729	758	1253	778	925	862
Land Capability	Class 5	Class 6	Class 4	Class 4	Class 4	Class 5	Class 5	Class 5	Class 5	Class 2	Class 5	Class 4	Class 4-5
Frost Free Days	44	25	45	35	50	50	51	18	40	18	25	33	36
Killing Frost Free Days	67	50	74	81	85	68	77	51	54	88	61	66	69
Precipitation (mm)	107	162	125	57	145	179	159	98	98	95	174	134	128
(°C) Max Temperature	31.1	29.6	28.7	34.1	33.2	35	30.8	27.3	27.3	34.1	29.6	30.2	30.9

2.0 Soil Moisture under dryland and irrigated conditions with Watermark soil sensors

Cooperators: Tom Rudge, Wayne Grove, Gord Sinclair, PFRA

Location: Flat Creek area near Whitehorse, YT

Funding: Yukon Government, AAFC PFRA

Objective: To understand the variability in soil moisture over the growing season in dryland and irrigated conditions for optimal irrigation levels.

Introduction

Soil moisture values were recorded throughout the growing season at two sites in the Takhini Valley, one under irrigation and one dryland. The objective of monitoring soil moistures was to understand the variability in soil moisture over the growing season and determine optimal irrigation levels.

Materials and Methods

Soil moisture sensors from Watermark (Spectrum Technologies Inc.) were installed at the WG and TR sites within the Flat Creek area of the Takhini Valley. Watermark moisture sensors are a resistance block which evaluates soil moisture tension by measuring the electrical resistance between two electrodes. Resistance blocks take up and release moisture as the soil wets and dries. The higher the water content of the blocks the lower the electrical resistance. The resistance is recorded over time by the WatchDog weather station. Because there is a known and consistent calibration between electrical resistance and soil moisture for the Watermark sensor, it can closely estimate soil moisture tensions in centibars or kPa.

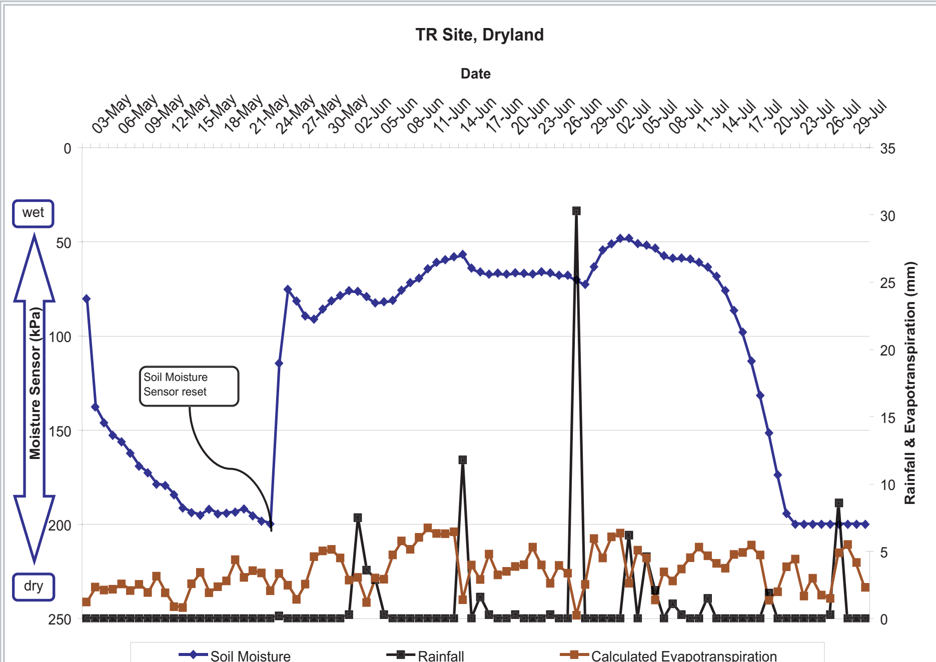
The sensors were installed by drilling a hole into the ground down to over 30 cm. The sensors were soaked in water and mud was packed around the outside. The sensor was then installed vertically, measuring soil moisture from 24-30cm, at expected root depth. The soil was packed around the sensor and the hole filled. One sensor was installed in a dryland system and one in an irrigated system within the Flat Creek area of the Takhini Valley.

Results

Soil moisture values were recorded throughout the growing season at two sites in the Takhini Valley, one under irrigation and one dry land. This moisture data was collected using the WatchDog weather stations which also collected the following climate information :

- Air temperature
- Wind speed and direction
- Relative humidity
- Rainfall
- Solar radiation

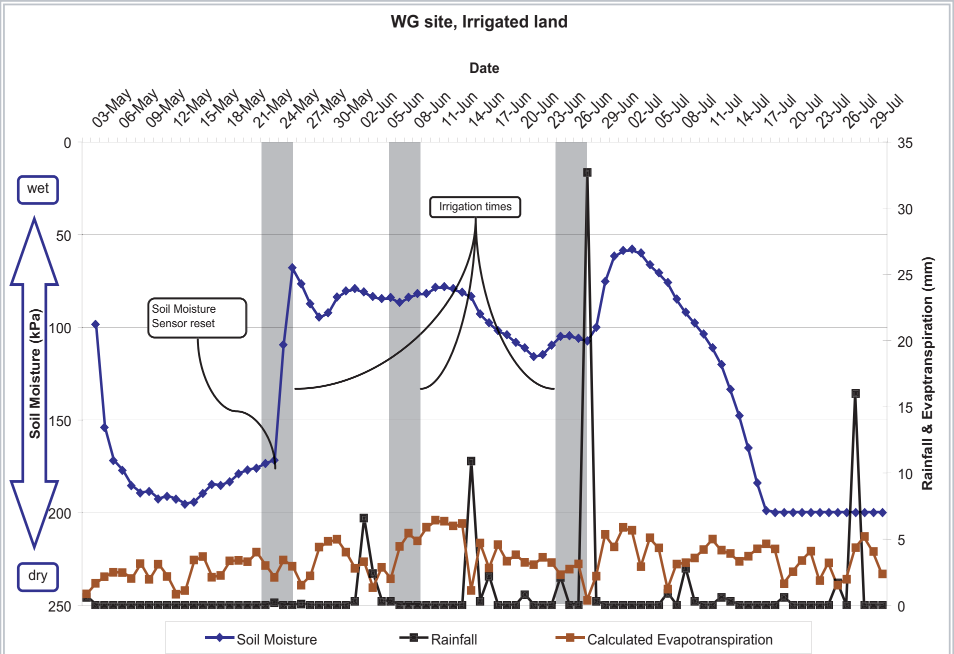
Graph 2.1 : Comparison of soil moisture tensions, rainfall and evapotranspiration at the TR dryland site.



Site Observation:

- Dry land site, no irrigation
- Moisture sensor lost suction and was reset May 24 as indicated by the sharp increase in the graph.
- Moisture sensor started losing suction again approximately July 14 and not reset following this date
- Significant rainfalls were observed June 3, June 15, June 28, July 4 & 28th
- The evapotranspiration was calculated using Penman's equation.

Graph 2.2 : Comparison of soil moisture tensions, rainfall and evapotranspiration at the WG irrigated site.



Site Observation:

- Irrigate site, with field irrigation around May 24, June 7 and June 25 as indicated by the grey bars in the above Chart
- Moisture Sensor lost suction and was reset May 24 as indicated by the sharp increase in the graph.
- Moisture sensor started losing suction sometime after July 7 and not reset following this date
- Significant rainfalls were observed June 3, June 15, June 28, July 28
- The evapotranspiration was calculated using Penman's equation.

With the additional climate information the soil moisture data was plotted, and compared to the rainfall data, and calculated evapotranspiration as shown in the following Graph 2.1 and Graph 2.2.

Discussion

The objective for the 2006 growing season was to understand the variability in soil moisture and determine optimal irrigation levels. Both sites experienced some difficulties with the Watermark Moisture sensors which required the sensors to be reset May 24 as a result of high readings which indicated poor contact or loss of suction with the soil. The sensors were reset using a method suggested by Agriculture and Agri-food Canada. After the sensors were reset, monitoring of the soil moisture was conducted until the sensors lost contact or suction again in July.

Soil water tension levels mean different things in different soils and, unfortunately, there is no simple way to translate centibar readings into water volumes or vice versa. The following Irrigation Guideline (Table 2.1) supplied by Watermark, Irrometer Company helps translate the tension levels.

For the TR site (dryland site) from May 26 to approximately July 17, the moisture reading ranged from 48 kPa to 91 kPa. The soils for the TR site are part of the Champagne soil association which is dominantly silty clay to clay loam. This would be classified as moderate fine to fine textured soils. Referring to the Irrigation Guidelines Table 2.1, for fine and medium texture soils, tension readings in the range 40-90 centibars would require irrigation. Using this reference to interpret the moisture in the soil, it can be concluded that although the soils required irrigation to increase yields, there still remains moisture in the soil in this pressure range.

Table 2.1 : Irrigation guidelines based on centibar readings

Reading	Interpretation
0-10 centibars	Saturated soil
10-20 centibars	Most soils are at field capacity
30-40 centibars	Typical range of irrigation in many coarse soils
40-60 centibars	Typical range of irrigation in many medium soils
70-90 centibars	Typical range of irrigation in heavy clay soils
> 100 centibars	Crop water stress in most soils

Adapted from Watermark Soil Moisture Sensors Manual, The Irrometer Company, Riverside, CA.

A common indicator of soil moisture is soil water tension

Some soil moisture monitoring instruments give volumetric readings – moisture per foot or per inch of soil – while other instruments indicate the level of soil water tension. Soil water tension is usually measured in centibars, where a centibar is 1/100th of a bar, and a bar is roughly equivalent to one atmosphere of pressure. Centibars measure the force that a plant must exert to extract water from the soil. As the plant works harder to remove water, the centibar number increases. So larger centibar numbers mean drier soil. Soil water tension levels mean different things in different soils and so – unfortunately – there is no simple way to translate centibar readings into water volumes or vice versa. Depending on soil texture, for example, field capacity may be between about 10 and 33 centibars. Coarse soils (such as sands and sandy clay loams) have released 50 percent of their available water by the time soils have dried out to 40 to 50 centibars. On the other hand, many clay and silty soils still retain more than 50 percent of available water at 80 centibars.

For the WG site (irrigated site) the moisture ranged from 59 to 116 kPa between May 26 and July 12 before the sensor started to lose suction. The moisture sensor was set in a part of the land that falls in the Lewes soil association which is a dominant silty loam to fine loam sand with medium soil texture. Using the Irrigation Guidelines Table 2.1 for a medium textured soil, a range of 40-60 centibars is the typical range for irrigation. This indicates that this site is not receiving adequate water and with soil tension readings reaching above 100 kPa indicate the crops would be experiencing water stress.

To further evaluate the soil sensor, the tabulated data was compared to rainfall. At the TR site the moisture sensor data did not always respond as expected. For example the moisture sensor increased in pressure following the June 3 and June 15 rainfall, indicating the soil was drying. In between these rainfalls the soil started picking up moisture, with no significant input of precipitation. In contrast to these events, a heavy rainfall occurred on June 28, which resulted in an increase in moisture following this event. The short delay of the soil moisture sensor to observe this rainfall indicates slow penetration of the moisture to the sensor set 24-30 cm down in the soil layer. Taking into account that this is a fine textured soil, the delay for the moisture sensor to pick up the rainfall is expected. The fine textured soils have a larger water holding capacity, therefore more water can be held in the upper depths of the soil before a moisture balance occurs and the moisture moves downward through the soil to the moisture sensor set at 24-30 cm. This does not explain the moisture increase between the June 3 and 15 rainfalls. The delay in the response is much longer following the June 3 rainfall and there is no response following the June 15 rainfall. More data is needed to further understand the moisture readings.

For the WG Site, comparison of rainfall and irrigation to soil moisture readings can be difficult to interpret. During the irrigation periods the moisture sensor showed an increase in the wetness of the soil following irrigation (with the exception of the seasons first irrigation period, because the sensor was just reset and would need a stabilization period before giving a proper reading). The early June irrigation period showed only a slight increase in wetness which indicates the moisture is either not reaching the moisture sensor set at 24 to 30 cm into the soil depth and or there is not adequate irrigation to provide an increase in the soil moisture content. The late June irrigation period was followed by a good rain, although there was a slight delay in the moisture sensor response, the effect of these two water addition event was picked up by the soil tension reading, resulting in a jump from 100 kPa to 59 kPa. This was the largest change monitored by the moisture sensor for the 2006 season. Although the irrigation and rainfall event was picked up by the moisture sensor, the accuracy of the moisture sensor is questionable. Could the moisture sensor already be losing contact with the soil? In mid June the moisture sensors readings were on the decline and there was no response to a June 15 rainfall. Although the moisture sensor responds to the late June irrigation and rainfall, the soil sensor reading shows a sharp decline in moisture immediately following the event until eventually losing contact with the soil. Again more work is needed to understand the moisture levels at this site.

Conclusion

It is difficult to make a final conclusion on the soil moisture results at either location. Many factors came into play when using these moisture sensors. For example, soil texture, drainage, sensor depth and soil to sensor contact. Further investigation is needed to understand the relationship of Watermark sensor reading to moisture levels in the two sites, including monitoring for the full season without loss of contact. This should be easily accomplished. According to the specs and other users, the Watermark sensors should operate in soils as dry as 200 kPa and in medium and fine textured soils. There are other methods for installing the sensors which may provide better and longer term contact with the soil. The potential for these sensors to monitor irrigation requirements and control irrigation rates have been shown to be successful in other agricultural areas. To improve on the use of these Watermark sensors it is recommended to add an additional soil sensor in close proximity to the primary sensor as a comparison. Placing the secondary sensor at a different depth would provide information on moisture migration through the soil and through the root profile.

3.0 Understanding Soil Temperature in the Plow Layer

Cooperators: Tulio Albertini, Dawn Charlie LSCFN, Dave Andrew, Bill Drury

Location: Various Locations, YT

Funding: Yukon Government, APF Science and Innovation

Objective: To understand the variability in soil temperature at various depths over the growing season.

Introduction

Soil temperature measurements within the plow layer are important in order to understand the effect of latitude, elevation, cover, slope, and aspect on the soil temperature regime. In cold soils microbial activity is reduced, minimizing the cycling of bio available nutrients. The critical temperature for elevated levels of biological activity in the soil is 5^{o}C and for nitrogen fixation a minimum 10^{o}C (Rice et al., 1995). Cold soils also affect varietal performance, impact yields, and reduce pesticide decomposition.

Prior to this experiment, soil temperature data for the Yukon had been collected at lower depths in context to permafrost. For this experiment four sites recorded soil temperature values in the plow layer: the LSCFN community garden, farm site BD, farm site TA and farm site DA. In contrast to the permafrost data, these sensors were deployed at root zone depths, 0-20 cm deep.

Materials and Methods

HOBO dataloggers manufactured by Onset Corporation were used for data capture.

Photo 3.1 : Stainless steel temperature probe TMC6-HC

A hole was dug in the Ap horizon and two soil sensors were installed in the face of the hole horizontally at 10 cm and 20 cm. A tube was inserted into the soil horizon to make space for the probe, the sensor was inserted and the soil was then backfilled and packed. Where required, we installed chicken wire in the ground 20 cm from the sensor to prevent disturbance of the sensors. Sensors were installed under a garden, and in two dryland and one irrigated hay fields around the southern and central territory.

Results

The graphs on the next page present the range of values recorded daily through the growing season for the 10 cm depth at three of the four sites. The average values recorded at the BD farm site on a cleared, flat field near the Takhini River are very similar to those recorded on the sloped TA farm site and the LSCFN site.

The 20 cm depth (data not shown) was always cooler but with less diurnal variation with the average difference over the whole season between the 10 cm depth and 20 cm depth is only 0.5 - 1.5^{o}C. The main difference is that at 20 cm depth the temperatures never exceed 12^{o}C at the BD farm site and were as high as 16^{o}C at the LSCFN site. The diurnal variation between the 2 locations and the heating during the day contributed to warmer soils at depth in the central Yukon.

2006 was a cool year. The soil warmed up slowly and only reached a mean of 10^{o}C in late May. This is approximately a month later than in 2005 (data not shown). The variability between the minimum and maximum temperatures at the shallow depth shows the diurnal cycle of heating from solar radiation.

The length of time during the season at which the mean soil temperature remains above 10°C is 94 days at the BD farm site, 83 days at the LSCFN site, and 86 days at the TA farm site.

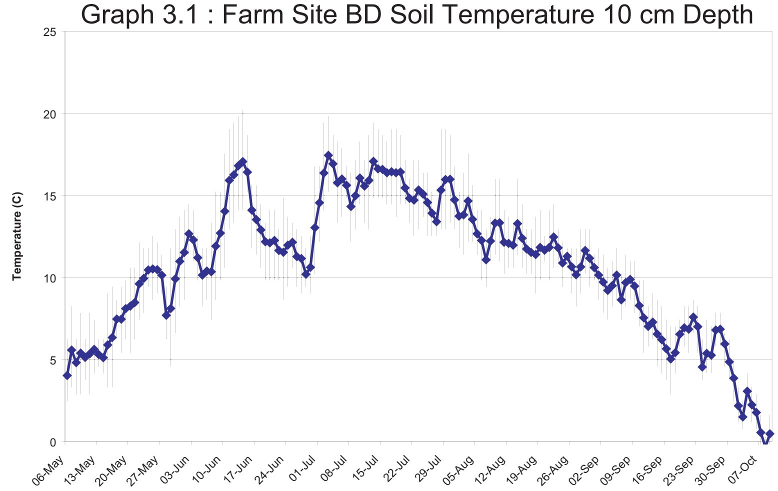
Discussion

As expected, the BD farm site, with a flat aspect and large cleared area exhibited the longest season. The LSCFN site recorded the greatest diurnal variability in the 10 and 20 cm depths and recorded the highest temperature. The soils in the upper profile warm to 10°C by early June and remain above this temperature for a couple of months. It is during this time that nitrogen fixation and important microbial activity is taking place.

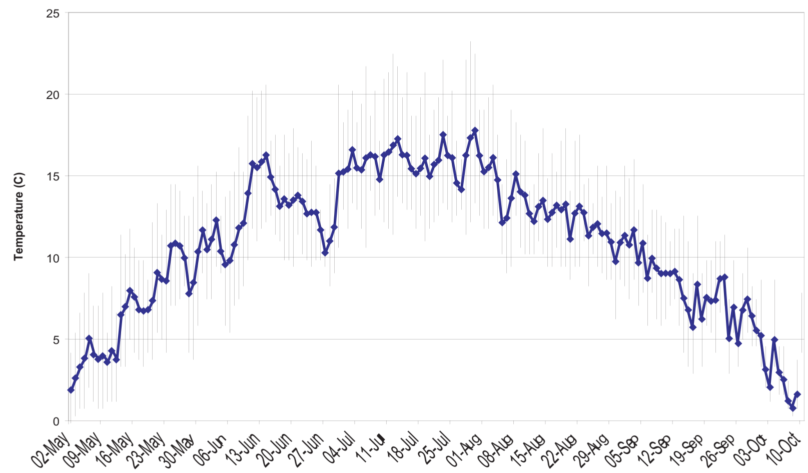
Conclusion

Year over year variations in the soil temperature appear to have a greater effect than changes in latitude. The expectation was that the central Yukon LSCFN site would exhibit much higher soil temperatures and this is shown by the variability in the maximum temperatures, but what was a surprise is that the average soil temperatures in the central Yukon follow a very similar trend to those in the Whitehorse area.

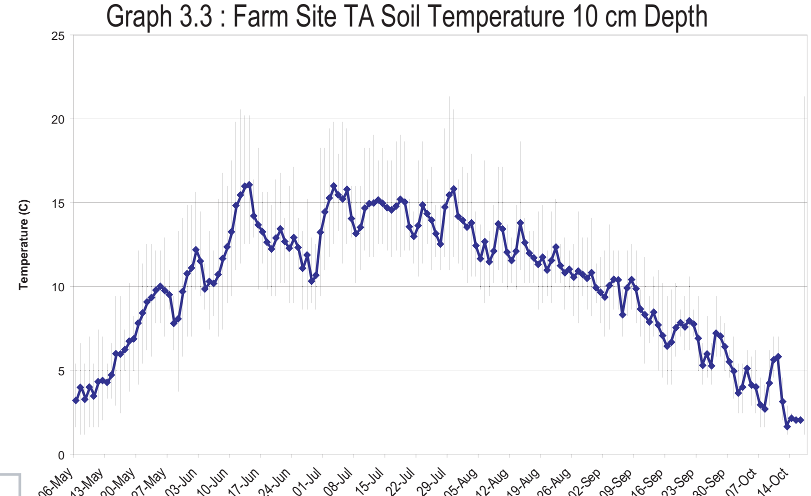
Graph 3.1 : Farm Site BD Soil Temperature 10 cm Depth



Graph 3.2 : LSCFN Soil Temperature 10 cm Depth



Graph 3.3 : Farm Site TA Soil Temperature 10 cm Depth



The line represents the mean temperature with the minimum and maximum temperatures displayed by the bars.

4.0 Understanding Nutrient Flux using Plant-Resin Simulator (PRS™) Probes

Location: Research Farm, YT

Funding: Yukon Government and ACAAF

Objective: Use of Plant Resin Simulator (PRS^{tm}) Probes to monitor changes in soil nutrient supply in a subarctic bromegrass/ alfalfa sward under irrigated conditions.

Introduction

This investigation took place over the 2005 growing seasons to determine if we could detect subtle changes over time from fertilization of Phosphorous and Nitrogen using Plant Resin Simulator (PRS^{tm}) Probes from Western Agriculture Labs.

PRS resin membrane ion exchange probes are a product from Western Ag Labs and have been used extensively to track the change in the available nutrients. Although there is no direct correlation of the data collected from the PRS™ Probe that can be made to a standard soil test, the probes allow the plants available supply of nutrients to be monitored over time.

Ion exchange probes have been in use for over 50 years to measure nutrient availability. They have been adopted to measure the amounts of plant available nutrient ions in the soils and the rates at which they are released (Qian and Schoenau 2002). The use of ion exchange resins in membrane form has been widely adopted due to ease of use and the ability to measure the flux to a defined surface (Qian 1992).

These probes were used to watch the flux of N and P throughout the growing season.

Materials and Methods

Plant Root Simulator (PRS^{tm}) – Probes were supplied by Western Ag Labs. Probes arrived in a cooler with ice packs and were promptly stored at 5^{o}C until used. Probes were placed in the soil into slits 15 cm in depth at 8 different locations within each experimental unit. Four nutrient cation exchange probes and four nutrient anion exchange probes were placed in the slits. Probes were inserted in the ground for 48 hours during a period of irrigation. This was repeated each month throughout the summer. The short duration that the probe is in the ground was intended to minimize competition from ion sinks, but to be long enough to pick up the nutrient trends.

