Cash & Bioenergy Crop Feasibility Study for the Bulkley-Nechako Regional District

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Acknowledgments

Funding for this project has been provided by Agriculture and Agri-Food Canada and the B.C. Ministry of Agriculture through the Canada-B.C. Agri-Innovation Program under *Growing Forward 2*, a federal-provincial-territorial initiative. The program is delivered by the Investment Agriculture Foundation of B.C. Funding and support for this project has also been provided by the Chan Sisters Foundation, Nak'azdli First Nations Band, and the Aboriginal Business Development Centre.

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Prepared by

This report was researched and written by Hallbar Consulting Inc. (www.HallbarConsulting.com). Research and support was also provided by Northern Grown Consulting (https://northerngrownconsulting.com/) and the University of Northern British Columbia (www.unbc.ca/).

Disclaimer

Abbreviations and Acronyms

B.C.	British Columbia
BNRD	Bulkley Nechako Regional District
GDD	Growing Degrees Days
FFD	Frost Free Days
NRR	Natural Resource Regions
NPV	Net Present Value
U.S.	United States

Contents

Tables

Figures

1. Executive Summary

The objective of this study was to evaluate the suitability of growing specialty and alternative crops in the Bulkley Nechako Regional District (BNRD). A suitability assessment was conducted as detailed models for most specialty and alternative crops are currently not available. The suitability assessment evaluated over sixty specialty and alternative crops in the BNRD. Crop appropriateness was deemed to be suitable, potentially suitable, or unsuitable using current BNRD climate and soil conditions, current soil and potential climate conditions resulting from projected climate change in the next ten years, and potential climate and soil conditions resulting from projected climate change in the next few years and/or achievable modifications through investment (e.g., irrigation, improvements to soil nutrient content and organic matter, and drainage).

The first step of the suitability assessment evaluated if a specialty or alternative crop could successfully grow in the BNRD based on current local climate and soil conditions. The key criteria used were historic average temperature, precipitation, winter minimum temperature, and growing days, and soil texture, pH, and drainage. The BNRD is characterized as having low annual precipitation, long cold winters, cool springs, and fall months that can have below-freezing temperatures. The major soil classifications in the BNRD are moderate to poorly drained, with compact structure. Soils also tend to have neutral to acidic pH, and low organic matter. Crops that were assessed as being able to successfully grow in these climate and soil conditions were considered suitable.

The second step of the suitability assessment evaluated if a specialty or alternative crop could successfully grow in the BNRD based on anticipated climate change in the next few years, or with some reasonable level of investment to improve growing conditions. For most climate change scenarios, the BNRD is projected to experience a mean annual temperature increase, which will increase the annual number of growing degree and frost free days. The BNRD is also projected to experience a slight increase or decrease in precipitation (depending upon the scenario). Crops that were assessed as being able to successfully grow in anticipated climate and current soil conditions were also assessed as suitable, while crops assessed as being able to successfully grow in anticipated climate conditions and with some type of modification resulting from a reasonable level of investment to overcome climate or soil limitations, were considered potentially suitable.

Of the specialty and alternative crops assessed, fifteen were identified as being suitable for commercial production in the BNRD. Of these fifteen crops, Black Chokeberry, Camelina, Garlic, Haskap Berry, Hemp, Hops, Jerusalem Artichoke, Quinoa, Saskatoon Berry, and Sugar Beet were chosen for further assessment using multiple criteria, including product versatility, uniqueness, potential local interest, market opportunity, and competition. Of the ten crops identified, the suitability of five of these crops was also assessed for bioenergy production. These were Camelina, Jerusalem Artichoke and Quinoa residues, Hemp, and Sugar Beet.

The economic feasibilities of the identified specialty and alternative crops were estimated using net present value (NPV) calculations. Garlic, Haskap Berry, Saskatoon Berry, and Jerusalem Artichoke were found to have the highest NPV. Black Chokeberry, Hops, and Quinoa were found to have a low, yet still positive NPV. Hemp had the lowest, negative, NPV, whereas Sugar Beet had a negative to positive NPV, and Camelina had a slightly positive NPV. Bioenergy production using Camelina, Jerusalem Artichoke or Quinoa residues was calculated to have a very small positive impact on NPV (when done in conjunction with the sale of the crop's seeds or tubers). Bioenergy production using Hemp or Sugar Beet increased the uncertainty of the crop's NPV.

Production costs can vary greatly depending upon a multitude of factors, including acreage grown, required inputs, and assumed equipment cost and availability. Crop yield can be heavily affected by variety, and suitability to local conditions, while crop value can be impacted by quality, market demand, transportation and marketing costs, and end use. Bioenergy costs can vary with the cost of harvesting and storing the

biomass, savings on fuel displaced, cost of required equipment, and size of project. Because of this, estimated NPVs for the identified specialty and alternative crops should be viewed as ballpark only. Site-specific, local research into the identified specialty and alternative crops is required to refine estimated NPVs based on actual acreage, variety, quality, local conditions, market demand, etc.

A Crop Decision Tool was also created. This Tool was developed to help overcome the often limited amount of information or local experience available to farmers interested in specialty or alternative crops. The Crop Decision Tool can be used by farmers and others to assess the suitability of crops based on local conditions. The Crop Decision Tool should be viewed as a simple, yet effective first step for crop suitability assessment. Once a crop is assessed using this Tool, and if the results look promising, further investigation should be carried out to confirm its suitability and potential.

2. Introduction

Over the past few decades agricultural productivity and diversity in the Bulkley-Nechako Regional District (BNRD) has declined relative to the province of B.C.[1] During this time food production and distribution have also become increasingly globalized and consolidated; resulting in greater competition from agricultural producers elsewhere who can often take advantage of economies of scale, cheap labour, and/or production subsidies. Food sales are also becoming dominated by large stores that often won't purchase local fresh produce due to its higher price, often limited scale, and lack of year-round availability.

Declining productivity and diversity, globalization, and consolidation have driven down the demand for and prices paid to many BNRD farmers[2]; making profitability increasingly difficult, and impacting the success of new entrants to agriculture. With fewer new and young farmers, average age of the agriculture workforce is increasing. At the same time, increasing demand for renewable energy has increased interest in bioenergy crops. This demand is especially high in communities where expensive and environmentally less attractive propane and diesel are used for heat and/or power, or using 'dual-purpose' crops that produce food/feed/other products in addition to being suitable for renewable energy production.