At the end of the burial, the PRS-Probes were removed and washed with deionized water to remove soil and plant material, then placed into ziploc bags and shipped to the lab for subsequent testing.

In the lab the probes were placed in a dilute acid or salt solution to elute the absorbed ions into solution and measured analytically for nutrient concentration.

Ion supply rates are defined as the amount of ion absorbed per amount of ion exchange surface area per time of direct burial in the ground. The resultant ion supply rate was reported in mg/10cm^2/48 hr.

The Donnan exchange principle uses counter ions Na and HCO_3 because they are easily desorbed from the resin, thereby allowing nearby soil ions to be absorbed. Saturating the ion-exchange membrane with the same counter-ion ensures consistent ion-exchange chemistry across the entire PRS™ Probes' ion-exchange membrane, thereby, increasing the measurement precision among treatments.

Photo 4.1 : Tools for PRS-Probe insertion, a knife to cut a slit, hammer to tap the probe into place, and the probes (purple - cation, orange - anion).

Results

The results from the incubations are graphed at right and allow us to assess the supply rate of the soil nutrients over time.

Irrigation and moisture at time of incubation

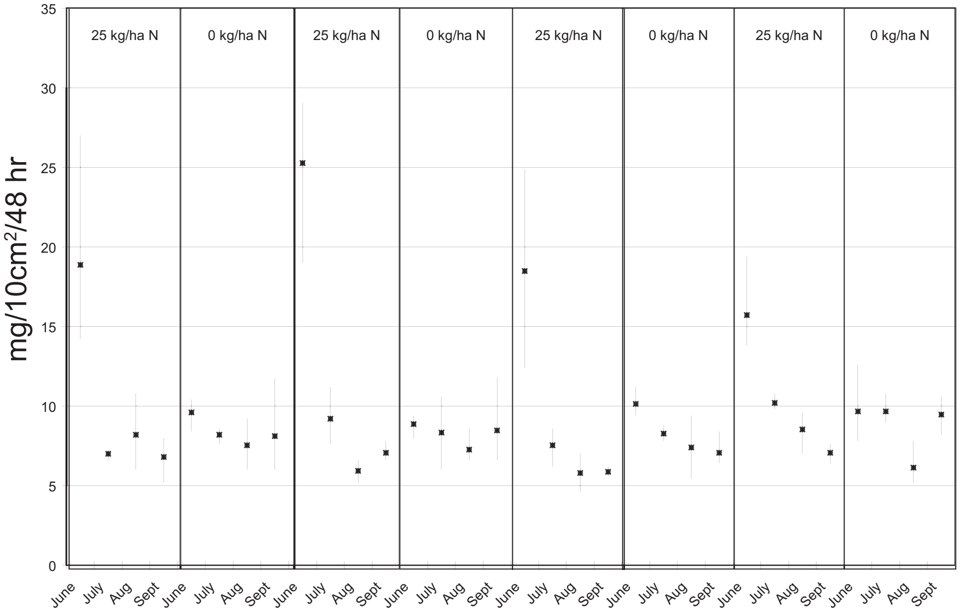
June 8-10 2005
Irrigation : 21 mm
VMC : 16% at start

July 10-12 2005
Irrigation : 17 mm
VMC : 25% at start

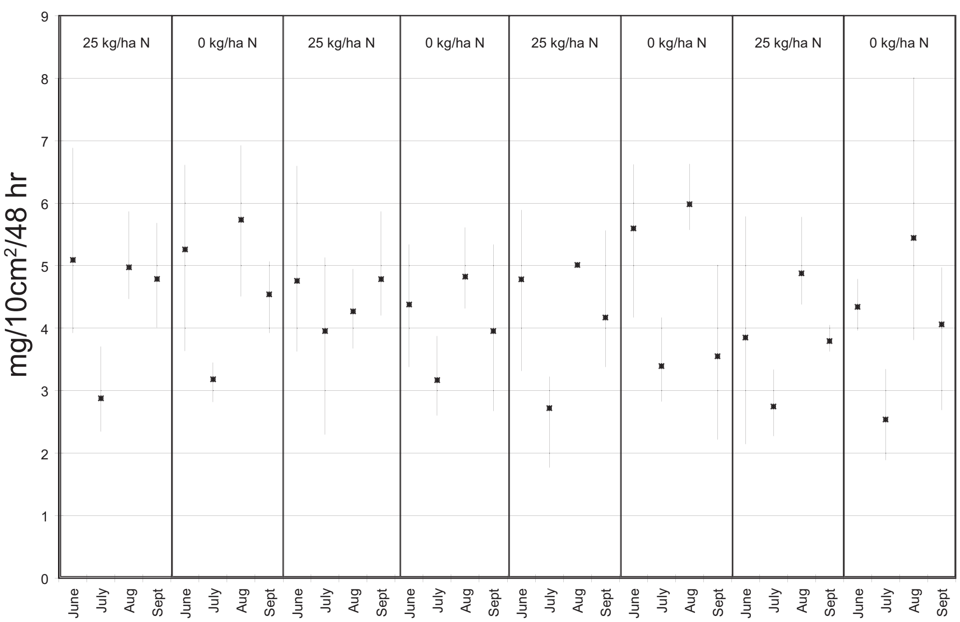
August 12-14 2005
Irrigation : 22 mm
VMC : 20% at start

September 12-14 2005
Irrigation : 24 mm
VMC : 21% at start

Graph 4.1: Nitrate levels in the soil through the season



Graph 4.2 : Phosphorous levels in the soil through the season



Discussion

In previous studies ion uptake by the PRS™ Probes is consistently related to plant uptake. In the fertilized samples graphed at right, there is a high level of NO_3 (nitrate) indicated by the PRS-Probes in the soil after fertilizer application in June. In subsequent incubations in July and onwards the nitrate level drops off and remains low, indicating that there is substantial plant uptake in June. June is the period of greatest plant biomass change. The Phosphorous levels show a similar but somewhat different trend with high June ion levels, a substantial drop in July, an increase in August and a drop in September. The P levels closely follow plant growth curves, with plant demand for P greatest during the steep slope of the growth curve (from June to mid July), indicated on the graph by the reduced amount of P available in the soil in the July sample. The P level increased after this because of bugs releasing Phosphorous.

Conclusion

PRS-Probes are a useful method to investigate soil nutrient flux and there is reason to use this technology in northern environments. It is very important in cold soils and dry conditions that the incubation times be longer than normal. In an irrigated grass stand as used in this experiment, the incubation times should be increased to 96 hours or more to gain better trends.

5.0 OILSEEDS PRODUCTION POTENTIAL IN THE YUKON FOR BIODIESEL

Cooperators: Dan Halen, Dorine Girouard, Steve Mackenzie-Grieve,

Location: Various locations, YT

Funding: ACAAF

Objective: To examine the feasibility of producing oil for biodiesel from cropped oilseeds.

Photo 5.1 : *Camelina sativa* pods

Introduction

As concerns about high energy costs, supplies of fossil fuels and environment issues continue to grow, industry and governments are looking to alternative environmentally friendly fuels. Biofuels have drawn interest as a fossil fuel replacement and an environmentally friendlier fuel by helping to reduce the amount of greenhouse gas (GHG) emissions. Most sources of biofuels have been coming from agriculture including ethanol from corn and grain crops, and biodiesel from oilseeds. In 2006 a research project was conducted to determine if the Yukon can produce it own biofuels. It was determined that biodiesel from oilseeds would be the best fit, in large part because oilseeds are more suited to the cooler Yukon climate. Biodiesels also provide more usable energy than ethanol and have higher level of GHG reduction compared to its fossil fuel equivalent.

The research into oilseeds is slated to be ongoing for four years. For year one, four varieties of oilseeds were tested to determine the following:

- Can oilseeds be grown in the Yukon?
- What oilseeds produce the best yields and total oil content?
- What types of lands are required?
- Is irrigation necessary?
- Is there any value to the oilseeds byproduct (meal)?

Of the 4 varieties of oilseeds tested, two canola varieties, false flax and true flax were evaluated. It should be mentioned for this project no GMO varieties were or will be tested. Short season Polish Canola (*Brassica rapa*) was evaluated against a longer season Argentine Canola (*Brassica napus*). The evaluation was expanded to a Flanders flax (*Linum usitatissimum*), and a False flax (also know as gold-of-pleasure) (*Camelina sativa*). The canolas were evaluated because they are a high oil producing crop, and are more suited to cooler climates vs. some of the other warmer climate oilseeds such as soya. The Flanders flax was included in this project because of its health properties as an oil seed and it is also another high oil content crop. The *C. sativa* was a recommendation by Plant Pathologist Richard Gugel, M.Sc. of Agriculture and Agri-Food Canada, because it is a short season low input crop, therefore it was considered more suited to the Yukon. The oil content for the *C. sativa* is lower-in the region of 37% oil, but expectation of the crop hardness may provide a favorable total oil output per hectare.

Materials and Methods

Seed selection was made with consultation from Kevin Falk Ph.D. and Richard Gugel M.Sc. from Agriculture and Agri-Food Canada, Saskatoon Research Centre, and Scott Horner, HyTech Production Ltd. The decision was made to try a long season *B. napus* canola, a short season SW Spirit River *B. rapa* canola, low input *C. sativa* False flax and Flanders flax. Table 5.1 provides the detail information for each of the four oilseeds tested.

Photo 5.2 : Evaluating the RF test plot

Table 5.1 : Oilseeds evaluated

	Argentine Canola	Polish Canola	Flanders Flax	False Flax (Gold of Pleasure)
Type	*Brassica napus*	*Brassica rapa*	*Linum usitatissimum*	*Camelina sativa*
Seed name	-	SW Spirit River	Flanders	-
Test Number	6803-01	SW C3497	FP 859	CN30476
Supplier	Test supplied by HyTech Productions Ltd.	Bonis & Co. Ltd	Se-Can Association	Test supplied by Crop Development Centre
Breeder	DSV Canada	Svalof Weibull Ltd	Crop Development Centre, Saskatoon	Crop Development Centre, Saskatoon

Each of the varieties selected were planted at five different locations in the Yukon mostly around the Whitehorse area, with one site located in the central Yukon. The sites used in this evaluation are DH, DG, RF, SM and HN (refer to Site Descriptions for additional information).

At each site composite soil samples were taken in the spring and sent out for testing to assure optimum fertilizer rates. Fertilizer was added according to excellent canola growing conditions on irrigated sites and average growing conditions on dryland sites as recommended by Norwest Labs.

Fertilizer was applied with a broadcast spreader at rates reported in Table 5.2. Approximately 50 gallons of water was added to each area to soak in fertilizer immediately after fertilization.

Table 5.2 : Fertilizer rate as reported by Norwest labs:

Site	Nitrogen		Phosphorus		Potassium		Sulphur	
	lbs/acres	kg/ha	lbs/acres	kg/ha	lbs/acres	kg/ha	lbs/acres	kg/ha
Site SM	83	93	24	27	29	33	41	46
Site DG	97	109	10	11	11	12	26	29
Site DH	83	93	10	11	44	49	24	27
Site HN	95	106	0	0	60	67	23	26
Site RF	165	185	0	0	0	0	0	0

For each site, sixteen 2x2 meter plots were set up using a completely randomized design to evaluate the 4 different oilseed varieties . Diagram 5.1 and photo 5.3 shows the details of a 4x4 plot design. Each site was raked to remove sticks and debris and was laid out with measuring tape and survey markers. Seed lines were drawn in the soil with a modified rake that spaced the seed rows 20 cm apart with 11 rows per plot, and then was hand seeded into the furrows as shown in diagram 5.2 and photo 5.4. Following seeding, each plot was raked and rolled with a weighted roller. A 0.5 m buffer was left between the plots.

Seeding rate:

- Canola @ 8 kg/ha (equal to 3 g for a 2x2m plot)
- *C. sativa* @ 5 kg/ha (equal to 2g for a 2x2m plot)
- Flanders flax @ 30 kg/ha (equal to 12g for a 2x2m plot)

Seeding depth 1 – 2.5 cm

Diagram 5.1 : 4x4 Randomized plot design (also set up in 2x8 & 1x16)

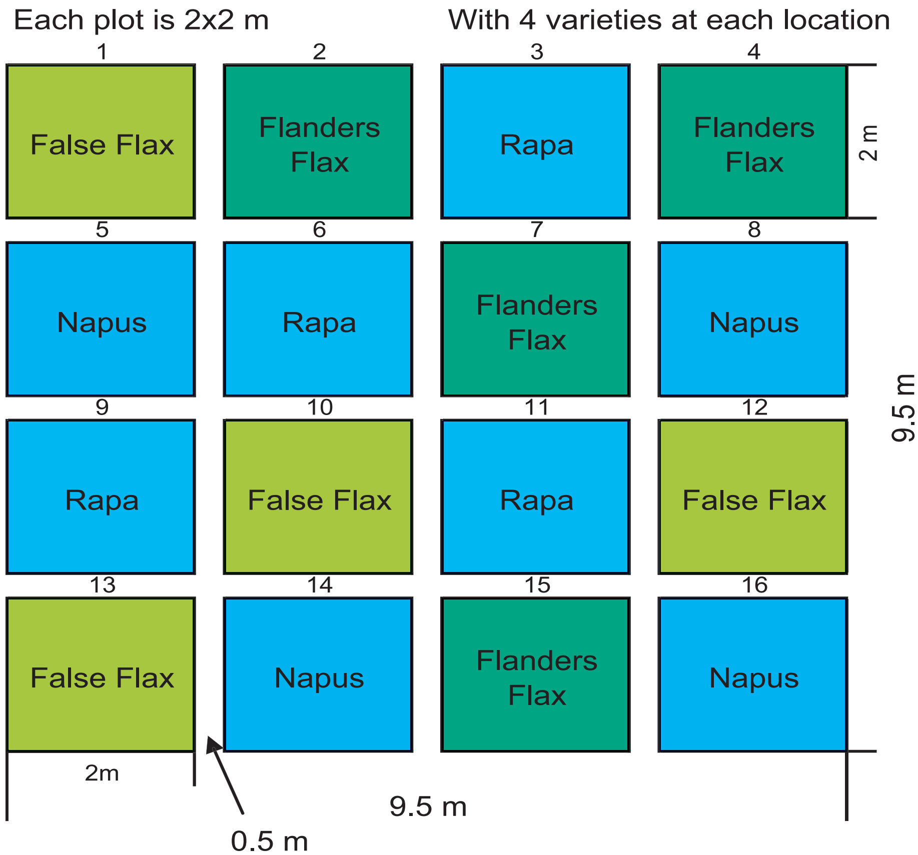


Diagram 5.2 : Seed spacing for individual plot

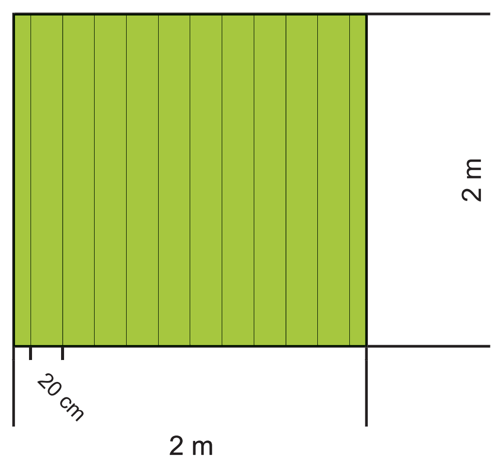


Table 5.3 : Seeding & Harvest dates:

	Seeding Dates	Harvest Dates
Site SM	May 29/06	Oct 20/06
Site DG	May 24/06	Oct 23/06
Site DH	May 26/06	Oct 23/06
Site HN	May 19/06	Nothing to harvest
Site RF	June 1/06	Oct 21*&24/06

**C. sativa* samples were collected only

Photo 5.3 : Example of a 4x4 plot layout staked out and rolled.

Photo 5.4 : Seeding individual plot was done by hand.

At a minimum, monthly visits were made to each site to record presence of species, stage of growth, plant height, and pod stage.

Climate monitoring data loggers were installed at most sites to record the growing season and compare the heat units at each site.

The plants were harvested in late October from a 1 m^2 area as shown in photo 5.5 and stored in paper bags until the plants could be thrashed at a later date.

Photo 5.6 : Photo of SM test plot in late October before harvest, with some opportunistic birds feasting on the *C. sativa*.

The harvested plants were thrashed using a cloth bag. After thrashing, the stocks or straw material was separated by hand, leaving the remaining seeds, broken pods, leaves etc in the bag. This remaining material was separated using hand screens, which separated the seeds from the bulk of the scrap material as shown in photo 5.7. These steps were easiest with the *C. sativa*, as it did not take as much time to thrash and screen out the scrap material from the seeds. Following the screening, the seed needed to be further cleaned to separate the fine scrap material. An air separation system was set up, as shown in the photos 5.8 and 5.9. The crude set up worked by placing the seed in the tube with a fine screen at one end. Air was blown through the screen and tube which separated lighter scrap material away from seed. A collection box was set up at the exit of the tube to determine if any seeds were being lost.

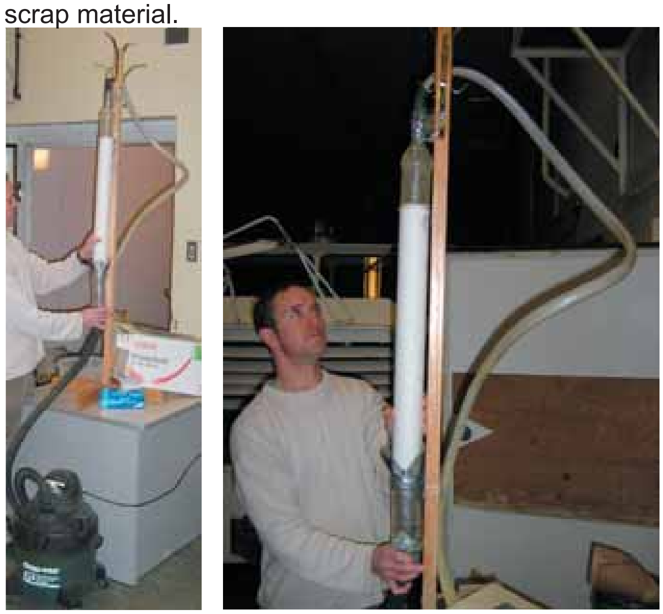
Photo 5.5 : 1 m^2 frame set in test plot, used to define the area to harvest. Paper bag used for storage.

This method successfully separated the seed from the scrap material, although it may have been too efficient because further separation of the *B. napus* was required at the lab to discard some of the damaged and immature seed that would not have been collected by conventional harvesting.

The seeds were weighed and sent to the Saskatoon Research Centre for oil and protein analysis.

Photo 5.7 : Hand screens used to separate the seeds from a bulk of the scrap material left over from the thrashing.

Photos 5.8 & 5.9 : A blower system set up to separate the finer scrap materials from the seed. Seed placed inside the tube on top of a fine screen and air was blown through the seed to push off any remaining scrap material.



Results

Photo 5.10 : *B. rapa* plot showing poor establishment

During the 2006 growing season the climate around the test plots were monitored along with the growth rates of the crop. Graphs 5.1 to 5.4 show the growth rate for each variety. The graphs show noticeably higher growth curves for the irrigated sites; RF and SM. Noticeably absent in these graphs is any data for the HN site. We had high hopes for site HN because of it's warmer central Yukon summers. The HN site was also showing signs of a earlier spring as indicated by the flushing willows and aspen observed in mid May. The HN site was the first test plot seeded May 19. The site was next inspected June 21, there was hardly anything established. A few plants were visible up to 10 leaf stage for Flanders flax, 7 leaf stage for *B. napus*, 4 leaf stage for *C. sativa* and 4 leaf for *B. rapa*. Irrigation was added at this time, approximately 100 gallons over the area. On a subsequent visit July 21, there was again barely any plants visible with maximum heights of 4 cm. On a final visit in September there was no evidence of any plants at the site. It is hard to understand exactly what/who the culprit is at this site, the suspicion is that the gophers enjoyed the crop as there were many of them camped out in the area.

The growth curves for the *B. rapa* show good maturity or growth but observations, as seen in photo 5.10, found that the *B. rapa* was not establishing well. A germination test was conducted to determine if this was a result of the growing conditions at the test plots or the seed itself not germinating. The results of the germination test:

- Test 1: 38 of 100 seeds germinated
- Test 2: 42 of 100 seeds germinated.

The test indicates that the seed do not germinat well and this resulted in poorer establishment likely contributing to lower yields.

Graph 5.1 to 5.4 : Growth curves of oilseeds for 2006

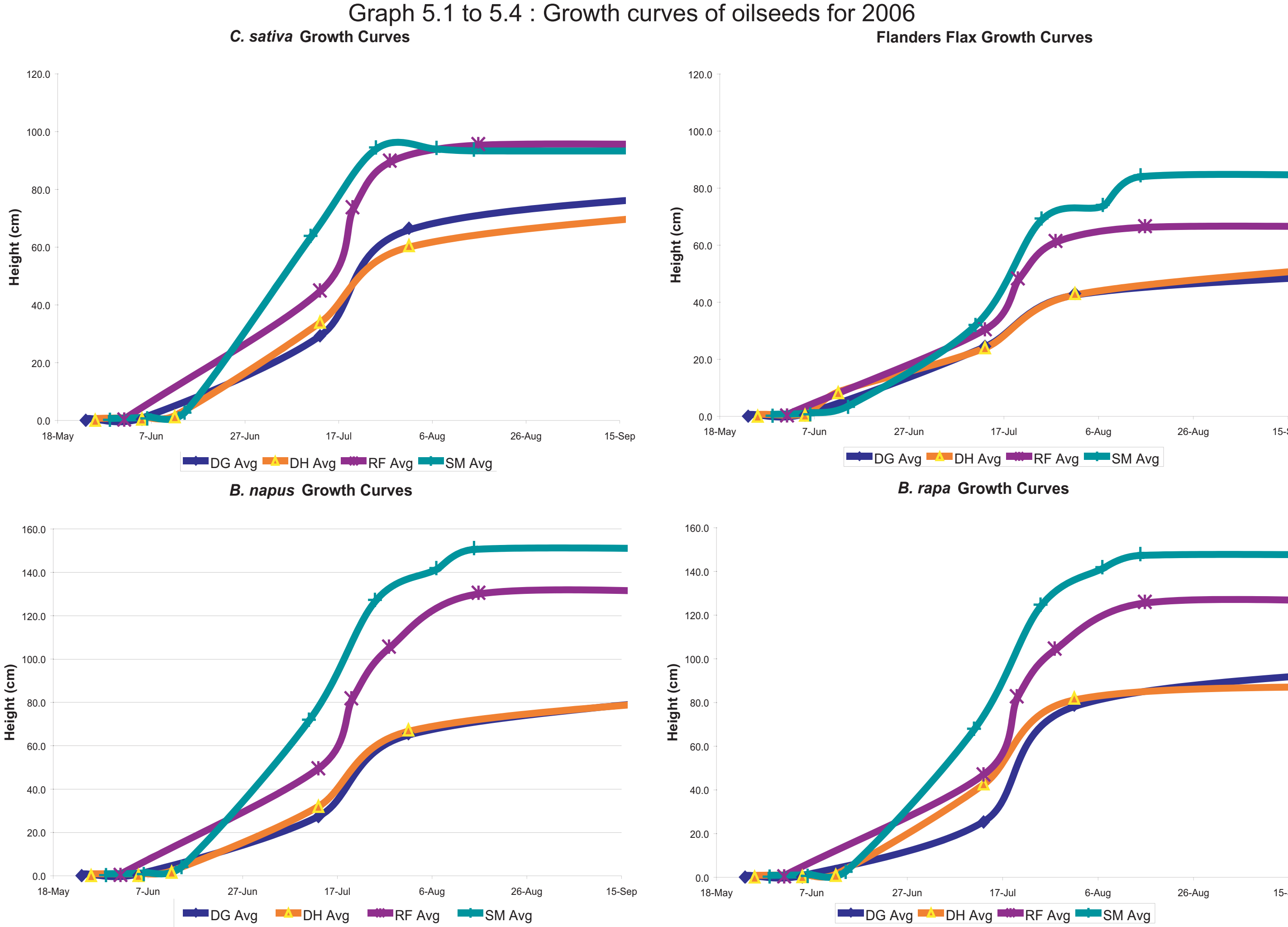


Table 5.4 summarizes the key points for the 2006 growing season at each site. Although climate monitoring was not done specifically for the DG site, the summary data from the Takhini Valley was used for this site. The Carmacks data is used to represent the HN site.
Initial evaluation of Graph 1.1 shows the weather is very similar between the locations. The only location to stand out was the central Yukon site, which shows higher mean temperatures observed between mid May and the beginning of August. Graph 1.1 shows some noticeable spikes or drops in temperature in May and June. These drops are a result of very cool overnight lows and low day time highs. The overnight temperatures reached below freezing (frost) at all sites with the exception of the central Yukon. Although a frost was experienced in late June, the plants visually seemed to be unaffected by this frost occurrence.