One possibility for improving the economic viability, profitability, and resilience of the BNRD's agriculture community is through the introduction of suitable specialty or alternative crops.[3] These crops, with appropriate markets and infrastructure, can represent improved income opportunities for BNRD farmers by avoiding competition on a commodity basis. Furthermore, specialty and alternative crops can also enable national and international market penetration, increase local youth retention, job creation, and business development, and also help meet increasing demand for renewable alternatives to fossil fuels.

Potential for growing specialty and alternative crops in the BNRD, which can result in a wide range of products, from gourmet and healthy foods, to natural health products, ethnic foods, herbs (both culinary and medicinal), and non-food products, such as oils, lotions, materials, fuels and energy, is highlighted in the 2012 Regional District of Bulkley-Nechako Agriculture Plan.[4] The Plan states that "local producers may be able to capitalize on the unique characteristics of their products" and that "distinctiveness is a powerful strategy when competing with large industry [and is] efficient from both the retailer and consumer perspective" (page 106).

The purpose of this study was to identify ten non-invasive, non-forestry, specialty or alternative crops eligible for cultivation in the Agricultural Land Reserve that could be successfully grown in the BNRD, and that have potential to provide new economic opportunities for local farmers. These crops were identified based on their suitability to local climate and soil conditions, both in the short and long-term, as well as their versatility, uniqueness, market opportunity, and economic feasibility.

The hope is that information from this study will be used by local farmers, industry specialists, and others in the BNRD to help achieve the long-term goal of establishing new agricultural industries in the region; agricultural industries that positively impact the profitability and sustainability of local agriculture, and increase local youth retention and employment.

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[1] Regional District of Bulkley-Nechako Agriculture Plan 2012. Available at www.rdbn.bc.ca/images/pdf/planning/AgriculturePlan/Agriculture_Plan.pdf

[2] *Ibid.*

[3] Specialty and alternative crops are those that are currently not widely grown in the BNRD, or that can be grown for bioenergy production purposes, and have potential for high sales value or specialized benefits.

[4] Available at www.rdbn.bc.ca/images/pdf/planning/AgriculturePlan/Agriculture_Plan.pdf

3. Climate & Soil

The first consideration for specialty and alternative crop assessment is whether the crop can grow in the BNRD. Potential for growth is dependent upon the key criteria of climate and soils.

3.1 Climate

Temperature

From 1981-2010, Vanderhoof and Smithers had similar average annual temperatures of 4.4 and 4.2°C respectively, whereas Fort St. James and Prince George were both colder with average annual temperatures of 3.5°C. Of the four areas, Vanderhoof was warmer in the late spring, summer and early fall months, with daily average temperatures from April to October of 11.3°C, compared to 10.2, 10.2 and 10°C for Smithers, Fort St. James, and Prince George, respectively. Smithers was warmer in the winter months, with daily average temperatures from November to March of -4.1°C and a daily minimum of -11°C, compared to -5.1°C and -13.3°C in Vanderhoof, -5.8°C and -13.7°C in Fort St. James, and -5.6°C and -12.5°C in Prince George (Table 1).

Table 1: 1981-2010 Temperatures for Smithers, Vanderhoof, Fort St. James & Prince George[5]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr/Av
Smithers (°C)													
Daily Av	-7.2	-4.4	0.1	4.8	9.4	13.0	15.2	14.6	9.9	4.4	-2.1	-7.1	4.2
Daily Max	-3.5	0.2	5.2	10.9	15.9	19.4	21.6	21.3	15.8	8.8	1.0	-3.6	9.4
Daily Min	-11	-8.8	-4.9	-1.3	2.9	6.5	8.6	7.9	4.0	-0.1	-5.2	-10.7	-1.0
Vanderhoof (°C)													
Daily Av	-9.0	-5.5	-0.2	5.6	10.7	14.4	16.3	15.9	11.0	5.0	-2.8	-8.1	4.4
Daily Max	-4.5	-0.1	5.9	12.4	17.8	21.3	23.5	23.3	17.9	10.3	0.9	-4.1	10.4
Daily Min	-13.3	-10.9	-6.3	-1.3	3.5	7.4	9.1	8.3	4.1	-0.3	-6.5	-12.1	-1.5
Fort St. James (°C)													
Daily Av	-9.5	-6.8	-1.8	3.9	9.2	13.4	15.4	14.8	10.2	4.3	-3.0	-7.8	3.5
Daily Max	-5.3	-1.7	4.0	9.9	15.6	19.6	21.8	21.7	16.4	9.0	0.6	-3.8	9.0
Daily Min	-13.7	-11.8	-7.7	-2.2	2.8	7.2	8.9	7.9	3.9	-0.5	-6.5	-11.7	-2.0
Prince George (°C)													
Daily Av	-9.0	-6.2	-1.4	4.3	9.7	13.3	15.5	14.7	9.4	3.1	-3.8	-7.8	3.5
Daily Max	-5.4	-2	3.6	10.2	16.3	19.7	22.2	21.4	15.2	7.1	0.9	-4.4	8.7
Daily Min	-12.5	-10.4	-6.4	-1.7	3.0	6.9	8.7	7.9	3.6	-1.0	-6.7	-11.1	-1.6

Precipitation

From 1981-2010, Vanderhoof and Fort St. James received similar annual precipitation of 489 and 487 mm (~19.2 inches), respectively. Monthly precipitation for Vanderhoof and Fort St. James was also similar; with the greatest monthly difference being no more than 6.4 mm (~0.25 inches). With 549 mm (~21.6 inches) of annual precipitation, Smithers received slightly more than Vanderhoof and Fort St. James. However, from March to September, when precipitation is often most important for crops, total precipitation in Smithers was only 10 mm (~0.4 inches) greater than Vanderhoof or Fort St. James. Prince George received the greatest amount of annual precipitation at 654 mm (~25.7 inches), and the greatest total precipitation from March to September; up to 74 mm (~2.9 inches) more than the other areas (Table 2).

[5] Source: www.climate.weather.gc.ca

Annual and monthly rainfall for Vanderhoof and Fort St. James from 1981-2010 were also similar; annual rainfall was 332 mm (~13.1 inches) and 315 mm (~12.4 inches), respectively, and the greatest difference in monthly rainfall was no more than 6.2 mm (~0.24 inches). From 1981-2010, annual rainfall for Smithers was 367 mm (~14.4 inches), while monthly rainfall from March to September was only 14 mm (~0.5 inches) greater than Vanderhoof or Fort St. James. From 1981-2010, Prince George received the greatest amount of annual rainfall at 420 mm (~16.5 inches), and the greatest monthly precipitation from March to September; up to 66 mm (~2.6 inches) more than the other areas (Table 2).

Table 2: 1981-2010 Precipitation for Smithers, Vanderhoof, Fort St. James & Prince George[6]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr/Av
Smithers													
Rainfall (mm)	10.1	5.5	6.7	18.7	37.4	55.2	45.6	43.8	53.8	56.9	25.6	8.0	367.3
Snowfall (cm)	44.5	23.5	16.7	5.6	0.7	0	0	0	0	8.6	37.4	45.6	182.6
Precip (mm)	54.6	29.0	23.4	24.3	38.1	55.2	45.6	43.8	53.8	65.5	63	53.6	549.2
Vanderhoof													
Rainfall (mm)	6.6	5.4	7.1	19.4	34.2	56.8	52.3	43.1	44	43.3	16.1	3.8	332.1
Snowfall (cm)	37.8	21.2	17.3	6	0.5	0.2	0	0	0.3	7.5	29	37.5	157.3
Precip (mm)	44.4	26.6	24.4	25.4	34.7	57	52.3	43.1	44.3	50.8	45.1	41.3	489.4
Fort St. James													
Rainfall (mm)	4.9	3.6	5.9	18	38.2	50.6	50.6	45	39.1	38.7	15.7	4.2	314.5
Snowfall (cm)	43.2	26.4	19.8	5.7	0.7	0	0	0	0.2	9.4	28.8	38.4	172.6
Precip (mm)	48.1	30	25.7	23.7	38.9	50.6	50.6	45	39.3	48.1	44.5	42.6	487.1
Prince George													
Rainfall (mm)	6.9	7.1	9.4	34.6	43.3	64.8	53.7	49.9	57.7	67.5	21	4.3	420.2
Snowfall (cm)	58.8	29.5	25	7.7	1.4	0	0	0	0.4	10.6	44.4	56.2	234
Precip (mm)	65.7	36.6	34.4	42.3	44.7	64.8	53.7	49.9	58.1	78.1	65.4	60.5	654.2

Growing Degree Days

Growing Degrees Days (GDD) are estimated using the mean daily temperature above a certain threshold base temperature, such as 0 or 5°C, accumulated on a daily basis over a period of time, such as a year. From 1981-2010, Smithers (2,305 GDD), Fort St. James (2,280 GDD), and Prince George (2,238 GDD) all had similar annual GDD above 0°C. Unfortunately, no historical GDD data could be found for Vanderhoof. Monthly GDD above 0°C for Smithers, Fort St. James, and Prince George were also similar from March to September, with differences less than 1%. From 1981-2010, and as with GDD above 0°C, annual GDD above 5°C and monthly GDD from March to September were also similar for Smithers, Fort St. James, and Prince George (Table 3).

Frost Free Days

Frost Free Days (FFD) is the number of days between the last date of 0°C in spring and the first date of 0°C in fall. FFD therefore determines the time available for crop production, and as such, which crops can be grown. Average dates for last frost in Smithers, Fort St James, and Prince George vary by six days (Prince George being the earliest and Fort St. James the latest), while average dates for first frost varies by ten days (Smithers being the latest and Fort St. James the earliest). On average, Fort St. James has 10 and 12 fewer FFD than Prince George and Smithers, respectively. Unfortunately, no historical data could be found for Vanderhoof.

[6] *Ibid.*

The range of FFD is also important as it shows the number of days which can be frost free in any given year. Vanderhoof has the smallest range of FFD (41), followed by Prince George (54), and then Smithers (63). Fort St. James has by far the largest range of FFD (97). This means there is a 10% chance the last frost of spring in Fort St. James could be as late as July 10th and the first fall frost as early as July 21st. This is important to keep in mind when considering a crop's intolerance to frost (Table 4).

Table 3: 1981-2010 Growing Degree Days for Smithers, Fort St. James & Prince George[7]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr/Av
Smithers													
GDDs >0°C	9.1	15.2	53.9	148.4	291.2	389.5	470.2	453.1	297.5	144.4	25.5	7.4	2,305.4
GDDs >5°C	0.2	0.1	2.4	33.3	139.5	239.5	315.2	298.1	149.5	33.2	1	0.2	1,212.2
Fort St. James													
GDDs >0°C	6.3	11.6	38.3	125.5	283.8	401.6	477	458.9	306.3	144.6	22.2	4.3	2,280.4
GDDs >5°C	0.2	0.1	2.4	33.3	139.5	239.5	315.2	298.1	149.5	33.2	1	0.2	1,229.8
Prince George													
GDDs >0°C	4.9	8.5	37.7	138.4	300.3	399.5	479	454.8	282.5	113.7	14.3	4.2	2,237.8
GDDs >5°C	0.1	0	0.7	28.9	149.7	249.5	324	299.8	137.2	22.6	0.4	0	1,212.9

Table 4: 1981-2010 Frost Free Days for Smithers, Vanderhoof, Fort St. James & Prince George[8]

	Smithers	Vanderhoof	Fort St. James	Prince George
Average Date Last Frost	May 31st	N/A	June 1st	May 26th
Average Date First Frost	Sept 16th	N/A	Sept 6th	Sept 10th
Average Frost-Free Days	108	N/A	96	106
Range Frost-Free Days	62 – 125	88 – 129	10 – 107	72 – 126

Climate Summary

The above climate data shows the BNRD is characterized as having low annual precipitation, long cold winters, cool springs, and fall months that can have below-freezing temperatures. Of the four areas, Vanderhoof is the warmest during late spring, summer, and early fall months (April to October). During the other months (November to March) Smithers is the warmest and Fort St. James the coldest. This means crops could be planted earliest in Vanderhoof, and crops requiring higher summer temperatures may have a slightly greater chance of success in Vanderhoof. This also suggests that perennial crops may also have a slightly greater chance of success in Smithers because winter months are warmer.