Table 5.4 : 2006 Summary Agroclimatic data at the oilseeds research sites

Site	Irrigated Sites		Dryland Sites		Crop lost
	RF	SM	DH	DG (Takhini Valley)	HN (Central Yukon)
Effective Growing Degree Days (EGDD)	926	1020	866	884*	1191
Land Capability Class	Class 4	Class 4	Class 5	Class 4-5*	Class 3
Frost Free Days	33	43	35	35*	84
Fall Killing Frost	Sept-01	Sept-05	Sept-10	Sept-9-10*	Sept-13

*Data is an average for Takhini Valley

2006 summary Table 5.4 again verifies that the central Yukon does have the best agroclimatic conditions resulting in the highest effective growing degree days (EGDD) and most amount of frost free days. The central Yukon also has the highest land capability rating of Class 3 which is defined by the total EGDD. Class 3 is characterized as lands with moderate limitations that restrict the range of crops to small grain cereals and vegetables. The land capability for the sites in the Whitehorse area were rated as class 4 & 5 which is defined as lands with severe limitations that restrict the range of crops to forage production, marginal grain production, improved pastures and cold hardy vegetables. The dryland sites did experience poorer growing conditions compared to the irrigated sites as indicated by the EGDD results in the range of 866-844 compared to the irrigated sites which had an EGDD of 926-1020. The SM site had the highest EGDD and frost free days of the sites in the Whitehorse area. This is also observed in the growing curves with the SM site experienced on average higher growth heights as shown inGraphs 5.1 to 5.4.

In October the plants were harvested from 1 m^2 area from each plot at each site. The plants were later trashed and the seeds separated from the rest of the plant. Photos 5.11 to 5.13 are samples of the seeds collect from the test plots.

Yields and quality varied with each site and crop. The quality, although not graded, can be generalized with noticeable more mature seeds for the irrigated sites vs. the dryland sites. The *C. sativa* from site to site was most consistent in seed size and uniformity, with the canola seeds showing less uniformity and more damaged or immature seeds. The quality of the *B. napus* was observed to be poorer compared to the *B. rapa*, having more damage and immature seeds in the samples.

Photo 5.11 : *C. sativa*

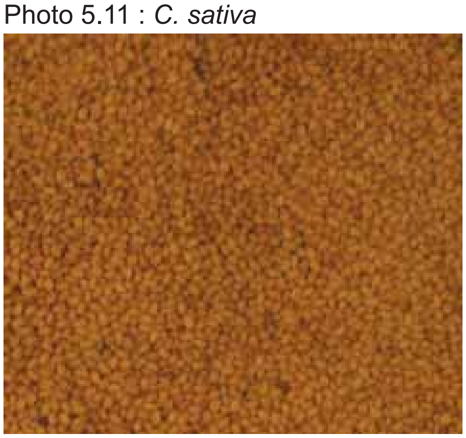


Photo 5.12 : *B. napus*

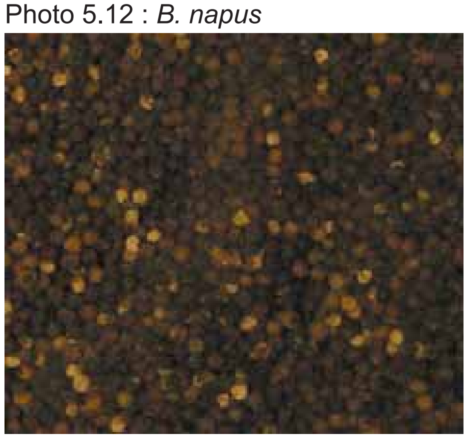


Photo 5.13 : *B. rapa*

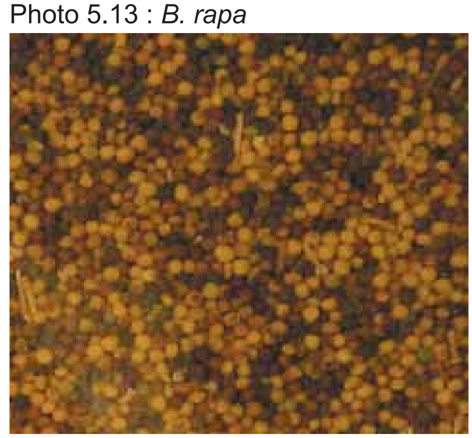


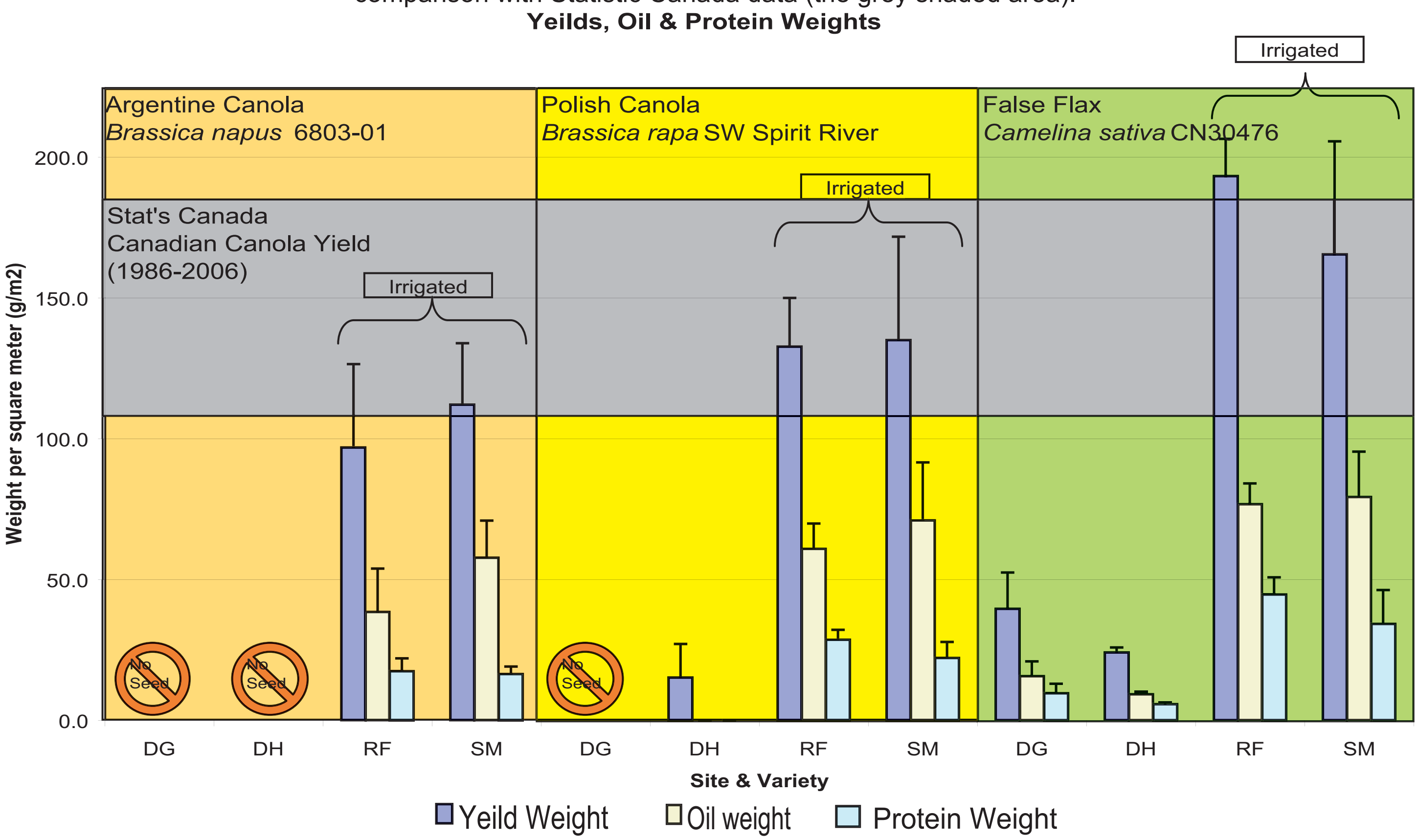
Table 5.5 : Yield reports and lab results for each variety harvested at each site.

Seed	Site	Average yield weight (g/m^2)	Standard deviation of yield weight	Calculated kg/hectare	Average % Oil	Average % Protein	Average Oil weight per hectare (kg/hectare)
B. napus	DG	No seed					
B. napus	DH	No seed					
B. napus	RF	97.0	29.5	970	39.0	18.5	378
B. napus	SM	112.2	21.8	1122	51.4	14.9	577
B. rapa	DG	No seed					
B. rapa	DH	15.4	11.7	154	-	-	
B. rapa	RF	132.9	17.2	1329	45.9	21.7	610
B. rapa	SM	135.2	36.7	1352	52.4	16.7	708
C. sativa	DG	39.8	12.7	398	39.8	24.6	158
C. sativa	DH	24.3	1.6	243	38.9	24.3	94
C. sativa	RF	193.4	13.2	1934	39.8	23.1	769
C. sativa	SM	165.6	40.1	1656	48.3	20.5	800

Samples of each of the seeds were sent to Saskatoon Research Centre for oil and protein analysis. The lab used near infrared (NIR) technology to analyze the samples for percent oil and protein. Results were averaged out and reported in theTable 5.5. The oil content ranged from 38.9% for the *C. sativa* to as high as 52.4% for the *B. rapa*. These results were higher than expect, as the 10 year average was 43% for canola and the limited documentation for the *C. sativa* reported oil content around 30%. The protein results ranged from 14.9 for the *B. napus* to 24.6 for the *C. sativa*, which indicates that the meal component after oil separation would have good nutritional value as an animal feed.

The percentage of oil and protein was used to calculate the total oil output per hectare and reported in the Graph 5.5. The graph shows

Graph 5.5 : Total, oil and protein yield comparison between varieties and sites. Included is a yield comparison with Statistic Canada data (the grey shaded area).



a comparison of the total yield compared to Statistics Canada canola yields from 1986-2006. The Statistics Canada data is included in the appendix.

The statistics for the completely randomized design were run using an alpha value of 0.05 (results are reproducible 19 times, out of 20). The statistics found that there were some a significant differences between locations and treatments based on Bonferroni critical distances. Further comparison of the yields and oil contents are reported inTable 5.6 and 5.7.

Table 5.6 : Yield comparisons based on Bonferroni critical distances

Comparison	Location & Treatment	Comments
A	DG *sativa*, DH *rapa*, DH *sativa*	Dry land sites
B	RF *napus*, RF *rapa*, SM *napus*, SM *rapa*,	Irrigated sites
C	RF *rapa*, SM *napus*, SM *rapa*, SM *sativa*	Irrigated sites
D	SM *sativa*, RF *sativa*	*C. sativa*, irrigated sites

Table 5.7 : Oil comparisons based on Bonferroni critical distances

Comparison	Location & Treatment	Comments
A	DG *sativa*, DH *sativa*, RF *napus*	-
B	RF *napus*, RF *rapa*, SM *napus*	Irrigated sites
C	RF *rapa*, RF *sativa*, SM *napus*, SM *rapa*, SM *sativa*	Irrigated sites

Note: Location and Treatment with the same letter are not significanly different

Discussion

The results for the first year were very encouraging, although not without some hardship. The central Yukon site showed the best agroclimatic conditions but the plants were lost before harvest. The results from the remaining four Whitehorse locations showed interesting differences between varieties and also from the dryland vs. irrigated conditions. Most notable, was the success of the *C. sativa* and the failure of the Flanders flax. The Flanders flax did establish and showed noticeable growth through the season but never matured and no seeds could be harvested. The Flanders flax is a longer season oilseed and the cooler Yukon weather and low number of frost free days prevented any productivity of the crop. The Flanders flax might have done better in the central Yukon, although the climate would still likely limit maturity.

The *C. sativa* performed very well in the first year of the research project; the total yields significantly exceeded the canola varieties. The lab analysis of the *C. sativa* showed higher than expected percent oil values. The percentage oil content of the *C. sativa* is slightly lower to the canola, but total yields of oil were still highest in the *C. sativa*, with an average of 784 kg/hectare on irrigated sites. This was further calculated to determine the biodiesel output for the best Yukon oilseed crop (refer to diagram 5.3 for calculation). Based on 100% recovery of the oil from the *C. sativa* test sites this crop would produce approximately 724-753 l/hectare biodiesel.

The irrigated sites for all varieties performed best as observed in the growth curves and yield values. Crop growth and yields at the dryland sites were well below the irrigated sites. The dryland sites did not produce any significant amount of canola yields and yields for *C. sativa* were marginal. The dryland sites did show poorer climatic growing conditions compared to the irrigated sites, which would have an impact on growth and yields, though there is such a dramatic decrease in growth and yield without irrigation, the effect of warmer temperatures would not offset the need for irrigation.

A slightly warmer climate was seen to have some improvements in total yields although not conclusive. Data from the central Yukon could have gone a long way to proving this. Without the central Yukon yield data, comparison of the agroclimatic data for the two irrigate sites in the Whitehorse area showed a difference. The SM site experienced a total EGDD of 1020 and RF site experienced a total EGDD of 926. The yields in both varieties of the canola were higher for the warmer SM site, with the exception of the *C. sativa* which showed the opposite response, although these results are not significantly different as expressed in Table 5.6 and 5.7. Growth curves showed higher plant heights for the canola and Flanders flax at the warmer SM site, with the *C. sativa* showing no height difference between the sites. The canola was affected by small differences in climate, which indicates that a warmer climate may be necessary for improved canola yields. The *C. sativa* was not affected by the temperature variation, indicating that a warmer climate may not be needed for this crop (although the birds eating the data before harvest may have caused a drop).

The *B. rapa* canola show better yields compared to the *B. napus* canola, indicating that the shorter season *B. rapa* varieties are more suited to the Yukon climate. When compared to Statistic Canada 1986 to 2006 canola yield reports in Graph 2.6, *B. rapa* yields were average yields and the *B. napus* varieties were on the lower end to below average. The average performance for *B. rapa* canola is a good indicator that yields from the experimental plots are comparable to yields in the rest of Canada. The Statistics Canada results are a confusing benchmark for production because lands with the same soil and climate conditions have reported yield levels that are much higher than the 110 to 180 g/m^2 reported by Statistics Canada. The higher yields observed were in the range of 220 to 280 g/m^2 which would indicate poor yields from our oilseeds research. It is expected that yields for the *B. rapa* could have been improved if percent establishment was improved by increasing the seeding rate.

Conclusion

It has been proven that oilseeds can be grown in the Yukon, with the *C. sativa* and *B. rapa* canola showing the best yields in year one. Statistically, yield output looked favorable compared to Statistic Canada reports, but more work is needed to understand the true value of oilseeds as a crop in the Yukon and if year one results can be reproduced.

Year one provided data on what varieties perform best, with the *C. sativa* showing the most promise, producing 769 to 800 kg of oil per hectare based on calculations from lab results. Work with the *C. sativa* will continue because it has shown the most promise as a biodiesel crop for the Yukon and there are alternative uses for this oil as a functional food. For the canola varieties, the longer season *B. napus* canola did not perform, showing poor yields. Although, the production for the *B. napus* was below the others it cannot be statistically eliminated and it may have some merit for further research in warmer seasons. The *B. rapa* showed more promise with yields that were comparable to Statistic Canada data even with poor establishment. It will be interesting to further investigate different *B. rapa* varieties in future years to determine the effects of climate from year to year, best variety and maximum yields. The Flanders flax never matured and does not look to be a suitable crop for Yukon conditions.

Irrigation is a necessity; yields were significantly higher at irrigated sites vs. non-irrigated sites. The Yukon has too dry a climate to support dryland oilseed production. Future cost analysis will have to take into account the need for irrigation.

The promise of the warmer central Yukon needs to be further evaluated for oilseeds production. The loss of the year one data in the central Yukon is disappointing. The small increase in warmth in the one Whitehorse site indicates that the canola would perform better in this area, but this still needs to be proven.

This project should continue, hopefully in conjunction with other Yukon researchers who are focusing on biodiesel production. It is very important to find sites in the central Yukon and to maintain small plots and frequent inspection to understand the nature of growing oilseeds in the North.

Diagram 5.3: An example of diesel production based on Yukon best results.

For the highest oil yielding crop in 2006, the *C. sativa* produced 769 to 800 kg of oil per hectare. From this a rough estimate of 724 to 753 litres of diesel per hectare could be made based on the following calculation.

Biodiesel yield = oil yield x 0.8 approx.
Diesel = approx. 850 g / litre

6.0 Raspberry Input Management and Economics of Production Trial

Location: Research Farm, YT

Funding: Yukon Government, APF Science and Innovation

Objective: To employ best management practices around orchard production and determine the economics of raspberry production in the south central Yukon.

Introduction

This trial is the result of work initiated in 2002 with collaboration from the Pacific Agri-Food Research Centre in Summerland, BC. The purpose of the original trial was to examine best management practices for fertilizing and irrigating Yukon orchard crops. The goal was to apply only as much water and fertilizer as is needed. This not only conserves water resources, but it reduces the cost of production and risk of nitrate leaching. In addition, we are focusing on the economics of raspberry production and will be looking at methods to lengthen the season.

Materials and Methods

The key to minimizing water use is to have a clear understanding of how much moisture is used by the plant, how much is transpired through the leaves and how much is lost through the soil. Water is automatically delivered as computed utilizing data from the soil moisture and evapotranspiration (ET) sensors. Water is delivered through a drip irrigation system to the orchard and as the system is computer controlled, it only requires occasional manual involvement.

The raspberry orchard was established at the Research Farm in 2002 and took until 2005 before the orchard was mature enough to produce a meaningful harvest. Work on the orchard began as soon as the snow melted in early May of 2006, with thinning and pruning taking place, and florocanes being tied to trellis wires on the outside of the rows. Pre-emergent herbicide Princep-9T had been applied in 2005 and the weed incidence was negligible when assessed in late May. This pre-emergent herbicide was used to reduce weed growth within the rows, where cultivation would not be possible after the canes flushed.

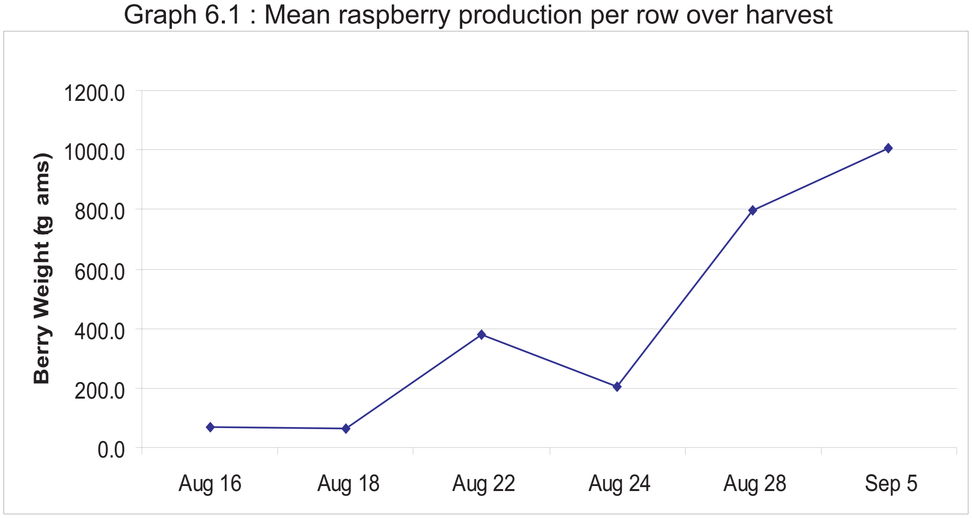
The CR-10, etgage and drip irrigation system were initiated June 12.

The fertilizer was applied at one and one half times the rate recommended for raspberry production. In total 5.6 Kg of $CaNO_3$ and 6380 gallons of water was applied at the full rate and 2.4 $CaNO_3$ and 5580 gallons was applied at the half rate.

Results

This was the second year the raspberry orchard produced a commercial crop and allowed us to make an assessment of the economics of raspberry production. Total harvest for the site was almost 100kg. Harvest began on August 16, very close to last year's date of August 17, and started on the most exposed branches of the Alaskan variety Kiska. The exposed branches may have received more heat or were more easily accessed by pollinators. The harvest looked to be peaking at the time of the last harvest date (just before the 1st frost) around September 5. Production is

Graph 6.1 : Mean raspberry production per row over harvest



The design of a trellis system can vary in the materials used. The structures set up at the Research Farm consist of wooden posts shaped as crosses with metal wires running horizontally from one post to the next. The objective of the system is to separate, support, and direct growing plants. Every season the healthiest and most productive canes are selected and the rest are pruned; roughly 15 canes per plant base are selected. By training the floral canes to the outside of the trellis, fruits can easily be picked during harvest. Also, this allows for light and insects to reach the new growing canes at the plants base. Since canes produce fruit only one season, the old canes can then be pruned the following year.

compared on a per row basis, each row is 15 meters (50 feet). Spacing between rows is 2 meters.

There were no significant differences between the fertilizer treatments. Overall mean production per row was higher for the kiska with upwards of 5 kg per row for the year. Souris production was lower with a mean production per row of up to 1.9 kg. When analyzed separately, souris responded to the recommended fertilizer treatment where as kiska responded to the ½ rate fertilizer.

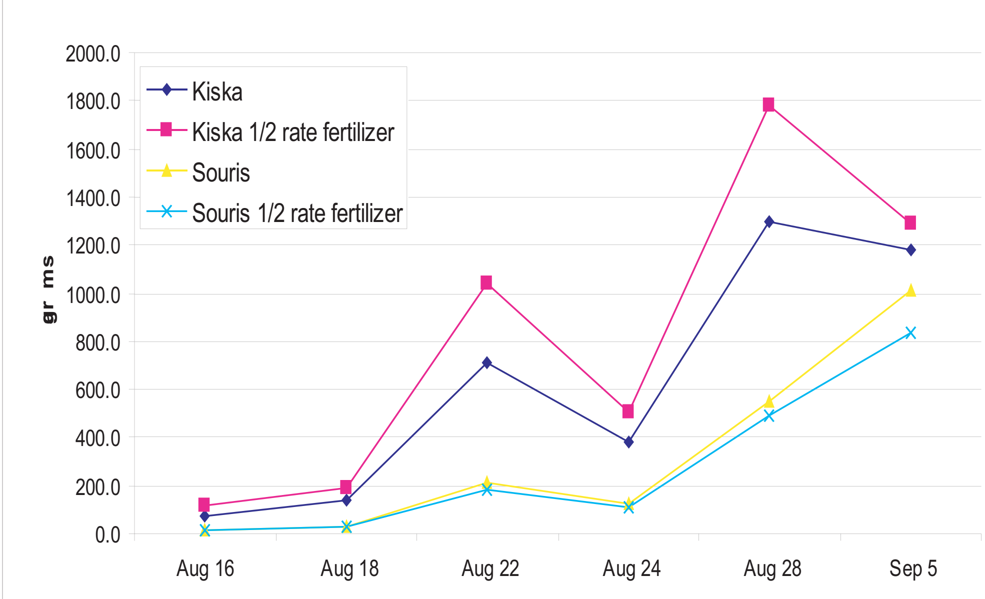
Kiska production was dominant through the harvest, with per row harvests that exceeded souris every day of picking.

There were spider mites observed on July 4 in one small area. The area of damage didn't extend beyond the initially observed location and will be monitored in the spring and dealt with if needed.

A hard frost occurred September 11 and 12 ending the berry harvest for 2006. At the time of the frost there was likely another 20-40 kg that would have been picked had it not been for the frost.

A primocane assessment was done at the end of the season to determine height and see if the ½ rate fertilizer had an effect on primocane growth. There is no difference between the fertilizer treatments when compared directly. There are some small differences between the Kiska variety which responded slightly better to the ½ rate fertilizer level with average cane height of 148 cm, the recommended fertilizer rate primocane height was 138 cm. The Souris responded the opposite way with the recommended rate canes coming in slightly taller at 129 cm and the ½ rate at 121 cm.

Graph 6.2 : Raspberry fertilizer and variety production per row



Discussion

This was the second year that a production raspberry harvest was achieved. The harvest was still in high production at the time of a killing frost on September 11 – 12 which eliminated a substantial part of the crop.

The Souris variety is infilling the rows and in some areas taking over the kiska rows which is a concern considering the kiska variety had better production per row.

Staff time commitment was noted throughout the season. The bulk of the staff time was during harvest, a total of approximately 104 hours were spent on harvest, this equates to approximately 1 hr. labour per kg of berries picked.

- pruning 29 hrs
- weeding 6 hrs
- burning canes 5 hrs
- trellis 16 hrs
- topped canes 7 hrs
- harvest 104 hrs

Total staff time to maintain and harvest the raspberry orchard was 167 hours with a net of 100 kg of raspberries in the whole orchard (300 linear meters). This is not a economical production system in its current form. Other options to reduce the staff time are mechanical picking, a upick operation, or value added sales.

Conclusion

Based on the research from this year, raspberry production has potential in the south central Yukon. Even though there was a frost that eliminated a portion of the crop, we are able to achieve production levels in the target range listed by the BC Minister of Agriculture and Forestry for the Vancouver area (BCMAFF Raspberry production bulletin). In the absence of mechanical picking equipment, a u-pick option or value added products, the economics of a stand alone fresh market production are not favourable.

7.0 Subarctic Nitrogen Fixation in Monoculture Alfalfa and Mixed Alfalfa/Grass Forage Swards

Cooperators: Bill Drury, Dave Andrew

Location: Research Farm, BD site, DA site

Funding: ACAAF, Yukon Government, NRI

Objective: Understand the legume contribution from nitrogen fixation to a forage crop.

Introduction

A series of experiments were carried out during the 2005 and 2006 field seasons designed to examine the dry matter yield, nitrogen yield and nitrogen fixation of monoculture alfalfa and binary mixed alfalfa bromegrass or timothy forage swards in subarctic conditions. The project goal was to look at methods to reduce imported fertilizer use on forage crops in the territory while maintaining forage yield and quality.

Section 7 outlines the materials and methods, results, and interpretations for the establishment phase (year 1 and 2) of alfalfa in forage stands. Results include soil nutrient levels, nodulation assessments, vegetation composition, weight, nitrogen yield, and soil moisture conditions

Five trials in three locations were established in the 2005 season. The locations included two co-operator sites on forage production farms and the Yukon Government Research Farm, all located near Whitehorse, Yukon. Unfortunately, one of the cooperator sites established poorly and was removed from the experiment mid way through the first season.

Materials and Methods

Fields were laid out in statistically relevant designs that allowed for the calculation of critical distances to compare means. Designs were either a) split plot-completely randomized designs with innoculant as the main effect and fertilizer or harvest on the split, or, b) completely randomized block designs.

Alfalfa was seeded standalone or into preexisting bromegrass or timothy forage stands. Alfalfa *Medicago sativa cv Peace* was chosen for these trials because of its brown root rot resistance, northern hardiness and high yield.

Seed was purchased from Prairie Seeds in 2005 and Quality Seed West in 2006. Seeding equipment delivered a seeding rate of approximately 10 kg/ha. Alfalfa seed was inoculated onsite prior to seeding with peat based TagTeam (containing both NRG-34 and PB-50), N-Prove (containing only NRG-34), or powder based fungal inoculant JumpStart (containing PB-50), all inoculants were supplied by Philom Bios.

N-Prove formulation had a titre of 3.14e9 rhizobia pre gram. The commercially available TagTeam had an internal titre of 6e8 rhizobia/gram and 2.4e7 Penicillium/gram. In order to provide equal amounts of rhizobia per treatment we increased the application of TagTeam to equal the higher titre of the N-Prove.

Alfalfa was seeded into existing grass stands in all experiments (except the monoculture alfalfa) with a Truax no-till seeder model FLX-812. This 2.4 meter wide double disc seeder was ideal for the circumstances as its hydraulics and weight allow the discs to penetrate through the thatch and surface compaction into the soil in one pass without destroying the fibrous grass roots (without killing the grass like tilling would). The seeder passed over the grass, cutting a groove in the soil in which the seed and treatment (if included) were deposited.

All Truax drills are equipped with depth bands on all disc openers. The size on the unit we were using allowed for a 3.5 cm penetration of the blade. The double disc openers create a v groove in the soil surface for the seed to be dropped into. According to the Truax manual seeds will drop into the seed slot about half the depth of the disc penetration which is ideal for alfalfa (1-2.5 cm is recommended for alfalfa) (Truax Company, 2004). The machine is equipped with a small seed box capable of handling small 1- 2 mm alfalfa seed. The small seed box contains small gears that rotate and deliver accurate amounts of seed to the discs.

The machine was calibrated prior to seeding. Calibration procedures were followed from the Truax manual. The drive wheel was turned 12.5 times. The seed collected was weighed and divided by 2. This result equals the seeding rate in bulk pounds per acre. This was repeated four times to determine average output and adjusted accordingly. Our target was 10 lbs/acre.

The small seed box is adjusted by moving the exposed flute. Even with adjustment there was some seed damage and irregular seeding rates in the field.

Soil samples were extracted using an Oakfield open ended soil probe with a 30 cm maximum sample depth. Ten composite samples from 0 - 15 cm were randomly taken within each trial in the spring to determine any nutrient requirements and establish a baseline.

Comprehensive soil sampling within each experimental unit was carried out each fall. Samples were kept cold prior to shipment to Norwest Labs in Edmonton, Alberta for analysis. Samples were either analyzed for NO_3, P, K, and SO_4 or for complete nutrients. The complete test included NH_4, NO_3, P, K, SO_4, Ca, Mg, Fe, Cu, Zn, B, Mn, Cl, pH, EC, OM, BS and TEC. At the lab, samples were dried and ground for analysis. Nitrate and sulphate were extracted with a weak calcium chloride solution. Phosphorus and potassium were extracted with a modified Kelowna extract. Iron, Cu, Zn and Mn were extracted using DTPA. Boron was extracted with hotwater. Chloride was extracted with deionized water. Analysis of the extractants was by colorimetry. pH and salinity were measured using a 2:1 water: soil mixture. Organic matter was computed using the loss on ignition method.

Fertilizer was applied as required, based on the recommendations of Norwest Labs. Phosphorus was already high in the soils, Nitrogen was applied based on experiment driven values, only S, K and B were applied during the trial.

Vegetation samples were harvested as close to 10% bloom as possible in all cases. Harvest was late at the Research Farm in 2005 to allow for increased alfalfa plant growth.

Photo 7.1 : Fall soil sampling October 3, 2005.

Photo 7.2 : Fall soil samples September 27, 2005.

Each experimental unit was divided into a grid and a number assigned to each grid point. Randomization sets were generated from the random number generator developed by Mads Haahr (July 1999 random.org). Depending on the design, two to four randomly selected samples were taken. Each sample consisted of above ground biomass, plant counts, percent basal cover, heights, stages of growth, plant ID, and weed incidence.

Plant samples were harvested, placed in paper bags, and dried for 48 hours at 40°C then weighed for as feed weight. Subsamples from each sample were grouped together and these composite hay samples from each experimental unit were sent to Norwest Labs in Lethbridge, Alberta for moisture and protein analysis. The LECO dry combustion method was used to determine total nitrogen. Protein is determined by multiplying the total nitrogen by 6.25 to account for non-protein nitrogen (Norwest Labs, 2005). Moisture was determined at 104°*C.*

Nitrogen fixation was determined using the total plant nitrogen difference method (ND). With this method, the nitrogen derived from soil is withdrawn from the total amount of plant nitrogen.

Estimations of how much N that is derived from soil is achieved by simultaneous cultivation of a non-fixing reference crop, usually grass, in the same field as the nitrogen fixing crop. The amount of fixed nitrogen is then assumed to equal the difference between nitrogen accumulated in the fixing crop and the reference crop (Danso, 1995; Ledgard, 1992).

This method is relatively cheap and easy to perform. The problem with the method is that the basic assumption that the two crops absorb soil nitrogen with the same efficiency, may sometimes be severely wrong. In fact, because grasses often use soil N at higher rates than legumes, the use of this method can lead to underestimated, and sometimes negative, values of NF (Danso, 1995; Hardarson, 1993; Ledgard, 1992)

Carlsson (2003) compared ND vs another commonly used method Isotope Dilution (ID). ND often gave lower estimates of NF when N yield in grass monocultures were compared with N yield in legume monocultures. Legume/grass mixtures on the other hand may utilize soil N more efficiently, and thus reach higher total N yields (Høgh-Jensen, 1994).

It is also possible that species composition influences soil microbial processes, such as mineralization, with indirect effects on soil N availability (Sparrow et al., 2000). Subtracting the N yield in a grass monoculture from the total N yield in a legume/grass mixture can therefore lead to an overestimation of NF. ND/ID values from experiments where grass monocultures were compared with legume/grass mixtures are significantly higher ($P < 0.001$) than the ND/ID values obtained in studies where grass monocultures were compared with legume monocultures. The outcome of the ND method thus seems to be dependent on the stand composition: for monocultures ND can lead to underestimations, and for mixtures ND can lead to overestimations of N_2 fixation, as compared to ID.

Photo 7.3 : Alfalfa plant in establishment year sampled in September 2005.

N in grass monoculture is subtracted from N in legume monoculture for ND. Below are the differences between the two methods.

ID	ND	ND/ID	Reference
84	79	0.94	Martensson 1984
58	52	0.9	Sparrow 1995
44	34	0.77	Sparrow 1995
63	43	0.68	Sparrow 1995
23	15	0.65	Sparrow 1995

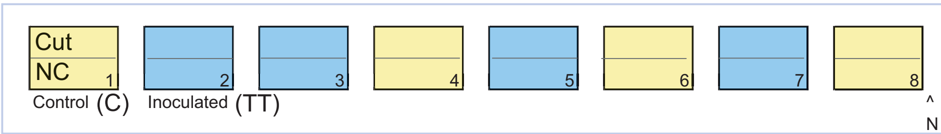
* Compiled by Carlsson (2003).

Generally, the highest estimates of transfer are obtained using the natural N15 abundance method whereas the N difference method generated consistently lower estimates of N transfer (Walley, 1996).

All data was analyzed using statistically relevant designs in SAS. Data was compared using alpha 0.05 and the conservative Bonferroni multiple comparisons method. Bonferroni testing is a stepwise, sequentially rejective method for hypothesis testing. Graphs within this section present data with greek symbols and/or letters. Graph bars and table figures with the same symbols or letters are not significantly different at alpha = 0.05. If the value is not statistically significant then we can make no inferences about the differences in the results as they may have been due to chance and other experimental errors, not from the treatments. Some graphs present both letters and symbols, these are to be treated as different comparisons.

7.1 Nodulation and Productivity of an Alfalfa (*Medicago sativa cv Peace*) Monoculture in Subarctic Environments

Diagram 7.1 : Monoculture Alfalfa Experimental Design



Objective: Assessment of alfalfa (*Medicago sativa cv Peace*) production in monoculture to determine dry matter (DM) weight, nitrogen (N) yield and nitrogen fixation (NF) achievable under optimum conditions without N fertilizer. Alfalfa was also monitored to determine the timing of nodulation.

Introduction

This experiment was carried out during the 2005 and 2006 field seasons at the Yukon Government Research Farm to assess DM production and NF achievable in south central Yukon conditions. The uninoculated plots were intended for use as a reference crop, but were well nodulated by mid season 2005 therefore NF was calculated from a perennial monocot crop (*Phleum pratense*).

Materials and Methods

Plants were seeded by hand in a completely randomized design with eight 2x2 meter plots with one meter spacing in a slightly shaded area of the Research Farm. The design was initially setup for two treatments, a control and a peat based inoculation with TagTeam (from Philom Bios). In the fall of the first year a split plot treatment was added to determine the effect of late season harvesting.

Seed was hand sown in rows with 20 cm spacing.

Seeded May 30, 2005 at 15 kg/ha.

Seed treatment inoculated with peat based TagTeam 5 g inoculant / 1 kg seed (TT); or seeded without inoculation (C). No fertilizer was added. Irrigation was 82 mm in 2005 and 70 mm in 2006.

Soil Moisture

Average soil moisture throughout both the 2005 and 2006 seasons was 10%. The permanent wilting point for this low organic content, silt loam soil was determined from a series of moisture retention curves to be 9-12% for 0-6 cm depth and 6-9% for 6-12 cm depth. Monitoring permanent wilting points is important because they are the point at which plants can no longer draw water from the soil. A moisture deficit results in plant stress exhibited by wilting (Brady, 2004). Throughout both seasons the monoculture alfalfa stand was within the wiling point range, this low overall moisture value was likely due to the low amount of irrigation added and the lack of ground cover. There are a number of points from 2005 and 2006 that fall within the range of the identified permanent wilting point.

Results and Discussion

The colour and growth difference between the inoculated and control plots was easily discernible through the early part of the 2005 season. As the first season progressed the health, growth and colour of the uninoculated plots was indistinguishable from the inoculated plots.

Nodule Assessment

Detailed nodule assessments were carried out on September 19, 2005 and October 6, 2006. Four plants with roots were randomly extracted from each experimental unit. Soil and plants were soaked in water to loosen the soil from the roots. Each plant was assessed using a modified Rice ranking system developed in 1977 (Rice, 1977). Rice developed a scoring system which included nodule colour, nodule numbers, nodule position relative to the crown, and nodule size. Nodules were cut open and examined to determine the level of pinkness which indicates the presence of leghemoglobin. The colour value was somewhat arbitrary because it was difficult to gauge accurately in the field and the time of sampling also prevented good indication of pinkness. After some sampling it was decided to remove colour from the assessment. Position, number and size of nodules were assessed for each plant.

Position was assessed by the ratio of the number of nodules within 5 cm of the crown to the remaining nodules. The maximum score without the colour being quantified was 6.

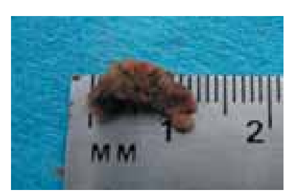


Photo 7.4 : Red colouring inside a large nodule indicating the presence of leghemoglobin.

Table 7.1 : Modifed Rice (1977) nodule ranking system

Characteristic	Criteria	Score
Number	5-20/plant	3
	>20/plant	2
	1-5/plant	1
	none	0
Position	60-100%	2
(% crown)	20-59%	1
	0-19%	0
Size	3-10mm	1
(diameter)	<3mm	0
	>10mm	0

Table 7.2 : Ranking of treatments

	TT	C
Year 1 Sept 2005	5.5 a	3.3 b
Year 2 Oct 2006	4.7 ab	4.5 ab

* Different suffix letters refer to numbers that are statistically significant at alpha 0.05 based on the Bonferroni critical distances.

The inoculated plots did far better in the initial assessment year. Scoring between 5.25 – 6 points with a mean of 5.5 compared to a mean of 3.3 for the uninoculated plots. In the second year the scores between treatments are very similar, with the nodule assessment of the inoculated plots only slightly greater than the uninoculated plots. This is not a surprising result since both plots were inoculated by mid season 2005.

Nodulation was evident within one month of seeding in both years.

Yield Assessment

Harvested August 28, 2005 at 10% bloom and harvested July 31, 2006 at 40% bloom.

Above ground biomass was harvested from randomly selected rows at 3 cm height to determine the DM weight, N yield, and NF. Samples were sorted into stage of growth, dried for 48 hours, weighed as feed weight and then 100 gram composite subsamples were sent to Norwest Labs in Lethbridge, Alberta for moisture and LECO protein analysis.

Nitrogen yield is the calculation of the percent nitrogen in the composite plant subsample multiplied by the DM weight.

Nitrogen fixation was calculated using the total plant nitrogen difference method. This method requires a non-nodulating reference crop be grown. A timothy (*Phleum pratense*) reference crop with no fertilizer was used in this experiment. Vance (1988) states that most often controls used are legumes grown in absence of bacteria or non-nodulating legume genotypes. Since the uninoculated stand became nodulated midway through the first season we had to rely on an alternative reference crop, a perennial monocot.

The disadvantage is that this assumption is based on similar N uptake characteristics for the fixing and nonfixing crops (Vance, 1988).

Table 7.3 : NON NF Mean Reference value for *Phleum pratense*

2005	2006	
18.0	23.0	Mean
4.7	4.6	SD
26.1	19.9	CV%

Table 7.4 : Monoculture Alfalfa Yields for 2005 and 2006

Alfalfa Establishment Year (2005)

	DM Yield	N Yield	NF
	kg/ha/yr	kg/ha/yr	kg/ha/yr
TT	3072.34	94.91	76.88
C	2521.15	82.65	64.62

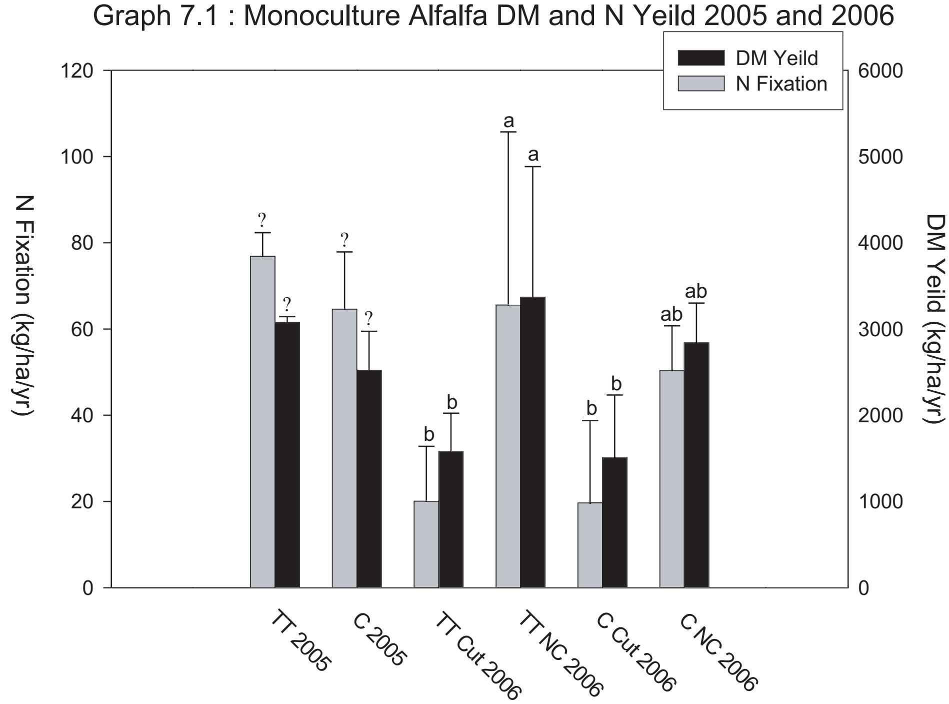
Alfalfa 2nd Year (2006)

	DM Yield	N Yield	NF
	kg/ha/yr	kg/ha/yr	kg/ha/yr
TT Cut	1579.15	43.10	20.06
TT NC	3369.12	88.61	65.57
C Cut	1507.75	42.72	19.68
C NC	2840.14	73.41	50.37

* Each value is the mean of 4 samples

In the establishment year the DM of the TagTeam (TT) inoculated plots resulted in a total weight of 3072 kg/ha and a resultant 95 kg/ha of N yield. The uninoculated plots, that eventually became inoculated mid-season 2005

Graph 7.1 : Monoculture Alfalfa DM and N Yeild 2005 and 2006



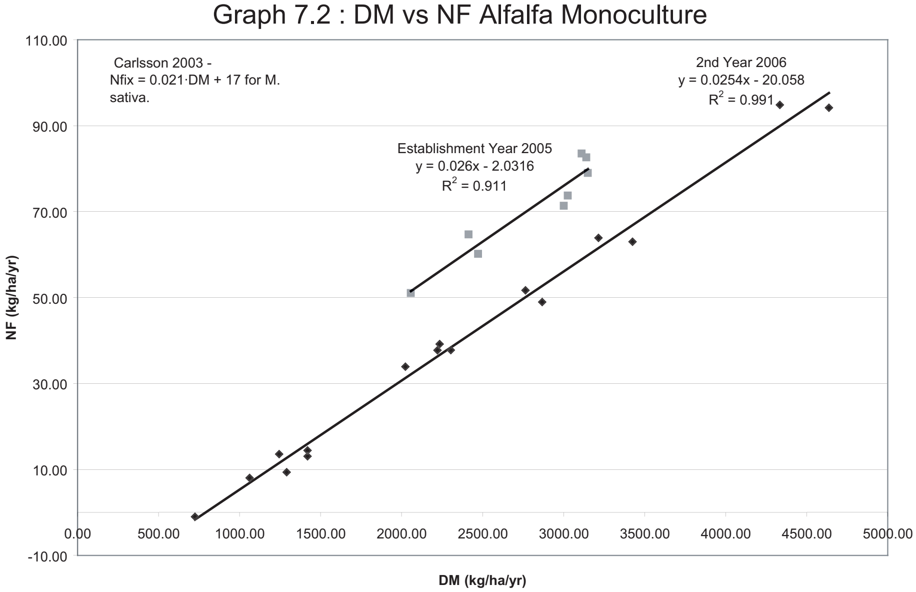
provided 2521 kg/ha of DM and 83 kg/ha of N. These figures are comparable to a first cut in a two cut system from Beaverlodge (Rice, 2000). It is worth noting that the plots were harvested in late August 2005 when the possibility of rain would limit dry time in field. This is not the ideal harvest time. Harvesting earlier, as would be required in a normal field situation, would result in reduced production for the establishment year, but would also result in better production in year two.