Vanderhoof and Fort St. James receive similar annual precipitation and rainfall, while Smithers and Prince George receive higher annual precipitation and rainfall. However, Vanderhoof, Fort St. James, and Smithers all receive similar monthly precipitation and rainfall from March to September, while Prince George receives higher monthly precipitation and rainfall for these months. This means that crops requiring higher precipitation might have a slightly better chance of success in Prince George.

Smithers, Fort St. James, and Prince George all had similar average annual GDD above 0°C and 5°C. Average date of last frost in Smithers, Fort St James, and Prince George is also fairly similar, as is the average date of

[7] *Ibid.*
[8] *Ibid*.

the first frost. Despite this, the average FFD for Smithers and Prince George is at least 10 days longer than Fort St. James. Finally, Vanderhoof and Smithers have the smallest range of FFD, followed by Prince George, and then Fort St. James. Crops requiring more GDD will likely have equal chances of success in Fort St. James, Prince George and Smithers, whereas frost intolerant crops will likely have the greatest chance of success in Vanderhoof and Prince George, and be at greatest risk in Fort St. James.

Climate Change Projections

Anticipated and relevant climate change effects, most importantly changes in temperatures and precipitation, may enable farmers in the BNRD to 'push the boundaries' with crops not traditionally grown on a commercial scale due to current climate limitations. Climate change could therefore provide opportunities to grow previously untested specialty or alternative crops in the BNRD.

In the Climate Change and Resource Development Scenarios for the Nechako Watershed: Workshop Report May 2015[9], two climate change scenarios (Low and High Change) are projected for 2010-2050. In the Low Change Scenario, the Nechako Watershed is expected to experience a mean annual temperature increase of 1.6°C, with this increase being more dramatic in the northern and central-eastern areas of the watershed. Annual precipitation levels are expected to decrease in all seasons except for spring, with the greatest precipitation decrease of 33 mm (~1.3 inches) in summer. This decrease will be more significant in the western part of the Watershed than in the northern and eastern areas. In the High Change Scenario, the Nechako Watershed is expected to experience a mean annual temperature increase of 3°C, again this increase being more dramatic in the northern and central-eastern areas of the watershed, and winter having the highest increase. Annual precipitation levels are expected to increase by 110 mm (~4.3 inches), with the greatest precipitation increases in the eastern and southwestern areas.

In the Omineca, Skeena, and Northeast Natural Resource Regions (NRR) B.C.[10] report, by 2055 mean annual temperature is projected to increase by 3.5°C, with summers warming more than other seasons. Fort St. James' mean temperatures are predicted to increase by 3.2°C in winter, 3.1°C in spring, 3.7°C in summer, and 3.2°C in fall. A mean annual precipitation increase of ~45 mm (with greatest increase in the fall and winter) is projected. Vanderhoof is predicted to see increases of 3.2°C in the winter, 3.1°C in the spring, 3.8°C in the summer, and 3.1°C in the fall. The area is also predicted to see a mean annual precipitation increase of ~35 mm (with greatest increase in the fall and winter). Any increase in precipitation is expected as rainfall because snow is projected to decrease by almost 30% in Fort St. James and Vanderhoof. Fort St. James and Vanderhoof are also expected to have 44 and 42 more frost free days respectively (Table 5).

While the Climate Change and Resource Development Scenarios for the Nechako Watershed Report and the Omineca, Skeena, and Northeast Natural Resource Regions Report estimate climate change scenarios 35 years or more into the future, the impact of climate change is already being felt in the BNRD. Below are two graphs showing the historical average and the 2016 GDD for Smithers and Prince George (Figure 1).[11] Both graphs show that in 2016 GDD were higher than the historical average (in the case of Smithers > 20% higher).

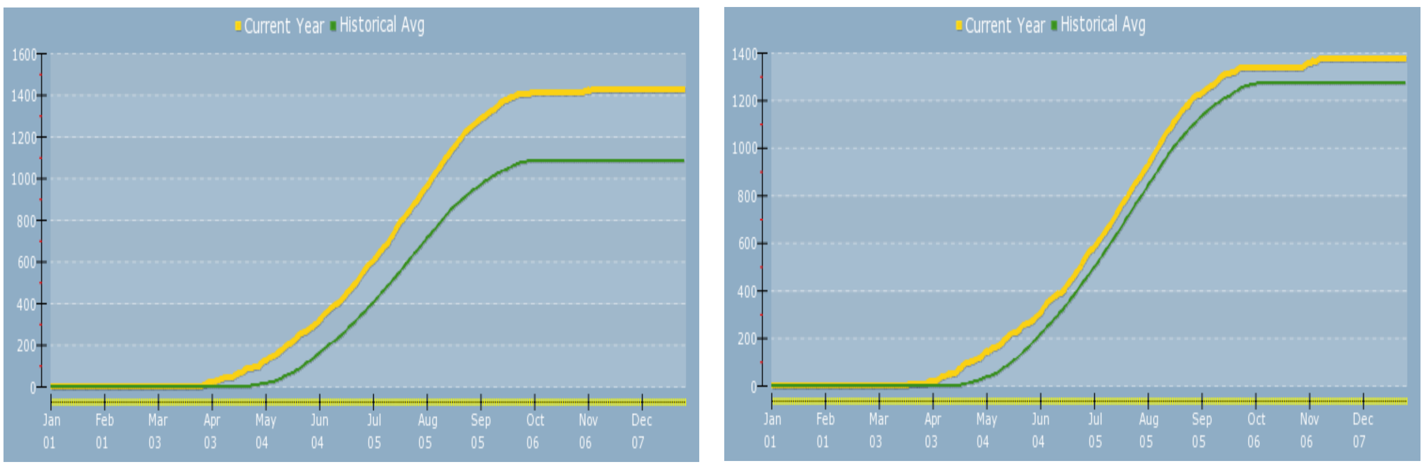
[9] Available at http://web.unbc.ca/~sdery/datafiles/FinalWorkshopReport2015.pdf
[10] Available at www.for.gov.bc.ca/hfd/pubs/Docs/Tr/TR097.htm
[11] Fort St James and Vanderhoof data was not available.