At the end of the first year a split plot treatment was applied to the design to determine the effect of late season harvest on the alfalfa. Half of each plot was clipped in late August 2005. Late season grazing is often associated with substantial losses in subsequent year yields. Late fall grazing or harvest removes the leaves that would otherwise be synthesizing substances translocated to the crowns and roots for energy reserves. This is a critical period for the accumulation of food reserves because when the plant is cut new growth is produced at the expense of winter reserves (McKenzie, 1988), leading to a reduction in hardiness and potential winterkill, resulting in reduced yields in subsequent years. This time of year is so critical for leaving alfalfa crops untouched that the northern United States extension services recommendation is for harvest 4 – 6 weeks before the expected first fall killing frost.

The effects of the late season harvest are startling and reflects the importance of removing grazing animals during this time period. The TagTeam inoculated plots that were not harvested in August 2005 (TT NC) had DM of 3369 kg/ha yielding 89 kg/ha N, compared to the harvested plots (TT Cut) that yielded 1579 DM kg/ha and only 43 kg/ha N.

The results of NF (kg/ha/yr) were graphed against DM yield (kg/ha/yr) to determine the ability to predict nitrogen fixation based on the total dry matter harvested. The resultant R^2 of 0.991 for the second year harvest shows a very good fit for the predictive model. In this monoculture crop, the equation NF = 0.0254xDM – 20.058 provides an accurate calculation of NF based on DM. For a specific season total DM and NF are often highly correlated (Vance, 1988). More study in this climate will be required to determine the accuracy of this equation over time.
A rough equation based on DM to determine NF in Northern Sweden by Carlsson (2003) is NF = 0.021xDM + 17 for *Medicago sativa*. The equation derived from our research is similar, but crosses the Y-axis at a much lower value.

Graph 7.2 : DM vs NF Alfalfa Monoculture



Conclusion

The inoculation of alfalfa with the Philom Bios TagTeam product leads to high nodulation scores and total DM yield of over 3000 kg/ha/yr and NF of 65-75 kg/ha/yr. The ability to compare a control non-nodulated alfalfa stand was compromised midway through the first season, due to either a healthy native rhizobia population or the movement of bacteria in the soil from the inoculated stand likely from surface and subsurface waterflow. In the absence of a non-nodulating reference crop the NF values were calculated using timothy (*Phleum pratense*) which may have lead to an underestimation of the nitrogen fixation in the alfalfa stand.

The most startling observation from this experiment was the effect of late season harvest on the subsequent year growth. DM yields for the late season harvest treatment were half of the unharvested samples in the second year and NF values were down to a third of the fixation achieved by the unharvested samples. Late season harvest of alfalfa in an establishment year allows for an economic use of the crop in the first year, either by harvesting or grazing, but the result of late season cutting as highlighted by this experiment and discussed in the literature is to reduce the energy level in the plant and lead to reduce second year growth.

7.2 On Farm Trial of Alfalfa (*Medicago sativa cv Peace*) and Smooth Bromegrass (*Bromus inermis Leyss cv Carlton*) Binary Forage

Objective: This trial was designed to provide a comparison of dry matter (DM) and nitrogen (N) yield between high fertilizer rates historically applied to monoculture smooth bromegrass *(Bromus inermis Leyss cv Carlton)* stands and a binary alfalfa/bromegrass forage stand with low fertilizer. The hypothesis being tested is that the seeding of TagTeam (from Philom Bios) inoculated alfalfa *(Medicago sativa cv Peace)* into an existing bromegrass stand while limiting nitrogen fertilization will lead to greater nitrogen yield at harvest than a monoculture bromegrass sward with higher fertilizer rate.

Introduction

Field experiments were conducted in the 2005 and 2006 growing season in the Takhini Valley west of Whitehorse, Yukon Territory. The experiments were set up on farms within large cleared fields. Unfortunately, one of the seeded sites established poorly and was removed from the experiment mid way through the first season. The remaining location, Site DA was seeded in a large 40 hectare field on a gently north facing slope at 700 meters elevation.

Diagram 7.2 : Site DA Experimental Design

170 Yeild	170 Yeild	170 Yeild	170 Yeild	25 N TT	25 N TT	25 N C
170 N C	170 N C	25 N C	25 N C	25 N PB	25 N PB	170 N C
25 N C	25 N C	25 N NP	25 N NP	170 N C	170 N C	25 N PB
25 N NP	25 N NP	25 N PB	25 N PB	25 N NP	25 N NP	170 Yeild
25 N PB	25 N PB	25 N TT	25 N TT	25 N C	25 N C	25 N TT
25 N TT	25 N TT	170 N C	170 N C	170 Yeild	170 Yeild	25 N NP
Block 1	Block 5	Block 2	Block 6	Block 3	Block 7	Block 4

Slope v

^ S < E

Soil Moisture

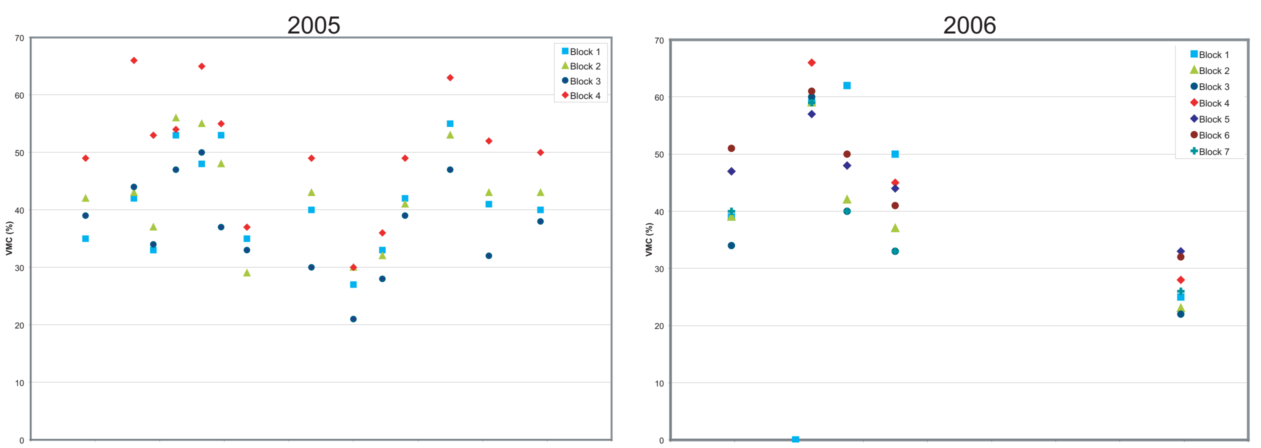
Soil moisture was maintained at an average of 43% throughout the peak growing season in 2005 and 2006.

Soil moisture TDR measurements (see graphs below) highlight the moisture variability in each block and suggest that the blocking effect is significant. The highest variability between blocks is from block 4, which was always substantially wetter than the other 3 blocks in 2005. In 2006, the difference in moisture is not as pronounced and the overall moisture is lower after mid June and trends downwards into the fall.

Materials and Methods

This trial was laid out in a randomized complete block design (see diagram above). Each block was split into six experimental units. Each experimental unit was 2.4 x 20 m. Four blocks were laid out in the 2005 season (blocks 1 - 4) and three additional blocks in the 2006 season (blocks 5 - 7). The trial seeding consisted of planting *Medicago sativa cv Peace* into the pre-existing irrigated grass hay stand using a no-till seeder. The Truax FLX-812 no-till drill was used to seed into the bromegrass stand. The seeder passed over the grass, cutting a groove in the soil in which the seed and treatment (if included) were deposited. Alfalfa was inoculated onsite with peat based TagTeam or N-Prove inoculant and/or a powder based fungal inoculant JumpStart, all inoculants were supplied by Philom Bios.

Graph 7.3 : VMC at Rafter 'A' Ranch 2005 and 2006



Treatments included:
25 N C > Uninoculated alfalfa with 25 kg/ha/yr N fertilizer;
25 N PB > Alfalfa inoculated with PB-50 penicillium bilaii and 25 kg/ha/yr N fertilizer;
25 N NP > Alfalfa inoculated with N-Prove NRG-34 rhizobia and 25 kg/ha/yr N fertilizer;
25 N TT > A dual inoculation with TagTeam (NRG-34 + PB-50) and 25 kg/ha/yr N fertilizer;
170 N C > Uninoculated alfalfa with 170 kg/ha/yr fertilizer;
170 Yield > No alfalfa with 170 kg/ha/yr N fertilizer;

Seeding occurred May 10, 2005 and May 18, 2006 and seeded at 10 kg/ha. The site was irrigated around 150 mm in 2005 and 130 mm in 2006 from May - late June.

Composite soil tests were taken in each block in the spring. Fertilizer was added to bring the soil to ideal nutrient levels for a grass/legume mixed forage stand based on recommendations from Norwest Labs. Nitrogen was applied based on experiment driven values each spring and other required fertilizers were applied to soil test recommendations in early June. A composite soil sample was taken for each experimental unit in the fall and analyzed for complete nutrients or for N,P,K, and S. Nitrate levels were near 0 ppm for all samples in the fall. There was very limited variability in the other tested nutrient levels across the site.

Harvest occurred July 6, 2005 and July 10, 2006. Brome was sampled at the early boot stage in both 2005 and 2006. Each treatment was divided into a grid and a number assigned to each grid point. Four randomly selected samples were taken from each treatment within each block with 0.5 x 0.5 m^2 sampling squares. Each sample consisted of above ground biomass, plant counts, heights, stages of growth, and weed incidence.

Results were analyzed based on dry matter yields and nitrogen yield using SAS.

Results and Discussion

The majority of the alfalfa plants were in the first trifoliate stage in early June 2005, three weeks after planting. Alfalfa growth was best in areas with sparse grass cover. Alfalfa production was poor in the 170 N C treatment (high fertilizer rate and alfalfa) and best production from the N-Prove and TagTeam treatments. Using small sampling squares meant that the samples were manageable, but there was a tremendous amount of variability in the data from each sample as shown by the standard deviations on the graphs next page.

Regrowth was monitored into the fall in 2005. TagTeam and N-Prove inoculated treatments measured

Photo 7.5 : Horses selectively grazing alfalfa on September 15, 2005.

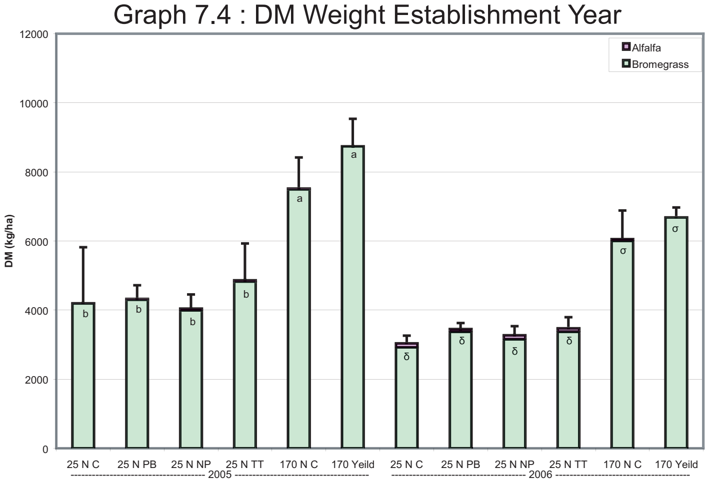
the best alfalfa regrowth. The height and colour of these treatments was generally as good or better than the regrowth of the bromegrass in the 170 Yield treatment. Heading into the winter 2005 the horses that were boarded on the property were let onto the field in early September and discovered the alfalfa within a couple weeks. The horses preferentially grazed the alfalfa in rows. As discovered in the monoculture alfalfa trial previously discussed, the result of this grazing is likely that yields were lower in the subsequent year (2006). Alfalfa is often not considered suitable for pastures because of preferential

Photo 7.6 : Block 1 Site DA showing regrowth of 25 N C (left) and 25 N NP (right) treatments, August 27, 2005.

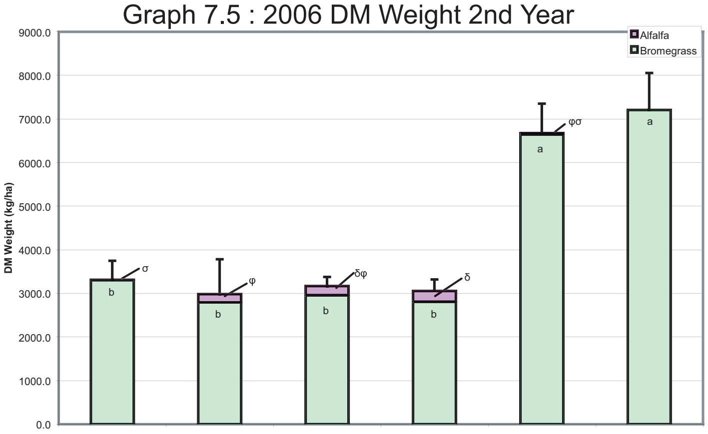
grazing (Papadopoulos, 2005). It is important that a grazing rotation be implemented that removes the animals from the alfalfa forage prior to freeze up.

In the establishment year, blocks (both 2005 and 2006), the alfalfa barely contributes to the stand dry matter. Although alfalfa has a noticable effect on the N yield of the sward, the N contribution of the alfalfa to the sward never exceeds 5% (based on the mean of the samples) in the establishment year. This is a result of competition from the bromegrass for the small amount of N fertilizer added. The shading of the alfalfa seedlings early on reduces their growth and requires there be more time for foliar development before harvest. Harvest occurred early in the seasons at this location, because of climate limitations, specifically the precipitation and heat patterns in early August that can prevent proper hay drying, so alfalfa was harvested in early July when the height ranged from 2 - 27 cm with a mean of 8 cm.

Graph 7.4 : DM Weight Establishment Year

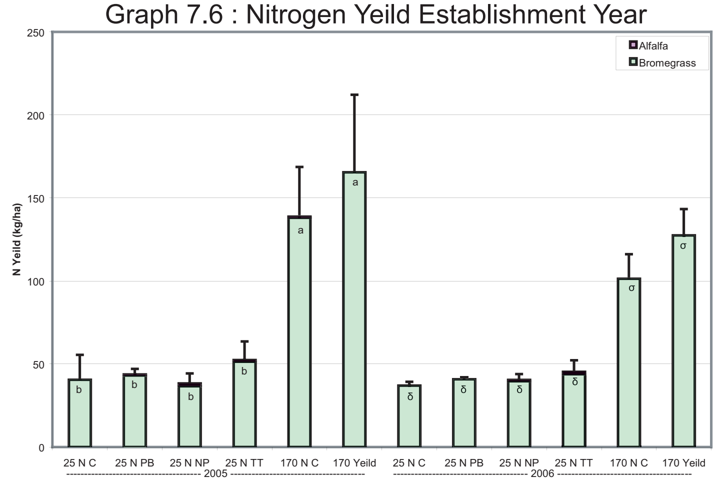


Graph 7.5 : 2006 DM Weight 2nd Year

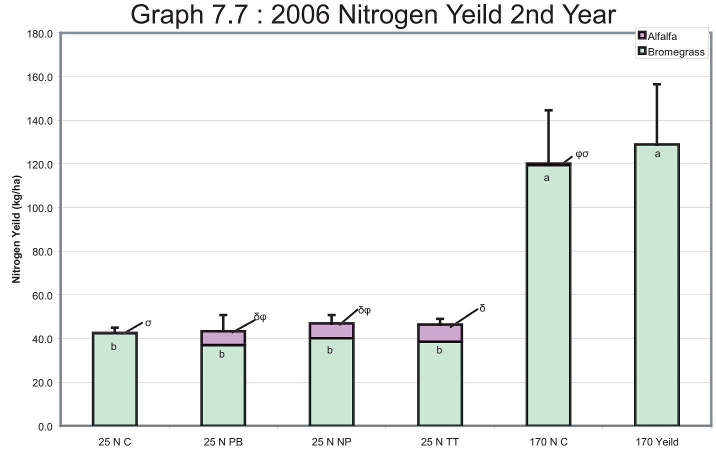


* Bars with different letters are significantly different based on an alpha of 0.05 using the Bonferroni Test.

Graph 7.6 : Nitrogen Yeild Establishment Year



Graph 7.7 : 2006 Nitrogen Yeild 2nd Year



In the second year we begin to see greater contribution of alfalfa to the mixed sward, even though grazing occurred late in 2005. We have only one year of data to analyze year two results, nonetheless the contribution of alfalfa was 12% in the TagTeam treatment and was significantly different than the other treatments. For the N yield the TagTeam treatment contributed 17% to the sward. By the second year we are seeing an increase in the contribution of alfalfa to the

Photo 7.7 : Tractor pulling no-till seeder (looking north) RAR site May 10, 2005.

stand both in terms of dry matter and nitrogen yield, but the production is far below the heavily fertilized monoculture bromegrass stand.

The amount of grass harvested in 2005 was 24% higher than for 2006, likely because of the difference in heat between the years.

Regardless of the difference between years, the same trend occurs with much reduced total harvest when comparing the high to the low fertilizer treatments.

Another interesting note is that the seeding of the alfalfa into the bromegrass had a negative effect on the total DM yield from the treatment.

Conclusion

On farm trials are important to help understand the applicability of production techniques in field situations. This research was initiated to understand the utility of no-till seeders planting alfalfa into existing grass stands and whether a low fertilizer treatment combined with alfalfa could achieve similar production when compared to a higher fertilized bromegrass stand. The results are quite clear, the ability for alfalfa to compete against bromegrass in a field situation where grazing and first season harvest occur does not appear to be possible based on this data. Seeding of *Medicago sativa cv Peace* into a *Bromus inermis Leyss cv Carlton* stand with a no-till drill is not a useful technique for ameliorating the forage N content of the stand in a highly managed, heavily fertilized, irrigated system.

Photo 7.8 : Seeding plots at RAR site May 10, 2005.

7.3 Alfalfa (*Medicago sativa cv Peace*) and Smooth Bromegrass (*Bromus inermis Leyss cv Carlton*) Binary Forage Mixture

Objectives: To determine the yield and nitrogen fixation of alfalfa in a mixed binary smooth bromegrass forage sward.

Introduction

Field experiments were conducted during the 2005 and 2006 growing season at the Yukon Government Research Farm, Whitehorse, Yukon, focusing on the establishment phase of alfalfa. Peace alfalfa was seeded into an established Carlton smoothbrome grass stand using a Truax no-till seeder.

Field History

A monoculture bromegrass stand was established in June 2002 and alfalfa was seeded May 28, 2005 and June 3, 2006. Other species present in the stand include:

Yarrow - *Achillea millefolium*
Tufted Hairgrass - *Deschampsia caespitosa*
Shepeard's Purse – *Capsella bursa-pastoris*
Alsike Clover - *Trifolium hybridum L*
Common Groundsel – *Senecio vulgaris*
Narrow-leaved hawksbeard - *Crepis tectorum*
Foxtail barley - *Hordeum jubatum*
Jacob's ladder - *Polemonium occidentale*

Soil Moisture

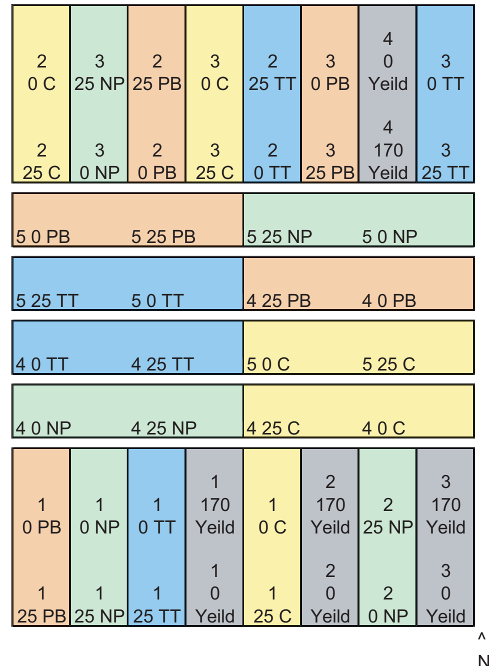
Average soil moisture throughout the 2005 season was 23% and 22% for 2006. The permanent wilting point (pwp) for this low organic content, silt loam soil was determined from a series of moisture retention curves to be 9-12% for 0-6 cm depth and 6-9% for 6-12 cm depth. Throughout both seasons the brome/alfalfa mixed stand reached into the pwp range at only one point (at the start of the 2005 season).

Materials and Methods

This trial was laid out in split plot completely randomized design with inoculant as the main effect and fertilizer on the split (see diagram at right). Each experimental unit was 2.4 x 5 m and was repeated 3 times in 2005 (1 - 3) and twice in 2006 (4 - 5). The trial seeding consisted of planting *Medicago sativa cv Peace* into the pre-existing irrigated grass hay stand using a no-till seeder. The Truax FLX-812 no-till drill was used to seed into the bromegrass stand. The seeder passed over the grass, cutting a groove in the soil in which the seed and treatment (if included) were deposited. Alfalfa was inoculated onsite with peat based TagTeam or N-Prove inoculant and/or a powder based fungal inoculant JumpStart, all inoculants were supplied by Philom Bios.

Treatments included an uninoculated control, inoculation with NRG-34, with PB-50 and combined TagTeam. Trials were hand fertilized with 0 kg/ha or 25 kg/ha nitrogen in urea formula spring application. These treatments were compared to two

Diagram 7.3 : Experimental Design



other treatments: a yield treatment without alfalfa fertilized at 170 kg/ha or 0 kg/ha N.

Treatments included:
C > Uninoculated alfalfa with 0 or 25 kg/ha/yr N fertilizer;
PB > Alfalfa inoculated with PB-50 penicillium bilaii and 0 or 25 kg/ha/yr N fertilizer;
NP > Alfalfa inoculated with N-Prove NRG-34 rhizobia and 0 or 25 kg/ha/yr N fertilizer;
TT > A dual inoculation with TagTeam (NRG-34 + PB-50) and 0 or 25 kg/ha/yr N fertilizer;
Yield > No alfalfa with 0 or 170 kg/ha/yr N fertilizer;

Alfalfa was seeded at 10 kg/ha and inoculated onsite. The site was irrigated approximately 110 mm in 2005 and 80 mm in 2006.

Composite spring soil samples revealed no deficiencies except nitrogen. Nitrogen was added based on experimental derived values on June 2, 2005 and June 8, 2006.

Vegetation sampling occurred August 5 – 8 in 2005 and August 14 - 24 in 2006. In 2005, bromegrass was sampled at the anthesis stage and alfalfa mean height was 30 cm. In 2006, the bromegrass was harvested at the early anthesis stage and alfalfa was harvested at 15% bloom for the second year crop. Each sample consisted of above ground biomass, plant counts, heights, stages of growth, percent basal cover, and weed incidence.

Results were analyzed based on dry matter (DM) yield, nitrogen (N) yield, and nitrogen fixation (NF) using SAS.

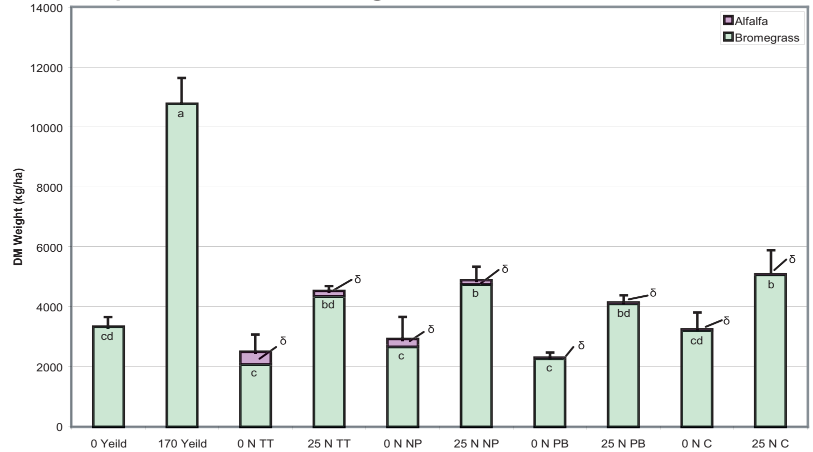
Results and Discussion

Observations were taken throughout both seasons. There were some fluctuations in the colour of the grass in the unfertilized plots, at times, showing severe signs of nitrogen deficiency with yellowing of leaves.

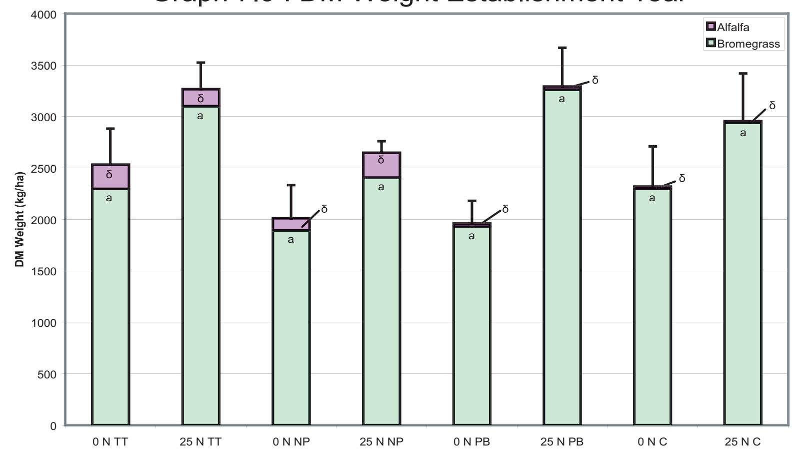
Fall soil samples taken October 3, 2005 revealed lower concentrations of some micronutrients compared to the spring sample in all treatments. The reduction in the amount of Mg, Mn, B and Zn could be due to the withdrawal by the alfalfa or due to the variability in soil that became apparent with the more detailed testing. Alfalfa growth was the greatest in the plots where no nitrogen was added.

Over the course of the two year study three different assessments were made. Two establishment year results and one 2nd year results were available for analysis.

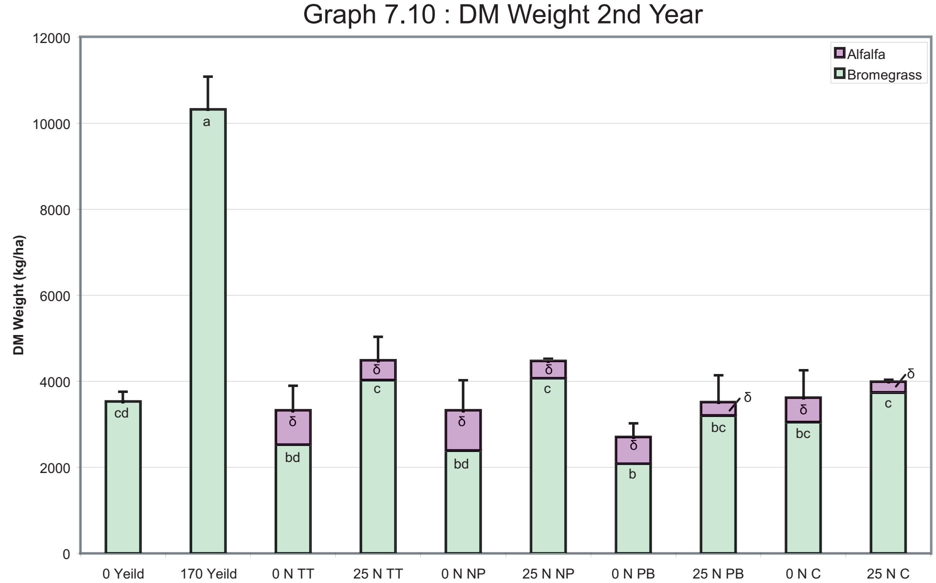
Graph 7.8 : DM Weight 2005 Establishment Year



Graph 7.9 : DM Weight Establishment Year



Graph 7.10 : DM Weight 2nd Year

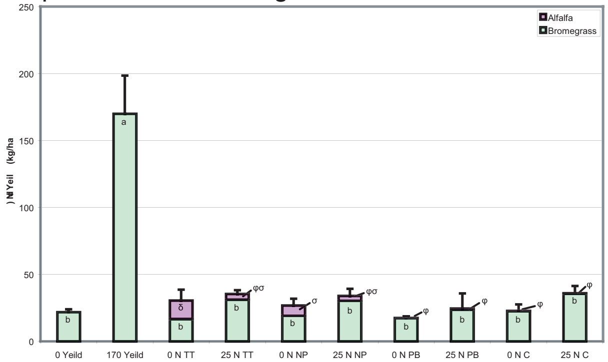


Yield Assessment

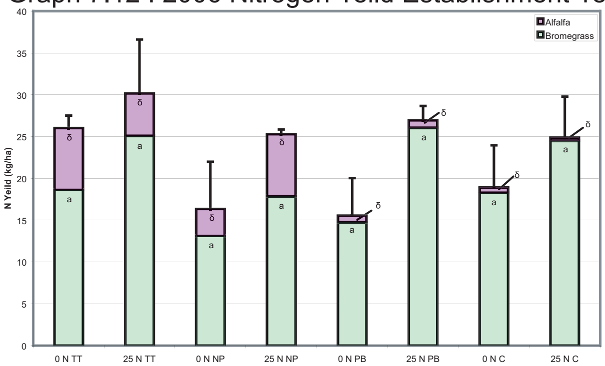
Mean DM weight comparisons show that there is a difference between grass weights based on the differences in fertilizer, but we can draw no conclusions about the alfalfa in the stand, as there is tremendous variability in the samples which leads to insignificant results. Bromegrass total DM was upwards of 11,000 kg/ha in 2005 for the 170 Yield treatment, far exceeding any other treatment. This is not surprising considering the recovery of nitrogen that bromegrass showed in 2005 (see next page).

Nitrogen yield was assessed for each treatment. We see a greater contribution of alfalfa to the stand by examining the N yield data as the alfalfa was fixing nitrogen and per kilogram of vegetation provides

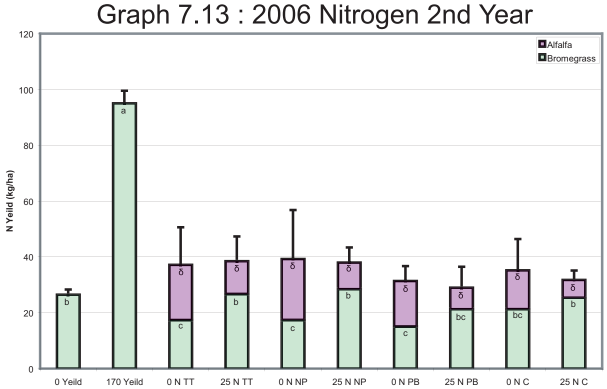
Graph 7.11 : 2005 Nitrogen Yeild Establishment Year



Graph 7.12 : 2006 Nitrogen Yeild Establishment Year



Graph 7.13 : 2006 Nitrogen 2nd Year



Nitrogen use efficiency was calculated to determine the recovery efficiency of bromegrass. Using the following equation:

RE = (Uf – Uo)/Na x 100
Uf is the fertilized N uptake
Uo is the unfertilized N uptake
Na is the nitrogen applied

Table 7.5 : Brome nitrogen recovery efficiency

2005	2006	
87.2	40.3	Mean
17.5	1.6	SD
14.1	14.1	

The recovery efficiency varies greatly between years, likely due to weather and precipitation and irrigation amounts.Crop growth response to N fertilizer varies with sites and years because of variations in the soil N supply (Belanger, 1997) and the climatic conditions.

Nitrogen Fixation

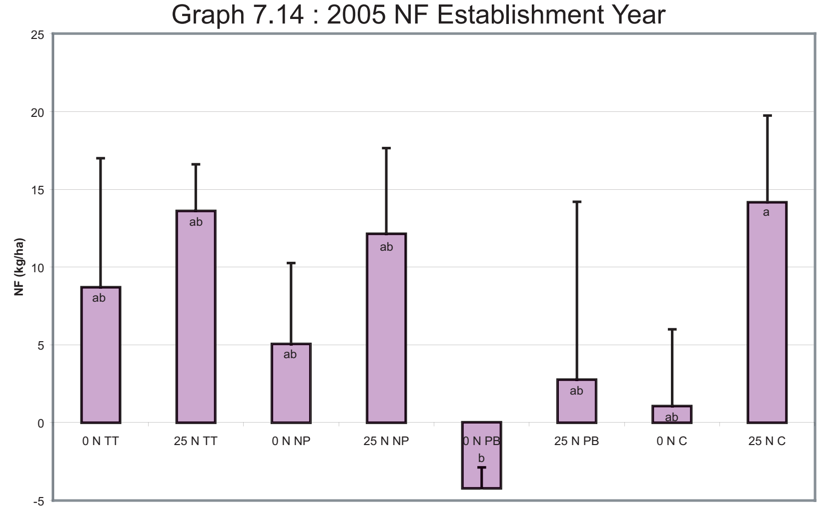
Nitrogen fixation was assessed using the total plant nitrogen difference method, using an unfertilized, monoculture bromegrass stand as the reference crop (see table below).

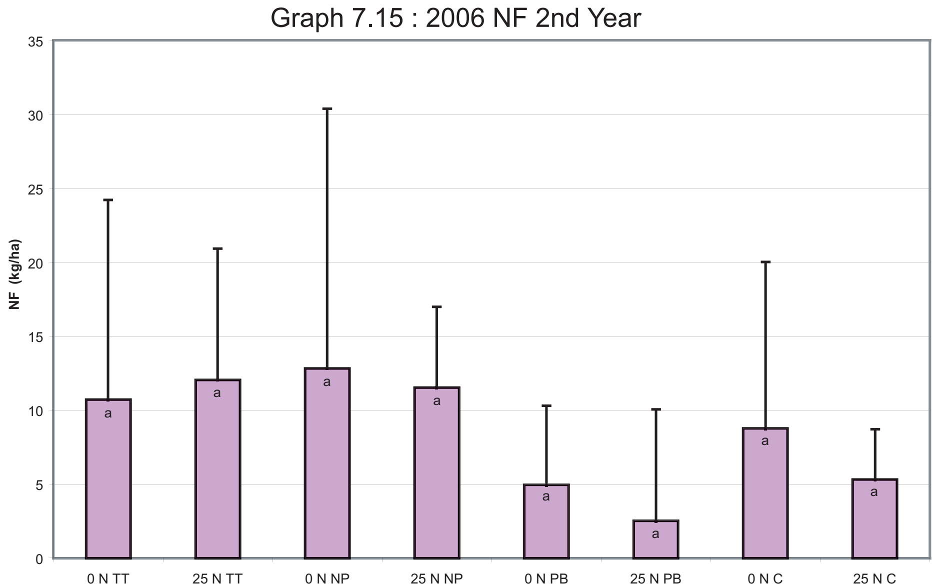
Table 7.6 : NON NF Mean Reference value *Bromus inermis L*

2005	2006	
21.6	26.4	Mean
2.3	1.9	SD
10.8	7.3	CV%

more nitrogen to the stand than grass. In the establishment years (2005 and 2006) a maximum of up to 10 kg/ha was contributed by the alfalfa to the forage sward. Means for the unfertilized treatments are generally higher, there was statistical significance in the model, but not at the individual treatment level. In the second year of the trial we do see the alfalfa contributing a greater amount to the stand, upwards of 20 kg/ha, so the trend is there, but this is a limited dataset and without more years of data it is hard to make inferences about the stand composition and the contribution of alfalfa into subsequent years.

Graph 7.14 : 2005 NF Establishment Year





The concern using this established brome stand was that the monocot grass is able to accumulate greater N reserves over the season and would not provide a good baseline to use, nonetheless it was the only option for this trial. As shown on the graphs below the NF for the mixed alfalfa/bromegrass swards are quite variable, with some negative values recorded in the establishment years, meaning that the reference crop had a higher concentration of N at harvest than the treatments. In the second year we see mean NF rates of 12 kg/ha, but no differences between the alfalfa treatments can be inferred because of the variability.

Conclusion

All plots were nodulated by the second year, the differences between the treatments is not significant, but the effect of adding alfalfa into a brome stand does increase the nitrogen yield of the stand.

Photo 7.9 : Irrigating timothy and brome stands at the Research Farm June 2005.

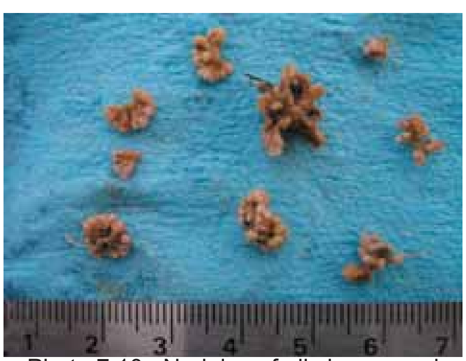


Photo 7.10 : Nodules of all shapes and sizes.

Photo 7.11 : N-Prove treatment with no nitrogen fertilizer, alfalfa foliage is evident in the stand August 5, 2005.

7.4 Alfalfa (*Medicago sativa cv Peace*) and Timothy (*Phleum pratense cv Climax*) Binary Forage Mixture

Objectives: To determine the yield and nitrogen fixation of alfalfa in a mixed binary timothy forage sward.

Introduction

Field experiments were conducted during the 2005 and 2006 growing season at the Yukon Government Research Farm, Whitehorse, Yukon, focusing on the establishment phase of alfalfa. Peace alfalfa was seeded into an established Climax timothy stand using a Truax no-till seeder.

A monoculture timothy (*Phleum pratense cv Climax)* stand was established in June 2002 and alfalfa was seeded May 28, 2005 and June 3, 2006.

Other species present in the stand include:

- Yarrow - *Achillea millefolium*
- Tufted Hairgrass - *Deschampsia caespitosa*
- Shepeard's Purse – *Capsella bursa-pastoris*
- Sweetclover Clover – *Melilotus alba*
- Alsike Clover - *Trifolium hybridum* L
- Common Groundsel – *Senecio vulgaris*
- Narrow-leaved hawksbeard - *Crepis tectorum*
- Smooth bromegrass - *Bromus inermis leyss*
- Foxtail barley - *Hordeum jubatum*
- Violet Wheatgrass – *Agropyron violace*

Materials and Methods

This trial was laid out in split plot completely randomized design with inoculant as the main effect and fertilizer on the split (see diagram at right). Each experimental unit was 2.4 x 5 m and repeated 3 times in 2005 (1 - 3) and twice in 2006 (4 - 5).

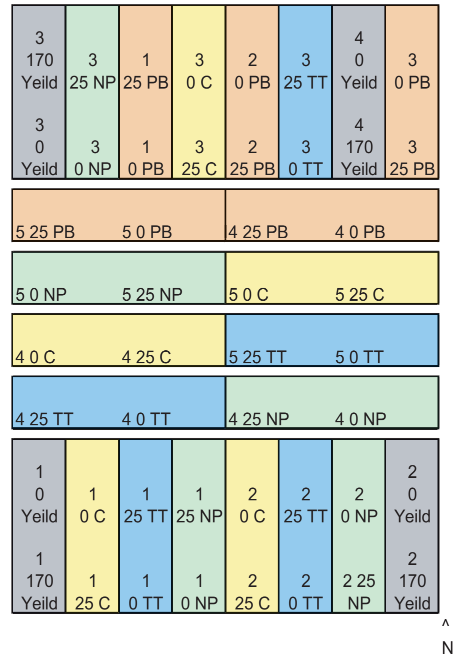
The trial seeding consisted of planting *Medicago sativa cv Peace* into the pre-existing irrigated grass hay stand using a no-till seeder. The Truax FLX-812 no-till drill was used to seed into the timothy stand. The seeder passed over the grass, cutting a groove in the soil in which the seed and treatment (if included) were deposited. Alfalfa was inoculated onsite with peat based TagTeam or N-Prove inoculant and/or a powder based fungal inoculant JumpStart, all inoculants were supplied by Philom Bios.

Treatments included an uninoculated control, inoculation with NRG-34, with PB-50 and combined TagTeam. Trials were hand fertilized with 0 kg/ha or 25 kg/ha nitrogen in urea formula spring application. These treatments were compared against two other treatments: a grass yield treatment without alfalfa fertilized at 170 kg/ha or 0 kg/ha N.

Treatments included:

C > Uninoculated alfalfa with 0 or 25 kg/ha/yr N fertilizer;
PB > Alfalfa inoculated with PB-50 penicillium bilaii and 0 or 25 kg/ha/yr N fertilizer;
NP > Alfalfa inoculated with N-Prove NRG-34 rhizobia and 0 or 25 kg/ha/yr N fertilizer;
TT > A dual inoculation with TagTeam (NRG-34 + PB-50) and 0 or 25 kg/ha/yr N fertilizer;
Yield > No alfalfa with 0 or 170 kg/ha/yr N fertilizer;

Diagram 7.4 : Experimental Design



Alfalfa was seeded at 10 kg/ha and inoculated onsite. The site was irrigated approximately 55 mm in 2005 and 80 mm in 2006.

Composite spring soil samples revealed no deficiencies except nitrogen. Nitrogen was added based on experimental derived values on June 2, 2005 and June 8, 2006.

Vegetation sampling occurred August 8 - 10, 2005, August 8 - 12, 2006 for the 2nd year plots, and August 22 - 26, 2006 for the establishment year stand.

In 2005 and 2006, timothy was sampled at the anthesis stage and alfalfa mean height ranged from 30 cm for establishment year plants and 80 cm for second year plants. Alfalfa was harvested at the less than 10% bloom in the establishment years and 40% in the 2006 second year collection. Each sample consisted of above ground biomass, plant counts, heights, stages of growth, percent basal cover, and weed incidence.

This site was sprayed with 2-4D Amine at 60 mL/500 L prior to alfalfa emergence in 2005 to reduce the competition from shepeard's purse (*Capsella bursa-pastoris*) and narrow-leaved hawksbeard (*Crepis tectorum*). Foxtail barley (*Hordeum jubatum*) was hand picked in both years. This is a very weedy site and although the vegetation sampling included high weed counts, the percent DM from the weeds was not substantial in most plots because the dried weight of the weeds was low.

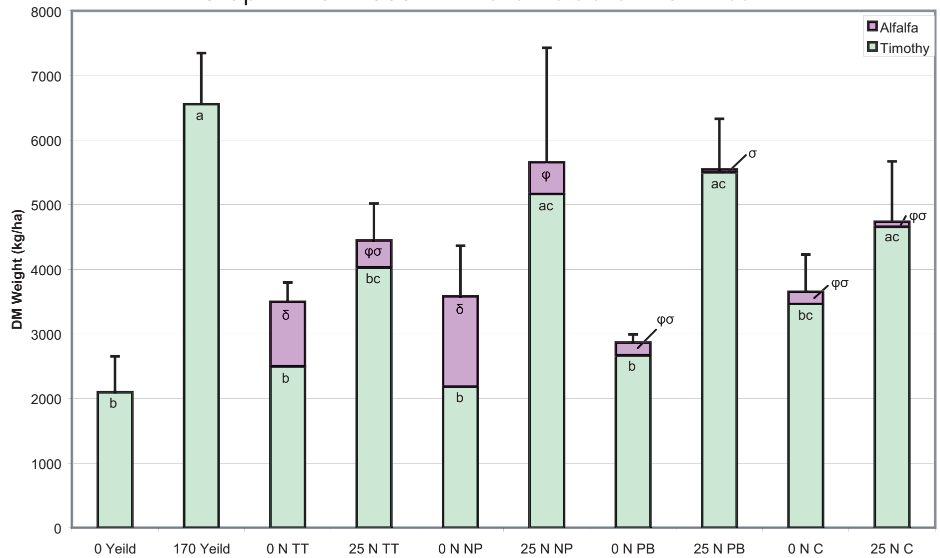
Fall soil samples taken October 3 within each block highlighted slight differences in the micronutrients compared to the spring soil sample. Lower amounts of B and Mn might be accounted for through the withdrawal by alfalfa, but likely is due to the variability in the soil because the samples by treatment do not show any consistent trends.