Table 5: Climate Change Projections for 2050*

	MAT (°C)	MAP (mm)	MSP (mm)	GDD >5°C	FFD
Smithers	7.4	545	152.5	1,876.1	154
Vanderhoof	7.8	525	154.6	N/A	N/A
Fort St James	7.0	532	149.1	1,920	140
Prince George	7.0	700	196.0	1,923	148
Abbotsford (today)	10.4	1,538	164	2,000	208

*MAT: Mean Annual Temperature. MAP: Mean Annual Precipitation. MSP: Mean Summer Precipitation. GDD >5: Growing Degree Days above 5°C. FFD: Number of Frost Free Days. * Note: Projected change in climate in the Omineca, Skeena, and Northeast Natural Resource Regions B.C. report were used with current climate data from the Government of Canada to calculate table data.*

Figure 1: Historical Average & 2016 GDDs for Smithers (left) and Prince George (right)[12]

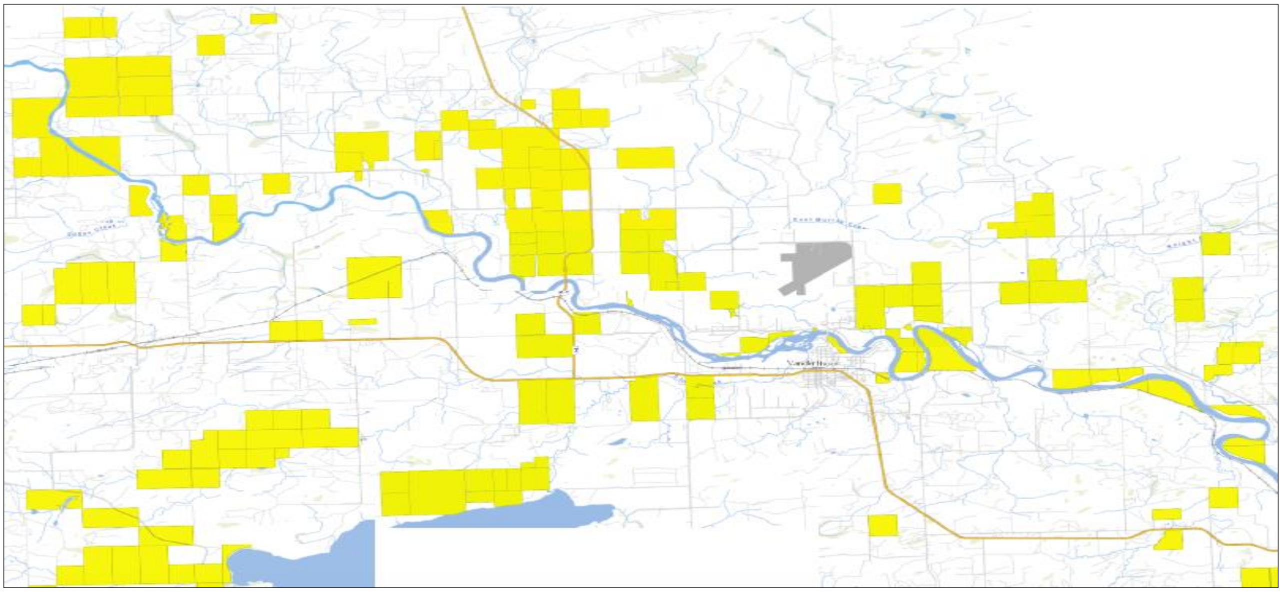


Projected climate changes in temperature, and therefore GDD and FFD, are often seen as having the greatest impact on which crops can be grown locally because any projected reductions in precipitation could potentially be mitigated using irrigation. Currently, only 1.2% of farmland (a total of 3,391 hectares) in the Omineca NRR has access to irrigation[13] (Figure 2). One reason for this is because historically irrigation hasn't been required for crops traditionally growth in the BNRD. Furthermore, farmers in the BNRD that do have water licences generally only use a small fraction of their annual water allocation (~3-4" of irrigation). Therefore, if farmers in the BNRD can secure water licences (i.e., the necessary waterway doesn't have restricted allocation status), they could irrigate up to 10-15" of irrigation annually. Irrigation equipment installation is estimated to cost ~$2,500-3,700/hectare ($1,000-1,500/acre).

[12] Source: www.farmwest.com

[13] Statistics Canada, 2011.

Figure 2: Ares of the Nechako Valley Currently with Water Licences (highlighted in yellow)[14]



Note: Map shows licences for all types of water use, not just agricultural.

3.2 Soils

While there is great variation in soils within the BNRD,[15] the most relevant soils in the Nechako Valley are the Vanderhoof, Fort St. James, and Chilako Series (Table 6):

Vanderhoof Series

Vanderhoof series is a silty clay loam located largely within the Nechako Valley and in small areas around Fort Fraser and Burns Lake. The surface horizon is lightly coloured and weakly structured, underlain with compact, almost impermeable clay. These soils tend to puddle in the spring and dry to a firm compact mass in the summer that may hinder emergence of seeds and plant growth. These soils are characteristically low in organic matter.

Fort St. James Series

Fort St. James series occur principally in the Necosli Creek, Fort St. James, and Pinchi districts. There is little to no surface horizon, and the B horizon has no structure and is very compact. In terms of agricultural use, these soils have issues with moisture resulting from their fine texture, compactness, and low organic-matter content. These soils tend to be acidic and have poor drainage.

Chilako Series

Chilako series are dominated by sandy loam texture with stones and gravel on the crests of knolls, and finer-textured soil at low-points. Excessive stones and boulders are often present on the surface, making these soils largely unsuitable for agricultural development.

Around the municipality of Fort St. James, the major soil classifications are Fort St James heavy clay and Chilako sandy loam. Around the municipality of Vanderhoof, the main soil classification is Vanderhoof clay. Fort St. James heavy clay and Vanderhoof clay were developed from water-deposited material and share texture and

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[14] Data collected from iMapBC www2.gov.bc.ca/gov/content/governments/about-the-bc-government/databc/geographic-data-and-services/imapbc

[15] Soil data was collected using Government of Canada surveys and maps. Soil descriptions are from Farstad, L. and Laird, D.G. (1954). Soil Survey of the Quesnel, Nechako, Francois Lake and Bulkley-Terrace Areas in the Central Interior of British Columbia. Queen's Printer and Controller of Stationery, Ottawa.

drainage characteristics. Both have clay to clay-loam texture, are moderate to poorly drained, and have compact soil structure. Furthermore, both soils tend to have neutral to acidic pH, and low organic matter. This means crops tolerant of neutral to acidic soil with fine to moderate texture, moderate to poor drainage, that require low nutrient levels, and are not affected by compaction will likely have greatest chance of success around the municipalities of Fort St. James and Vanderhoof.

Alternatively, management practices requiring a reasonable level of investment to improve soil health and overcome soil limitations can be implemented to enable production of high-value, low-volume crops on small parcels of land (as opposed to low-value, high-volume crops). Furthermore, and if necessary, soil pH can also be altered slightly (e.g., from 5.5 to 6.5 or vice versa). However, this requires inputs of lime or elemental sulphur which can become expensive.[16]

Table 6: Soil Type Classification & Descriptions for the Nechako Valley[17]

Soil Classification	Parent Material	Drainage	pH	Compact	Organic Matter
Fort St James Heavy Clay	Lacustrine clay	Moderately well to poorly drained	Neutral to acidic	Yes	Low
Chilako Stony Sandy Loam	Sandy loam to loam	Slowly penetrable; well to poorly drained	Neutral to acidic	No	Low
Vanderhoof Clay	Lacustrine clay	Moderately well to imperfectly drained	Neutral to acidic	Yes	Low

The most relevant soils in the Bulkley Valley are Barrett, Driftwood Loam, and Moricetown Series (Table 7):

Barrett Series

Barrett series varies from sandy loam to loam, with lots of stones that hinders land clearing. While these soils have high natural fertility, their use is hindered by topography and stoniness, and they also require frequent inputs of organic matter, nitrogen, and phosphorus.

Driftwood Loam Series

Driftwood series has various textures, from gravelly sandy loam, to loam, and clay loam. Providing good topography, these soils are highly satisfactory for agricultural use. However, these soils tend to have a lot of run-off, which causes erosion.

Moricetown Series

Moricetown series are coarse-textured soils occupying river terraces and benches around Moricetown and Cedarvale. For agricultural purposes these soils are considered marginal due to their low organic matter content, coarse texture, and nutrient deficiency.

Around the municipality of Smithers and southeast along the Bulkley River, the main soil types are Barrett sandy loam and Driftwood loam, both of which are well-drained. There are also areas of Doughty clay and Telkwa clay, which range from well to imperfectly drained. Around the village of Hazelton and Moricetown, the main soils are Barrett sandy loam and Moricetown sandy loam. Both have excessive drainage issues. Therefore, crops tolerant of fine to coarse textured soil with moderate to excessive drainage and that require low nutrient levels have greatest chance of success around the municipalities of Smithers, Hazelton, and Moricetown. Alternatively, management practices requiring a reasonable level of investment to improve soil

[16] Source: Dr. William McGill, Personal Communication: September 2016.
[17] Source: Farstad and Laird, 1954.

health and overcome soil limitations can be implemented to enable production of high-value, low-volume crops on small parcels of land

Table 7: Soil Type Classification & Descriptions for the Bulkley Valley[18]

Soil Classification	Parent Material	Drainage	PH	Compact	Organic Matter
Barrett Sandy Loam	Sandy loam to loam	Well to moderately well drained	Neutral to acidic	No	Low
Driftwood Loam	Loam to clay loam	Well to moderately well drained	Neutral to acidic	No	Low
Moricetown Sandy Loam	Alluvial sands	Very well drained	Neutral to acidic	No	Low

4. Specialty & Alternative Crop Selection

4.1 Crop Suitability

Crop suitability is degree of appropriateness for a crop in a specific area. This can be assessed in different ways. For this study, crop suitability was assessed using current climate and soil conditions, current soil and potential climate conditions resulting from projected climate change in the next ten years, and potential climate and soil conditions resulting from projected climate change in the next few years and/or achievable modifications through investment (e.g., irrigation, improvements to soil nutrient content and organic matter, and drainage).

To identify ten appropriate specialty or alternative crops that could be grown in the BNRD, a literature search, numerous internet web pages, and stakeholder input were used to create a list of crops of interest and their climate and soil requirements. Crop suitability maps and crop research from elsewhere in North America and Europe were also used to identify further crops of interest.

Once the list was complete, each crop was assessed using climate and soil conditions required for growth. The climate requirements considered were precipitation, daily temperature, minimum winter temperature (for biennials and perennials only), and frost free days. Soil requirements considered were texture, drainage, and pH (Table 8). Where information on crop requirements was missing, assumptions were made based on the crop's geographic origin, and/or requirements for similar crops from the same plant family or genus. Although other environmental (such as humidity and solar radiation) and soil conditions (such as rooting depth) impact crop growth, these were not included as this information wasn't generally available for most crops.

Once a crop was assessed using climate and soil conditions, each was given one of three suitability classifications for both the short-term (next few years) and long-term (> 10 years) based on anticipated climate change projections. The suitability classifications were:

- Suitable: There are none or very minor climate or soil limitations to crop suitability in the BNRD;
- Potentially Suitable: Although there are some climate or soil limitations which are enough to limit crop suitability in the BNRD, these could realistically be overcome based on climate change projections and/or with some level of investment; and
- Unsuitable: There are significant climate and/or soil limitations to crop suitability in the BNRD that cannot be realistically overcome.

[18] Source Farstad and Laird, 1954.

Table 8: Climate and Soil Conditions Used to Assess Crop Suitability

Requirement	Suitability
Precipitation:	Based on precipitation requirements for each crop. For crops where precipitation was less than required, the potential for irrigation was considered.
Temperature	Based on the range of daily minimum and maximum temperature requirements for each crop.
Min Winter temperature	Based on the extreme minimum winter temperature perennial and biennial crops can withstand. Minimum winter temperature was not used to assess annual crops.
Growing Season	Based on the required growing season length for each crop. The number of growing days was assumed to begin when the minimum daily temperature exceeds 5°C and end when the daily minimum temperature falls below 5°C.
Texture	Based on soil texture requirements for each crop (from fine to moderate and coarse). Soil texture is important as it influences numerous soil properties.
Drainage	Based on the drainage classifications required for each crop. Soil drainage classifications, which indicate the speed of water infiltration and level of saturation, range from excessively to poorly drained soil. For crops where soil drainage was less than required, the potential to improve drainage was considered.
pH	Based on the range of soil acidity or alkalinity required for each crop. For crops where pH was not suitable, the potential (within limits) for pH adjustment was considered.