Results were analyzed based on dry matter (DM) yield, nitrogen (N) yield, and nitrogen fixation (NF) using SAS.

Results and Discussion

The results for this trial had considerable variability from populations of other species, bare patches where no plants established, and evident nodulation on the few clovers in the field. Nonetheless, the first and second year results for this trial are very encouraging and warrant further research.

Graph 7.16 : 2005 DM Yeild Establishment Year

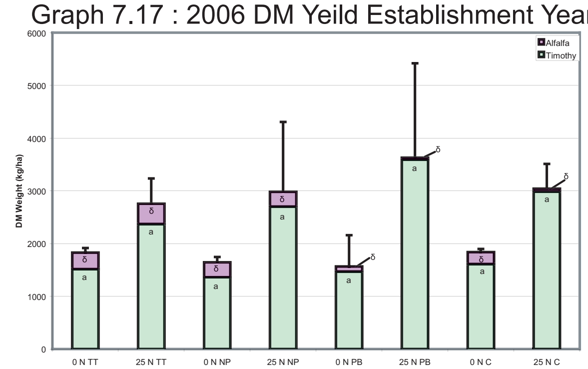


Yield Assessment

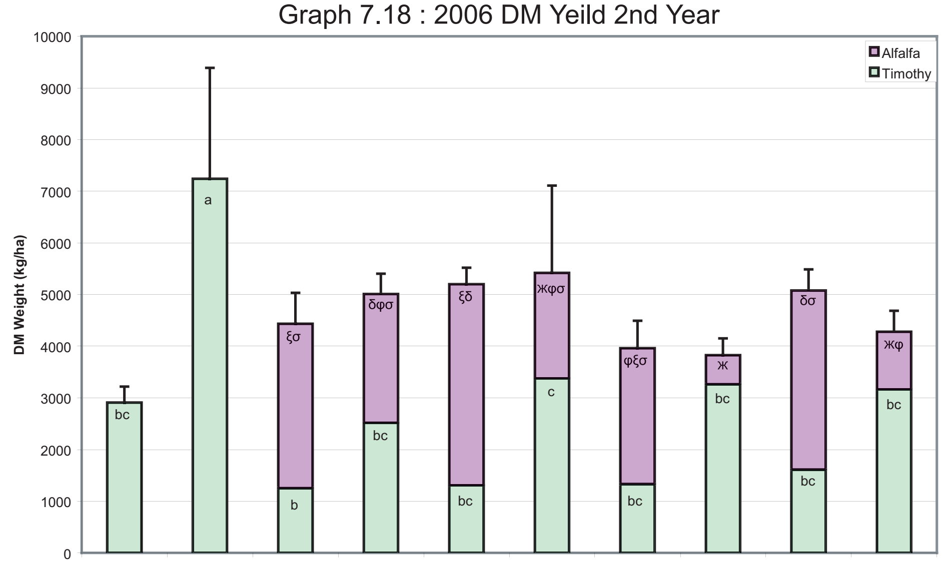
DM weight

In the establishment year the contribution of alfalfa depends on the fertilizer rate and treatment applied. When we look at the establishment year stand results, the data is very encouraging. The total DM yields were much higher for the 170 Yield treatment (high fertilizer), but the alfalfa yields of the N-Prove and TagTeam treatments

Graph 7.17 : 2006 DM Yeild Establishment Year



Graph 7.18 : 2006 DM Yeild 2nd Year



with no fertilized contributed substantially to the sward. The 0 N NP and 0 N TT treatments provided upwards of 1000 kg/ha in 2005, but this trend was hard to pick out of the 2006 establishment year data, where the results are not very clear. Into year 2 of alfalfa growth, the contribution of the alfalfa becomes dominant in the mixed swards.

Examining the N yields we see that the inclusion of alfalfa in the sward is quite dramatic with three unfertilized samples (0 N TT, 0 N NP, and 0 N C) providing N yields on a per hectare basis that are equal to or greater than the fertilized timothy stand. The N yield of the 0 N NP treatment was 102 kg/ha which is an N contribution of 90% to that mixed sward.

Nitrogen use efficiency was calculated to determine the recovery efficiency of timothy. Using the following equation:

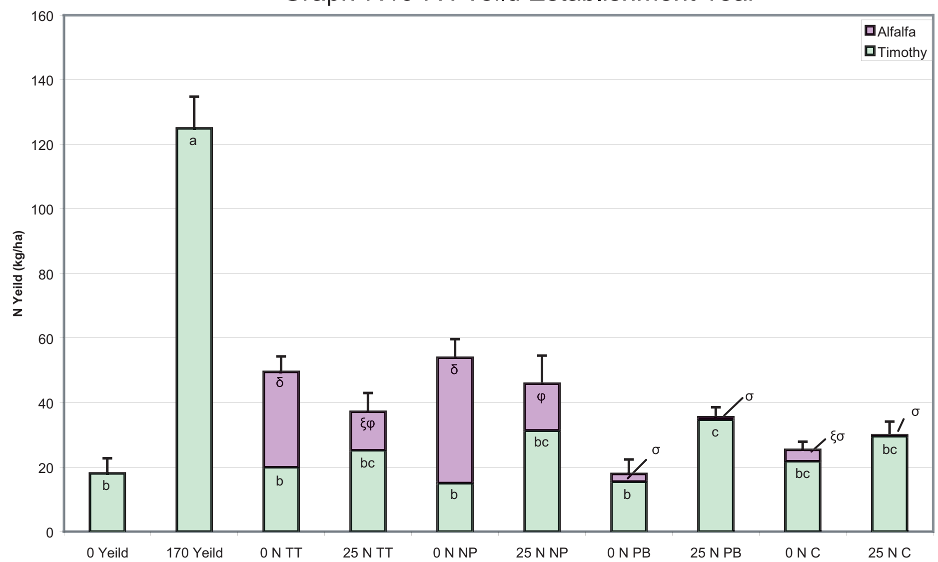
$RE = (Uf - Uo)/Na \times 100$

Uf is the fertilized N uptake

Uo is the unfertilized N uptake

Na is the nitrogen applied

Graph 7.19 : N Yeild Establishment Year



Graph 7.20 : N Yeild Establishment Year 2006

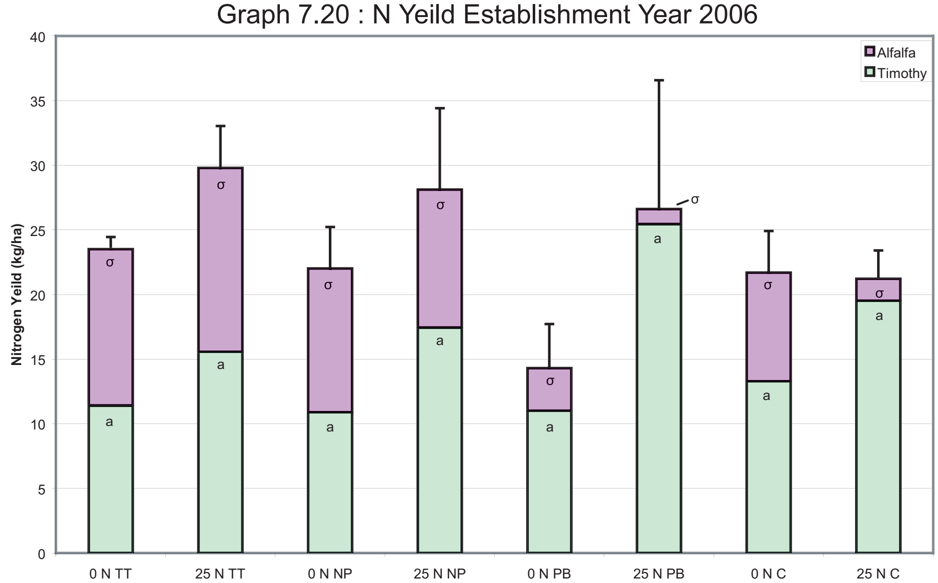
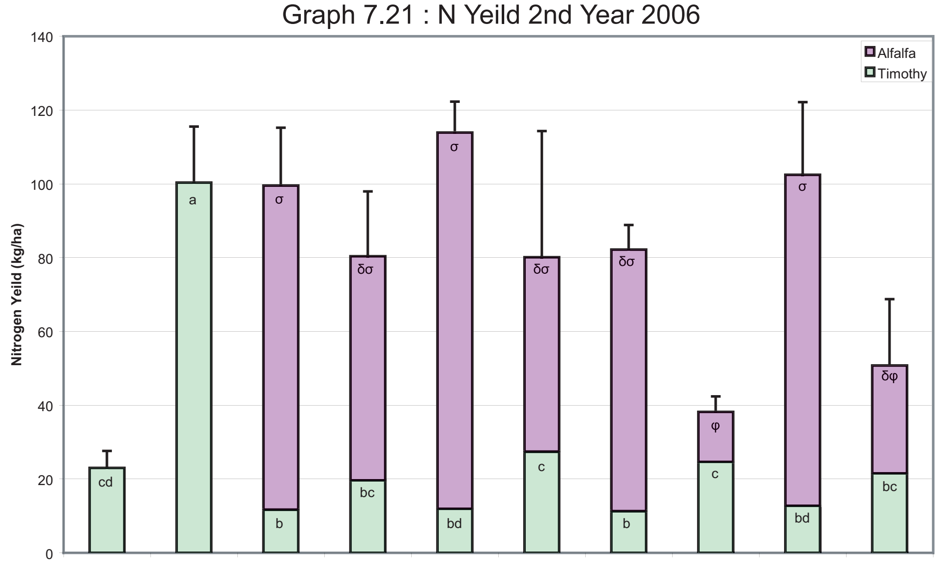
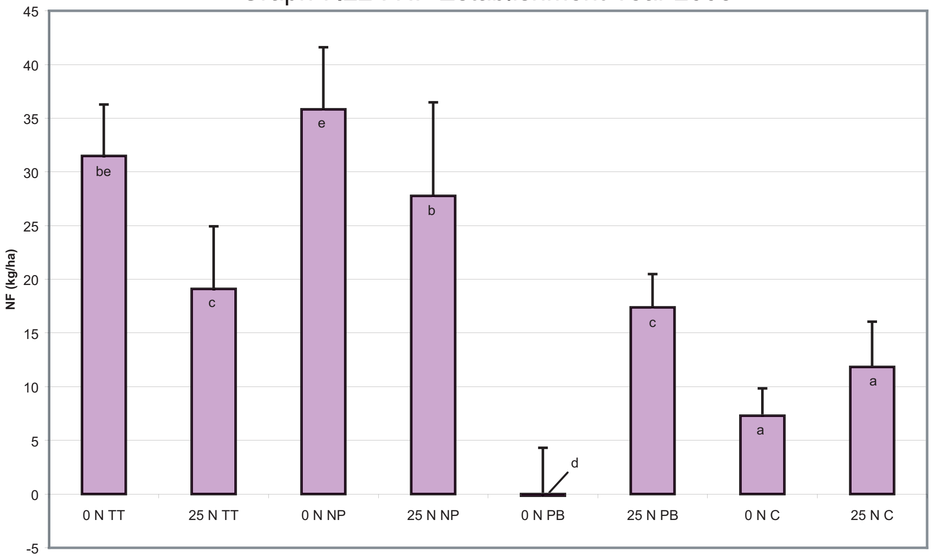


Photo 7.12 : Looking east at the timothy plot near the end of the season September 14, 2005.

Graph 7.21 : N Yeild 2nd Year 2006



Graph 7.22 : NF Establishment Year 2005



Graph 7.23 : NF 2nd Year 2006

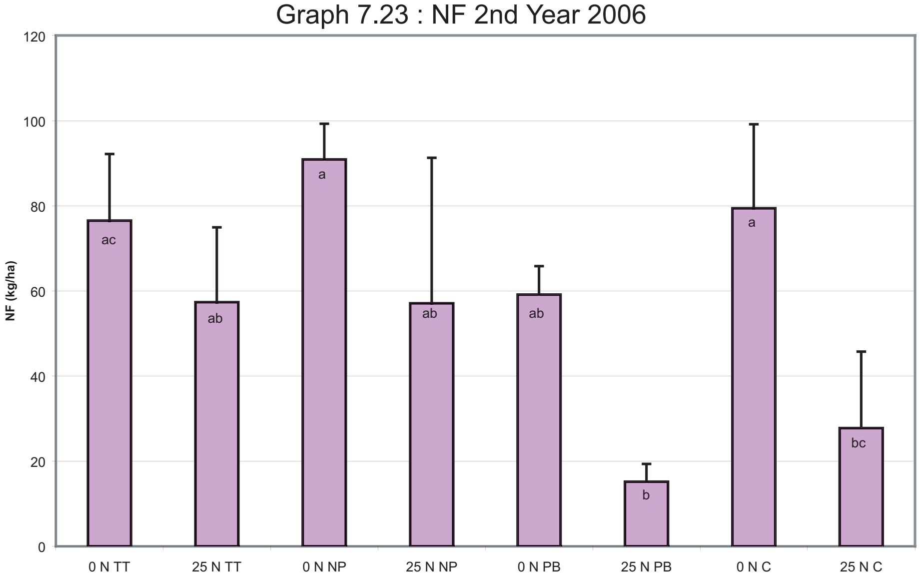


Table 7.7 : Recovery efficiency for timothy

2005	2006	
62.9	45.5	Mean
6.3	6.4	SD
10	14.1	CV%

The recovery of nitrogen ranges from 45 - 63% in 2005 and 2006, 2006 has a substantially lower recovery likely due to weather and lack of precipitation.

Nitrogen Fixation

Nitrogen fixation was assessed using the total plant nitrogen difference method, using an unfertilized, monoculture timothy stand as the reference crop (see table 7.8).

Table 7.8 : NON NF Mean Reference value for *Phleum pratense*

2005	2006	
18.0	23.0	Mean
4.7	4.6	SD
26.1	19.9	CV%

The concern using this established timothy stand was similar to that of the bromegrass, that the monocot grass is able to accumulate greater N reserves over the season and would not provide a good baseline to use. We have a little more comfort in using timothy as it is not as competitive in alkaline or dry conditions.

Based on this reference crop we see NF rates of upwards of 35 kg/ha in the establishment year based on N-Prove treatment with no fertilizer, and second year NF rates of 90 kg/ha based on the same treatment. By the second year the control treatments are nodulated so don't provide a non-nodulated reference NF of a mixed timothy/alfalfa sward. The most startling trend is the difference in the NF rates based on the fertilizer addition. Adding only 25 kg/ha N reduces the NF of the sward across all treatments by an average of over 50%.

Conclusion

The recommendation in extension publications is for a small addition of N in mixed legume/grass forage stands, based on this result it is important to keep in mind the species composition and conditions during stand establishment, a 0 N fertilizer rate will lead to good alfalfa establishment in a timothy mix.

8.0 Forage Demonstration

Location: Research Farm, Whitehorse YT

Funding: Yukon Government

Objective: To assess the yield and hardiness of various forages species in south central Yukon conditions.

Introduction

Forage demonstration plots were set up in August 2005 at the research farm. A series of 24 plots were established on the south side of the research farm for a demonstration of various forage species in Yukon conditions.

Methods & Materials

The site is on a slightly shaded, flat aspect within the 1.5 ha cleared area of the research farm. Irrigation and fertilizer are applied to provide optimum conditions.

An overwintering assessment was carried out in the spring to quantify the winterkill levels. The percent cover pace point intercept method was used to determine the percent cover and infer the rate of winterkill. A transect was delineated through the middle of each plot and at 0.5 meter paces the point of a bar was placed down randomly on the ground. Walking through the plot from West to East and recording what the point of the bar contacted - weed, grass/legume, bare ground or dead patch. If more than one contact is made, both are recorded. Each point is recorded and the percent of plant surviving in the stand is calculated.

Through the summer, growth conditions and weed problems were noted and dealt with as needed. On June 7, 500 mL embutox/100L in the sprayer was applied to the plots to reduce the incidence of weeds.

Results

This past season was considered another establishment year for this demonstration site. Many of the forage species had to be reseeded or overseeded because of poor survival. A weed management system was also implemented to knock back the scorpion-weed (*Phacelia franklinii*) and hawksbeard (*Crepis tectorum*). Alsom, another alfalfa, Tophand, was added, bringing the total number of alfalfa varieties demonstrated to 4.

Below in table 8.1 are the results from the percent cover assessment in the spring.

Table 8.1 : Winter Survival of Forage Species

	Observations	Weed	Grass	Bare	Dead	Inferred Winter Survival %
Carlton Smooth Bromegrass	21	17	5	0	0	24
Kirk Crested Wheatgrass	24	14	9	3	0	38
Fleet Meadow Bromegrass	25	19	2	5	0	8
Boreal Creeping Red Fescue	25	11	13	2	2	52
Richmond Timothy	25	13	12	2	2	48
Bellevue Reed Canary grass	25	22	1	2	0	4
AC Nordica Alfalfa	25	16	1	2	6	4
2065 MF Alfalfa	24	11	0	8	5	0
Ram Red Clover	23	9	0	9	5	0
Peace Alfalfa	24	12	3	5	4	13
Russian Wildrye	23	9	14	3	0	61
Violet Wheatgrass	24	17	8	1	0	33
Kentucky Bluegrass	23	2	22	0	1	96
Tufted Hairgrass	24	8	16	1	0	67
Slender Wheatgrass	24	11	9	7	0	38
Okay Orchardgrass	23	11	2	6	5	9

Discussion

Of the 16 species planted in 2005 only a handful showed strong overwintering ability. Winterkill was assessed May 30 using the percent cover method. Those grasses that faired well include Kentucky Bluegrass (a perennial favorite for lawns), russian wildrye, boreal creeping red fescue and tufted hairgrass. Although successful germination was noted last August on all plots, some of the species had to be reestablished because there were few plants that survived the winter. Alfalfa 2065 MF and AC Nordica, as well as Ram Red Clover, Meadow Bromegrass and Orchardgrass were all reseeded.

Physical pulling of plants and spraying herbicides were used for weed control. The main problem species were hawksbeard and scorpion weed. On June 7 Embutox 2-4,DB was applied to the whole plot. Embutox is formulated for use with both legumes and grasses. Scorpion weed was only mildly affected by the first pass of the Embutox.

There was very limited disease incidence, the only concern was smut on the slender wheatgrass, this smut also somewhat affected the violet wheatgrass to a lesser extent.

This demonstration site will continue to be monitored and data collection on stages of growth and biomass will be assessed in 2007.

Photo 8.1 : Overview of the Forage Demonstration Site

Appendix - Site data Tables for 1.0

Site WG Agroclimatic data for the 2006 growing season

Date	May	June	July	August	September	Totals
Mean Temp °C	7.3	11.8	14.2	10.6	7.3	
Max Temp °C	21.7	29.1	28.0	22.5	18.7	
Min Temp °C	-8.2	-2.7	1.9	-0.8	-7.1	
Total Precip mm	0.9	59.2	23.2	25.7	17.2	149.5
Calculated GDD	60.2	205.2	286.6	173.5	22.3	747.8
Calculated Effective GDD	71.1	242.2	338.2	204.7	26.4	882.5
Frost Free Days	13	22	31	27	15	
Last spring Frost, First Fall Frost		28-Jun		03-Aug		37
Killing Frost Free Days	19	27	31	31	20	
Killing Frost Free period		25-Jun			05-Sep	73

Site TR Agro-climatic data for the 2006 growing season

Date	May	June	July	August	September	Totals
Mean Temp °C	7.3	12.2	14.3	10.6	7.3	
Max Temp °C	20.2	30.4	26.4	21.7	18.7	
Min Temp °C	-9.8	-3.1	-0.3	-2.2	-8.2	
Total Precip mm	0.2	59.2	26.6	27.5	16.2	150.9
Calculated GDD	61.9	217.4	288.3	133.6	0.0	701.3
Calculated Effective GDD	73.1	256.6	340.2	157.7	0.0	827.5
Frost Free Days	13	20	30	20	15	
Last spring Frost, First Fall Frost		28-Jun	30-Jul			33
Killing Frost Free Days	20	24	31	28	21	
Killing Frost Free period		28-Jun		23-Aug		57

Site SM Agro-climatic data for the 2006 growing season

Date	May	June	July	August	September	Totals
Mean Temp °C	8.0	13.0	15.2	11.9	8.1	
Max Temp °C	19.5	28.4	29.1	21.3	18.7	
Min Temp °C	-6.0	-0.9	2.7	-0.8	-6.6	
Total Precip mm	0.0	31.3	85.4	20.7	16.0	172.9
Calculated GDD	76.5	232.1	316.4	213.9	25.7	864.7
Calculated Effective GDD	90.3	273.9	373.4	252.4	30.3	1020.3
Frost Free Days	18	25	31	30	19	
Last spring Frost, First Fall Frost		25-Jun		06-Aug		43
Killing Frost Free Days	26	30	31	31	24	
Killing Frost Free period	30-May				05-Sep	99

Site TA Agro-climatic data for the 2006 growing season

Date	May	June	July	August	September	Totals
Mean Temp °C	7.4	12.7	14.7	11.1	7.8	
Max Temp °C	18.7	29.1	24.8	19.8	17.9	
Min Temp °C	-3.4	-0.6	5.0	2.5	-3.4	
Total Precip mm	-	-	-	-	-	
Calculated GDD	64.8	231.2	301.0	188.0	56.2	841.1
Calculated Effective GDD	76.5	272.8	355.1	221.8	66.3	992.5
Frost Free Days	18	29	31	31	25	
Last spring Frost, First Fall Frost		24-Jun		10-Sep		79
Killing Frost Free Days	28	30	31	31	29	
Killing Frost Free period	30-May			16-Sep		110

Site DH Agro-climatic data for the 2006 growing season

Date	May	June	July	August	September	Totals
Mean Temp °C	7.5	11.7	14.0	10.2	7.0	
Max Temp °C	19.8	31.5	26.7	22.1	17.5	
Min Temp °C	-5.8	-2.9	0.3	-1.5	-6.3	
Total Precip mm	-	-	-	-	-	
Calculated GDD	56.4	201.8	278.1	160.9	36.6	733.8
Calculated Effective GDD	66.6	238.2	328.1	189.9	43.1	865.9
Frost Free Days	9	19	31	24	16	
Last spring Frost, First Fall Frost		28-Jun		01-Aug		35
Killing Frost Free Days	24	27	31	31	24	
Killing Frost Free period		25-Jun			10-Sep	78

Site BD Agro-climatic data for the 2006 growing season

Date	May	June	July	August	September	Totals
Mean Temp °C	7.4	12.0	14.3	10.6	7.2	
Max Temp °C	19.0	28.7	26.3	21.0	17.9	
Min Temp °C	-6.8	-2.9	0.3	-1.1	-7.9	
Total Precip mm	-	-	-	-	-	
Calculated GDD	59.4	210.7	289.5	173.7	37.9	771.3
Calculated Effective GDD	70.1	248.6	341.7	205.0	44.8	910.2
Frost Free Days	11	21	31	26	14	
Last spring Frost, First Fall Frost		28-Jun		31-Jul		34
Killing Frost Free Days	25	28	31	31	24	
Killing Frost Free period		25-Jun			09-Sep	77

Site Carmacks Agro-climatic data for the 2006 growing season

Date	May	June	July	August	September	Totals
Mean Temp °C	8.4	14.9	16.2	12.3	7.7	
Max Temp °C	23.2	31.1	27.9	23.6	19.8	
Min Temp °C	-5.8	-2.4	3.7	-1.5	-6.3	
Total Precip mm	-	-	-	-	-	
Calculated GDD	85.7	297.3	348.0	225.1	53.5	1009.8
Calculated Effective GDD	101.1	350.9	410.7	265.7	63.2	1191.5
Frost Free Days	14	28	31	30	18	
Last spring Frost, First Fall Frost		07-Jun		29-Aug		84
Killing Frost Free Days	20	29	31	31	23	
Killing Frost Free period		07-Jun			13-Sep	99

Site DA Agro-climatic data for the 2006 growing season

Date	May	June	July	August	September	Totals
Mean Temp °C	7.4	12.1	14.3	10.6	7.2	
Max Temp °C	19.8	28.3	27.5	20.2	17.9	
Min Temp °C	-5.8	-2.0	2.5	-0.2	-5.3	
Total Precip mm	-	-	-	-	-	
Calculated GDD	61.2	211.6	287.6	175.1	38.4	773.9
Calculated Effective GDD	72.2	249.7	339.3	206.6	45.3	913.2
Frost Free Days	16	26	31	30	18	
Last spring Frost, First Fall Frost		25-Jun		23-Aug		60
Killing Frost Free Days	26	30	31	31	26	
Killing Frost Free period	30-May				10-Sep	104

Site GZ Agro-climatic data for the 2006 growing season

Date	May	June	July	August	September	Totals
Mean Temp °C	7.4	11.7	14.3	10.6	7.2	
Max Temp °C	20.6	30.7	29.1	24.4	20.2	
Min Temp °C	-8.4	-2.9	0.7	-1.1	-7.3	
Total Precip mm	-	-	-	-	-	
Calculated GDD	61.6	201.2	288.1	173.8	38.7	763.4
Calculated Effective GDD	72.7	237.4	340.0	205.1	45.7	900.8
Frost Free Days	10	18	31	21	12	
Last spring Frost, First Fall Frost		28-Jun		01-Aug		35
Killing Frost Free Days	17	24	31	31	19	
Killing Frost Free period		28-Jun			09-Sep	74

Environment Canada Whitehorse Airport Agro-climatic data for the 2006 growing season

Date	May	June	July	August	September	Totals
Mean Temp °C	6.8	12.3	14.2	11.5	8.1	
Max Temp °C	19.6	29.4	25.8	20.3	18.6	
Min Temp °C	-3.9	0.4	1.4	1.1	-2.3	
Total Precip mm	16.2	38.0	33.4	32.5	35.6	198.3
Calculated GDD	56.2	217.5	285.1	195.4	82.1	836.3
Calculated Effective GDD	66.3	256.7	336.4	230.6	96.9	986.8
Frost Free Days	19.0	30.0	31.0	31.0	25.0	
Last spring Frost, First Fall Frost	May-30				Sep-10	104
Killing Frost Free Days	27	30	31	31	29	
Killing Frost Free period	May-30				Sep-23	117

Environment Canada Carmacks Agro-climatic data for the 2006 growing season

Date	May	June	July	August	September	Totals
Mean Temp °C	7.4	13.4	15.5	12.0	8.3	
Max Temp °C	23.1	30.4	27.9	23.6	20.4	
Min Temp °C	-5.5	-3.8	3.2	-1.9	-7.7	
Total Precip mm	-	-	-	-	-	
Calculated GDD	68.1	250.8	326.2	217.6	27.7	890.4
Calculated Effective GDD	80.4	295.9	384.9	256.8	32.7	1050.7
Frost Free Days	11	25	31	29	16	
Last spring Frost, First Fall Frost		Jun-25		Aug-06		43
Killing Frost Free Days	15	29	31	31	22	
Killing Frost Free period		Jun-07			Sep-05	91

Appendix - data Tables for 5.0

Statistic Canada, Canola yield report from 1986-2006

Canadian Canola Yield - updated February 12, 2007								
Tonnes/Acre								
Source: Field Crop Reporting Series - Statistics Canada								
Year	Ontario	Manitoba	Saskatchewan	Alberta	British Columbia	Total Canada	Avg. West	
							kg/hectare	g/m2
1986	0.791	0.579	0.572	0.567	0.433	0.572	1413	141
1987	0.738	0.585	0.574	0.575	0.499	0.576	1423	142
1988	0.494	0.397	0.401	0.548	0.543	0.459	1134	113
1989	0.622	0.351	0.412	0.521	0.455	0.445	1099	110
1990	0.863	0.529	0.518	0.523	0.369	0.523	1292	129
1991	0.707	0.634	0.513	0.544	0.374	0.544	1344	134
1992	0.849	0.647	0.485	0.485	0.364	0.526	1299	130
1993	0.768	0.485	0.526	0.607	0.445	0.526	1299	130
1994	0.809	0.607	0.485	0.485	0.485	0.526	1299	130
1995	0.768	0.526	0.445	0.566	0.526	0.485	1198	120
1996	0.89	0.687	0.566	0.566	0.485	0.607	1499	150
1997	0.849	0.647	0.485	0.526	0.404	0.526	1299	130
1998	0.89	0.647	0.526	0.566	0.607	0.566	1398	140
1999	0.768	0.687	0.607	0.647	0.607	0.647	1598	160
2000	0.849	0.647	0.566	0.607	0.687	0.607	1499	150
2001	0.89	0.607	0.445	0.607	0.566	0.526	1299	130
2002	0.728	0.687	0.404	0.485	0.445	0.485	1198	120
2003	0.809	0.728	0.485	0.687	0.566	0.566	1398	140
2004	0.849	0.687	0.526	0.768	0.687	0.647	1598	160
2005	0.566	0.566	0.728	0.849	0.849	0.728	1798	180
2006	0.93	0.728	0.607	0.768	0.445	0.687	1697	170
						Max:	1798	180
						Min:	1099	110

Appendix - Summary Data Tables for 7.0

2005 alfalfa monoculture establishment year data							
SUMMARY	kg/ha	%	kg/ha	kg/ha	Standard Deviations		
	DM	plantn	N Yeild	NF	DM SD	N SD	NF SD
TT	3072.3	3.1	94.9	76.9	70.0	5.4	5.4
C	2521.1	3.3	82.6	64.6	451.8	13.3	13.3

2006 alfalfa monoculture 2nd year data							
SUMMARY	kg/ha/yr	%	kg/ha/yr	kg/ha/yr	Standard Deviations		
	DM	plantn	N Yeild	NF	DM SD	N SD	NF SD
TT Cut	1579.1	2.7	43.1	20.1	444.6	12.8	12.8
TT NC	3369.1	2.6	88.6	65.6	1514.7	40.1	40.1
C Cut	1507.7	2.9	42.7	19.7	727.3	19.1	19.1
C NC	2840.1	2.6	73.4	50.4	460.7	10.4	10.4

2005 RAR establishment year data												
SUMMARY		%	kg/ha	kg/ha	%	kg/ha	%	kg/ha	kg/ha	kg/ha	Standard Deviations	
	DM A	plantna	nyeilda	DM G	plantng	nyeildg	contributiona	DM Weed	Total DM	Total N	DM SD	N SD
25 N C	3.1	0.0	0.0	4193.5	1.0	40.5	0.0	6.7	4196.6	40.5	1621.0	15.0
25 N PB	26.3	1.3	0.6	4298.6	1.0	43.1	1.9	28.7	4324.9	43.7	392.8	3.3
25 N NP	53.7	2.3	1.5	3987.4	0.9	36.8	4.8	30.2	4041.0	38.3	411.7	6.0
25 N TT	38.9	1.9	1.0	4823.2	1.1	51.4	2.5	10.9	4862.1	52.4	1067.3	11.2
170 N C	24.2	0.7	0.7	7493.5	1.8	138.1	0.9	19.0	7517.8	138.8	900.9	29.9
170 Yeild	0.0	0.0	0.0	8740.8	1.9	165.4	0.0	13.9	8740.8	165.4	793.8	46.7

2006 RAR establishment year data												
SUMMARY		%	kg/ha	kg/ha	%	kg/ha	%	kg/ha	kg/ha	kg/ha	Standard Deviations	
	DM A	plantna	nyeilda	DM G	plantng	nyeildg	contributiona	DM Weed	Total DM	Total N	DM SD	N SD
25 N C	118.4	0.0	0.0	2919.8	1.3	37.0	0.0	7.8	3038.2	37.0	223.3	2.3
25 N PB	78.4	0.0	0.0	3373.8	1.2	40.8	0.0	1.9	3452.2	40.8	175.1	1.1
25 N NP	111.2	2.0	0.9	3159.6	1.3	39.6	2.1	2.2	3270.9	40.4	265.1	3.5
25 N TT	96.7	3.3	1.5	3376.8	1.3	43.7	3.7	1.7	3473.5	45.3	322.4	6.9
170 N C	46.8	0.0	0.0	6005.6	1.7	101.3	0.0	0.8	6052.5	101.3	828.5	14.8
170 Yeild	0.0	0.0	0.0	6681.9	1.9	127.5	0.0	14.1	6681.9	127.5	287.8	15.8

2006 RAR 2nd year data												
SUMMARY		%	kg/ha	kg/ha	%	kg/ha	%	kg/ha	kg/ha	kg/ha	Standard Deviations	
	DM A	plantna	nyeilda	DM G	plantng	nyeildg	contributiona	DM Weed	Total DM	Total N	DM SD	N SD
25 N C	11.6	0.7	0.2	3300.8	1.3	42.4	0.4	41.6	3353.9	42.6	437.3	2.4
25 N PB	189.6	3.3	6.3	2793.4	1.4	37.0	13.7	6.9	2989.9	43.3	799.0	7.4
25 N NP	207.9	3.3	6.8	2960.5	1.4	40.1	14.2	55.3	3223.8	46.9	209.7	3.8
25 N TT	246.3	3.2	7.8	2810.8	1.4	38.5	17.2	28.5	3085.6	46.4	262.1	2.6
170 N C	27.0	1.8	0.8	6651.3	1.8	119.3	0.9	12.5	6690.8	120.1	674.0	24.4
170 Yeild	0.0	0.0	0.0	7208.1	1.8	128.9	0.0	5.5	7213.6	128.9	847.1	27.6

2005 RF smooth bromegrass establishment year data															
SUMMARY		%	kg/ha	kg/ha	%	kg/ha	%	kg/ha	kg/ha	%	kg/ha	Standard Deviations			
	DM A	plantna	nyeilda	DM G	plantng	nyeildg	contributiona	Total DM	Total N	RE	NF	DM SD	N SD	RE SD	NF SD
0 Yeild	0.0	0.0	0.0	3317.8	0.7	21.6	0.0	3317.8	21.6			345.0	2.3		
170 Yeild	0.0	0.0	0.0	10764.5	1.6	169.9	0.0	10764.5	169.9	87.2		861.0	28.5	17.5	
0 N TT	394.5	3.4	13.6	2085.9	0.8	16.7	43.5	2480.4	30.3		8.7	601.4	8.3		8.3
25 N TT	147.0	2.8	4.1	4361.4	0.7	31.1	11.7	4508.4	35.2		13.6	185.4	3.0		3.0
0 N NP	235.6	3.2	7.6	2672.3	0.7	19.1	26.4	2907.9	26.7		5.0	761.2	5.2		5.2
25 N NP	115.2	2.1	3.5	4755.3	0.6	30.2	10.9	4870.5	33.8		12.1	471.0	5.5		5.5
0 N PB	16.5	1.0	0.2	2273.4	0.8	17.3	0.9	2289.8	17.4		-4.2	192.8	1.3		1.3
25 N PB	23.1	1.1	0.7	4104.9	0.6	23.7	2.2	4128.0	24.4		2.7	261.5	11.5		11.5
0 N C	11.1	1.0	0.2	3218.7	0.7	22.4	1.0	3229.7	22.7		1.0	587.9	4.9		4.9
25 N C	6.8	0.8	0.1	5074.4	0.7	35.7	0.3	5081.3	35.8		14.2	807.2	5.6		5.6

2006 RF smooth bromegrass establishment year data

SUMMARY	DM A	% plantna	kg/ha nyeilda	kg/ha DM G	% plantng	kg/ha nyeildg	% contributiona	kg/ha Total DM	kg/ha Total N	kg/ha NF	Standard Deviations DM SD	N SD	NF SD
0 N TT	232.80	3.17	7.38	2297.92	0.82	18.63	27.93	2530.72	26.01	-0.39	351.66	1.50	1.50
25 N TT	162.60	3.06	5.04	3102.25	0.81	25.11	15.84	3264.85	30.15	3.75	258.98	6.46	6.46
0 N NP	112.83	2.97	3.20	1896.93	0.69	13.12	17.51	2009.76	16.32	-10.08	324.67	5.66	5.66
25 N NP	239.59	3.07	7.39	2406.90	0.74	17.88	28.97	2646.49	25.27	-1.13	113.52	0.58	0.58
0 N PB	27.93	1.60	0.76	1929.66	0.76	14.77	3.96	1957.58	15.52	-10.88	223.33	4.52	4.52
25 N PB	26.94	3.21	0.87	3263.82	0.80	26.07	3.21	3290.76	26.93	0.53	377.52	1.73	1.73
0 N C	21.62	1.58	0.60	2296.37	0.79	18.29	2.84	2317.99	18.89	-7.51	391.65	5.07	5.07
25 N C	12.67	1.70	0.34	2941.28	0.83	24.52	1.19	2953.95	24.86	-1.54	464.78	4.92	4.92

2006 RF smooth bromegrass 2nd year data

SUMMARY	DM A	% plantna	kg/ha nyeilda	kg/ha DM G	% plantng	kg/ha nyeildg	% contributiona	kg/ha Total DM	kg/ha Total N	% RE	kg/ha NF	Standard Deviations DM SD	N SD	RE SD	NF SD
0 Yeild	0.0	0.0	0.0	3516.7	0.8	26.4	0.0	3516.7	26.4			242.9	1.9		
170 Yeild	0.0	0.0	0.0	10313.5	0.9	95.0	0.0	10313.5	95.0	40.3		760.7	4.5	1.6	
0 N TT	782.1	2.5	19.7	2531.7	0.7	17.4	49.0	3313.8	37.1		10.7	585.1	13.5		13.5
25 N TT	443.3	2.6	11.7	4034.1	0.7	26.8	28.1	4477.3	38.4		12.0	555.2	8.9		8.9
0 N NP	919.4	2.4	21.8	2394.6	0.7	17.5	47.0	3314.0	39.2		12.8	711.7	17.6		17.6
25 N NP	385.3	2.5	9.5	4074.2	0.7	28.5	24.1	4459.4	37.9		11.5	57.3	5.5		5.5
0 N PB	609.1	2.7	16.2	2084.4	0.7	15.1	50.8	2693.5	31.3		4.9	329.6	5.4		5.4
25 N PB	292.0	2.7	7.6	3211.1	0.7	21.3	24.5	3503.1	28.9		2.5	638.4	7.6		7.6
0 N C	553.9	2.5	13.9	3053.2	0.7	21.3	33.6	3607.1	35.2		8.7	649.2	11.3		11.3
25 N C	232.2	1.8	6.3	3744.5	0.7	25.4	18.5	3976.7	31.7		5.3	58.8	3.4		3.4

2005 RF timothy establishment year data

SUMMARY	DM A	% plantna	kg/ha nyeilda	kg/ha DM G	% plantng	kg/ha nyeildg	% contributiona	kg/ha DM Weed	kg/ha Total DM	kg/ha Total N	% RE	kg/ha NF	Standard Deviations DM SD	N SD	RE SD	NF SD
0 Yeild	0.0	0.0	0.0	2096.0	0.9	18.0	0.0	0.7	2096.7	18.0			555.5	4.7		
170 Yeild	0.0	0.0	0.0	6554.9	1.9	124.9	0.0	51.0	6605.9	124.9	62.9		790.7	9.8	6.3	
0 N TT	998.4	3.0	29.6	2497.5	0.8	19.9	58.5	305.3	3801.2	49.5		31.5	300.6	4.8		4.8
25 N TT	414.9	2.9	11.9	4031.7	0.6	25.2	32.1	39.6	4486.2	37.1		19.1	572.5	5.8		5.8
0 N NP	1398.6	2.8	38.8	2182.4	0.7	15.0	70.8	286.7	3867.7	53.9		35.8	782.6	5.8		5.8
25 N NP	491.7	3.0	14.5	5164.8	0.6	31.4	32.1	161.3	5817.8	45.8		27.8	1772.6	8.7		8.7
0 N PB	195.2	0.9	2.4	2669.3	0.6	15.5	10.4	15.1	2879.7	17.9		-0.2	127.4	4.5		4.5
25 N PB	44.9	0.9	0.7	5500.1	0.6	34.7	1.8	1.8	5546.7	35.4		17.4	783.9	3.1		3.1
0 N C	187.1	1.0	3.6	3463.2	0.6	21.8	13.8	92.4	3742.7	25.3		7.3	578.5	2.5		2.5
25 N C	77.9	0.9	0.3	4656.6	0.7	29.6	0.9	211.6	4946.1	29.9		11.8	935.1	4.2		4.2

2006 RF timothy establishment year data

SUMMARY	DM A	% plantna	kg/ha nyeilda	kg/ha DM G	% plantng	kg/ha nyeildg	% contributiona	kg/ha DM Weed	kg/ha Total DM	kg/ha Total N	kg/ha NF	Standard Deviations DM SD	N SD	NF SD
0 N TT	311.8	3.9	12.1	1516.2	0.8	11.4	51.5	25.5	1853.5	23.5	0.5	87.2	0.9	0.9
25 N TT	385.1	3.7	14.2	2371.2	0.7	15.6	47.4	42.0	2798.3	29.8	6.8	479.1	3.2	3.2
0 N NP	282.2	3.9	11.1	1362.3	0.8	10.9	49.6	22.0	1666.5	22.0	-1.0	101.7	3.2	3.2
25 N NP	279.7	3.8	10.7	2702.3	0.6	17.4	39.9	113.0	3095.0	28.1	5.1	1325.1	6.3	6.3
0 N PB	95.2	3.5	3.3	1470.0	0.8	11.0	23.8	25.5	1590.8	14.3	-8.7	594.0	3.4	3.4
25 N PB	35.7	3.2	1.2	3592.6	0.7	25.5	4.8	48.0	3676.3	26.6	3.6	1789.8	10.0	10.0
0 N C	226.3	3.7	8.4	1612.2	0.8	13.3	37.9	41.3	1879.7	21.7	-1.3	58.9	3.2	3.2
25 N C	51.3	3.4	1.7	2989.6	0.7	19.5	7.9	83.3	3124.2	21.2	-1.8	469.5	2.2	2.2

2006 RF timothy 2nd year data

SUMMARY	DM A	% plantna	kg/ha nyeilda	kg/ha DM G	% plantng	kg/ha nyeildg	% contributiona	kg/ha DM Weed	kg/ha Total DM	kg/ha Total N	% RE	kg/ha NF	Standard Deviations DM SD	N SD	RE SD	NF SD
0 Yeild	0.0	0.0	0.0	2911.1	0.8	23.0	0.0	2.7	2913.8	23.0			308.8	4.6		
170 Yeild	0.0	0.0	0.0	7242.3	1.4	100.4	0.0	7.7	7250.0	100.4	45.5		2145.6	15.2	6.4	
0 N TT	3183.1	2.8	87.8	1251.5	0.9	11.7	87.7	47.8	4482.4	99.5		76.5	599.5	15.7		15.7
25 N TT	2493.9	2.4	60.7	2516.6	0.8	19.7	74.3	8.0	5018.5	80.4		57.4	392.8	17.6		17.6
0 N NP	3896.7	2.6	102.0	1305.4	0.9	12.0	89.6	60.0	5262.2	113.9		90.9	318.9	8.4		8.4
25 N NP	2046.1	2.6	52.7	3375.1	0.8	27.4	63.0	34.7	5455.8	80.1		57.1	1687.6	34.2		34.2
0 N PB	2629.1	2.7	70.9	1333.3	0.9	11.3	85.7	5.8	3968.2	82.2		59.1	529.1	6.7		6.7
25 N PB	561.8	2.4	13.6	3264.4	0.8	24.6	34.7	3.8	3830.1	38.2		15.2	325.2	4.2		4.2
0 N C	3465.9	2.6	89.7	1612.9	0.8	12.8	87.2	363.0	5441.8	102.4		79.4	409.2	19.7		19.7
25 N C	1117.7	2.7	29.2	3162.9	0.7	21.6	53.1	22.7	4303.2	50.8		27.8	406.6	18.0		18.0

Glossary

Above Mean Sea Level (AMSL) - Refers to the elevation (on the ground) or altitude (in the air) of any object, relative to the average sea level.

Atmometer - An instrument used to measure evaporation.

CR-10 - Campbell Scientific programmable datalogger used to measure soil moisture, soil temperature, and water flow, also used to compute irrigation run times.

Cultivar – cultivar is a cultivated selection that can be propagated reliably in a prescribed manner.

DeciSiemens per metre (dS/m) - Salt tolerances are usually given in terms of the stage of plant growth over a range of electrical conductivity (EC) levels. Electrical conductivity is the ability of a solution to transmit an electrical current. To determine soil salinity EC, an electrical current is imposed in a glass cell using two electrodes in a soil extract solution taken from the soil being measured (soil salinity). The units are usually given in deciSiemens per metre (dS/m).

Effective Growing Degree Days (EGDD) - An upward adjustment made to the GDD value to account for the boost plants receive from the long daylight hours at northern latitudes.

Evapotranspiration (ET) - The combined water loss from soil evaporation and plant transpiration.

Field Capacity - The water content of the soil where all free water has been drained from the soil through gravity.

Furrow – a long shallow trench in the ground (especially one made by a plow).

Growing Degree Days (GDD) - Can be calculated in a number of ways, Agriculture branch calculates them by beginning the fifth consecutive day with mean temperatures above 5^{o}C, and terminating the day of the first killing frost (-2.2^{o}C) which occurs after mid-July.

Irrometer - Ceramic tipped soil water sampling device.

Management Allowable Depletion (MAD) - The percentage of water at field capacity which can be removed from the soil by the plant prior to reaching the wilting point, at which time irrigation should occur.

Permanent Wilting Point (PWP) - The soil moisture content at which the plant will wilt and die. Any remaining water in the soil is insufficient to meet the plant requirements.

pH - A measure of a solution's acidity or alkalinity based on it's activity of hydrogen ions (H^+).

Sward – land covered with grassy turf, a lawn or meadow.

Variety – a rank in botany below that of species.

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