Previous Crop Trials

In addition to assessing the suitability of the identified crops, research was undertaken to determine whether any trials had been conducted in northern B.C. for any of these or similar crops. Assessing the results of past trials provides some indication of the type of crops that might grow well in the BNRD, as well as highlighting any issues experienced to date. Summaries of the most relevant trials are as follows:

Lingonberry Demonstration Trial (1997-2002)

The trial included six sites (Sinclair Mills, Telkwa, and two each in Vanderhoof and Quesnel) where six varieties of Lingonberry were grown. Trial results suggest the crop was not well suited to clay soils regardless of amendments, and that frequent watering and fertilization were required for good growth. There was no difference in survival between varieties. Production was limited when late spring frosts killed early flowers, and berry ripening was uneven and continued until freeze-up in October.

Blueberry Demonstration Trial (1998-2008)

The trial included ten sites (Hazelton, McBride, Sinclair Mills, Vanderhoof, Telkwa, Fraser Lake, Smithers, Prince George, and two in Red Rock). The trial assessed 17 different blueberry varieties, many of which were 'half-high' varieties; a cross between low bush and high bush blueberries. Acidic soil was needed for the blueberries to be successful. Cold springs often delayed spring growth, resulting in erratic blossoming and fruit set. Heavy pruning in one site resulted in production of much larger berries. Many sites had issues with bird damage. Adequate irrigation, fertilization, and good weed control were necessary for success.

Edible Nuts Demonstration Trial (2000-2010)

The trial included six sites (Hazelton, Prince George, Quesnel, McBride, Red Rock, and Chilako) and evaluated six different varieties of edible nuts; Korean, Siberian, Swiss Stone, Pinion, Dwarf Siberian Pine, and Buartnut. Trial results concluded that the trees generally demonstrated hardy characteristics and were fairly self-sufficient once established. Trees grew more when the springs were wet and cool. The only reported losses were in the first years of the trial, likely due to transplanting stress. Pinion Pine trees survived the first few years, but were generally winter-killed prior to maturity. The trial indicated it was too early to determine productivity potential.

Raspberry Demonstration Trial (2001-2006)
The trial included twelve sites (Fort Fraser, Groundbirch, Dawson Creek, McBride, Fort St. James, Isle Pierre, Prince George, Telkwa, and two each in Red Rock and Vanderhoof,) growing primocane varieties (fruit in the fall), and floricane varieties (fruit in the summer). Trial results indicated that varieties with heavy suckers had the highest production rates. Primocane varieties exhibited significant winter damage and did not fully ripen. Grazing by moose and deer caused significant damage.

Saskatoon Berry Demonstration Trial (2001-2006)
The trial included six sites (Fort Fraser, Smithers, Vanderhoof, Prince George, and two in Redrock), and nine Saskatoon varieties. Trial results indicated sporadic flowering and yields, likely due to late hard frosts and drought conditions in late summer. Varieties all had strong survival, except for sites with spring flooding or excessive wildlife grazing. Varieties with early flowering often experienced frost damage, while smaller shrub size varieties tended to be the heaviest producers.

Hemp Trial Project (2010-2011)
The trail was conducted at eight locations in the central Interior B.C. (Vanderhoof, Quesnel, Beaver Valley, Horse Lake, Ashcroft, and three in 100 Mile House) using several different varieties. Trial results generally suggested that although hemp is a viable crop for fibre production, climatic conditions make seed production variable and inconsistent. There were also issues with inconsistent germination, and harvesting was complicated because the crop didn't dry in the field at several locations. Access to irrigation would have been an asset. Compaction issues limited germination and emergence.

Forage & Grain Variety Trials
Over the past fifteen years, several forage and grain variety trials have been conducted in northern B.C. These include the Forage and Cereal Variety Evaluation Highway 16 (2003-2006), the Highway 16 New Crop Trials (2008-2011), and the Demonstrating Innovative Forage Production Practices to Increase Climate Change Adaptation (2014-2017). These trails grew forage and grain varieties known to grow in Northern B.C. to determine which would produce the greatest yield. The Demonstrating Innovative Forage Production Practices to Increase Climate Change Adaptation project also included late maturing kale as a winter feed source. The kale grew well and kept its nutritional qualities until mid-December.

Past trials in northern B.C. indicate that crops suited to, or tolerant of heavy, clay soils will likely grow well within the BNRD, whereas those sensitive to compaction may struggle. Irrigation and fertilization is often required; in the case of high value crops the need for such inputs shouldn't be a significant impediment to crop choice. Crops sensitive to frost, drought, or that require long growing seasons will likely not be suitable. Perennials must be able to withstand cold winters without damage. Fruit crops are often eaten by wildlife and therefore require fencing/netting. Fruit crop varieties with heavy suckering may have the highest production rates. Crops that require significant drying in the field may have increased risk of failure.

Crop List

Table 9 shows the list of specialty and alternative crops identified for this study (in alphabetical order). Once identified, each crop was given a suitability classification for both the short-term and long-term.

Table 9: Suitability of Specialty or Alternative Crops for the BNRD

#	Common Name(s)	Family	Growth Form	Suitability	
				Short-Term	Long-Term
1	Amaranth	Amaranthaceae	Annual	Unsuitable	
2	Angelica	Apiaceae	Biennial/Perennial	Unsuitable	
3	Asparagus	Asparagaceae	Perennial	P. Suitable	**Suitable**
4	Beargrass	Liliaceae	Perennial	Unsuitable	
5	Black Chokeberry	Rosaceae	Perennial	**Suitable**	
6	Black Elderberry	Adoxaceae	Perennial	P. Suitable	
7	Blue Camas	Asparagaceae	Annual/Perennial	**Suitable**	
8	Borage	Boraginaceae	Annual	Unsuitable	
9	Calamus	Acoraceae	Perennial	P. Suitable	
10	Camelina	Brassicaceae	Annual	**Suitable**	
11	Canihua	Amaranthaceae	Annual	P. Suitable	**Suitable**
12	Cape Gooseberry	Solanaceae	Annual	Unsuitable	
13	Caraway	Apiaceae	Annual	Unsuitable	P. Suitable
14	Celeriac	Apiaceae	Annual	Unsuitable	P. Suitable
15	Chamomile	Asteraceae	Annual	P. Suitable	
16	Chia	Lamiaceae	Annual	Unsuitable	P. Suitable
17	Chokecherry	Roasaceae	Perennial	P. Suitable	
18	Cilantro/Coriander	Apiaceae	Annual	P. Suitable	
19	Crambe	Brassicaceae	Annual	P. Suitable	
20	Echinacea	Asteraceae	Perennial	P. Suitable	
21	Endive	Asteraceae	Annual	Unsuitable	
22	Fennel	Apiaceae	Annual	P. Suitable	
23	Fenugreek	Fabaceae	Annual	P. Suitable	
24	Flax	Linaceae	Annual/Perennial	P. Suitable	
25	Garlic	Liliaceae	Annual	**Suitable**	
26	Ginseng	Araliaceae	Perennial	Unsuitable	P. Suitable
27	Haskap	Caprifoliaceae	Perennial	**Suitable**	
28	Hemp	Cannabaceae	Annual	P. Suitable	**Suitable**
29	Hops	Cannabaceae	Perennial	P. Suitable	**Suitable**
30	Horse Gram	Fabaceae	Annual	Unsuitable	
31	Huckleberry	Solanaceae	Annual	Unsuitable	
32	Japanese Millet	Poaceae	Annual	P. Suitable	
33	Japanese Pear	Rosaceae	Perennial	Unsuitable	
34	Jerusalem Artichoke	Asteraceae	Perennial	**Suitable**	

#	Common Name(s)	Family	Growth Form	Suitability	
				Short-Term	Long-Term
35	Juniper Berry	Cupressaceae	Perennial	P. Suitable	
36	Kale	Brassicaceae	Perennial	**Suitable**	
37	Lamb's Lettuce	Caprifoliaceae	Annual	P. Suitable	
38	Lemon Balm	Lamiaceae	Perennial	P. Suitable	
39	Maca	Brassicaceae	Biennial	Unsuitable	
40	Marigold	Asteraceae	Annual	P. Suitable	
41	Miscanthus	Poaceae	Perennial	P. Suitable	
42	Orache	Amaranthaceae	Annual	P. Suitable	
43	Oregon Grape	Berberidaceae	Perennial	Unsuitable	
44	Pak-choi	Brassicaceae	Annual	Unsuitable	
45	Quinoa	Chenopodiaceae	Annual	P. Suitable	**Suitable**
46	Red Chokeberry	Rosaceae	Perennial	P. Suitable	
47	Red Elderberry	Adoxaceae	Perennial	P. Suitable	
48	Red Mulberry	Moraceae	Perennial	Unsuitable	
49	Safflower	Asteraceae	Annual	Unsuitable	
50	Saskatoon Berry	Rosaceae	Perennial	**Suitable**	
51	Shallot	Liliaceae	Annual	**Suitable**	
52	Sour Cherry	Rosaceae	Perennial	Unsuitable	
53	Spearmint	Lamiaceae	Perennial	P. Suitable	
54	Spelt	Poaceae	annual	Unsuitable	P. Suitable
55	Stevia	Asteraceae	annual	Unsuitable	P. Suitable
56	Sugar Beet	Chenopodiaceae	Annual	**Suitable**	
57	Summer Savory	Lamiaceae	Annual	Unsuitable	P. Suitable
58	Sunflower	Asteraceae	annual	Unsuitable	
59	Switch Grass	Poaceae	Perennial	Unsuitable	
60	Teff	Poaceae	Annual	P. Suitable	
61	Virginia Mallow	Malvaceae	Perennial	Unsuitable	
62	Woodland Strawberry	Rosaceae	Perennial	Unsuitable	
63	Yarrow	Asteraceae	Perennial	P. Suitable	

4.2 Crop Selection

Of the 63 crops assessed, 15 were identified as suitable in either the short-term, the long-term, or both. These crops were Asparagus, Black Chokeberry, Blue Camas, Camelina, Canihua, Garlic, Haskap Berry, Hemp, Hops, Jerusalem Artichoke, Kale, Quinoa, Saskatoon Berry, Shallot, and Sugar Beet. Of these 15 crops, 10 were selected for further assessment using multiple criteria including product versatility, uniqueness, potential local interest and market opportunity, competition, and results of the previous crop trials identified above. These crops are presented below in alphabetical order.[19]

[19] The five remaining crops (Asparagus, Blue Camas, Canihua, Kale, and Shallot) weren't selected simply because the purpose of this project was to identify 10 specialty or alternative crops. As such, these crops are still of interest and shouldn't be dismissed.

Black Chokeberry

About Black Chokeberry

Black Chokeberry *(Aronia melanocarpa),* with the preferred name Aronia Berry used by producers, is a deciduous, cold-hardy, low maintenance woody perennial shrub in the *Rosaceae* family, native to eastern parts of North America. Growing to heights of 1-2 meters, the Black Chokeberry has white flowers in the spring, bright orange and yellow leaves in the fall, and produces loose clusters of 10-15 berries. These berries, which darken to a purplish-black color as they ripen from late August through to mid-September, are about one-quarter inch in diameter (pea-size).

Black Chokeberry (Photo credit: AB Native Plants).

Due to the berry's high levels of vitamin C and antioxidants, which may explain its long tradition in folk medicine, the Black Chokeberry is commercially grown in Europe for use in drinks or as a food colorant. The Black Chokeberry should not be confused with the ChokeCHERRY (*Prunus virginiana)*, whose leaves, stems, and seeds contain toxic amounts of prussic acid.

Climate & Soil

Grown around the BNRD primarily as an ornamental in gardens,[20] Black Chokeberry is a cold tolerant perennial shrub that requires as little as 40 cm (~16 inches) of annual precipitation. Growing well in full sunlight, although moderately tolerant of shade, Black Chokeberry can withstand temperatures of -40°C. Bitter in flavor and sweetening up after a frost or two, the Black Chokeberry has a chilling requirement; meaning a cold period is required before flowering. While this chill requirement hasn't been determined, reports suggest at least 800-1,000 hours (< 0^oC) are required.

Known to grow best in well-drained soils, Black Chokeberry has a wide range of soil tolerance; from boggy poorly drained to well-drained soils. Owing to its root system structure, Black Chokeberry is successfully grown in soils with low and high-level ground waters. Known to grow on soils with a wide pH range (5-8), the optimum pH for Black Chokeberry is slightly acid (5.5-6.5).

Varieties

The two most common varieties in North America are the Viking, a vigorous Russian cultivar which can grow to heights of two meters and is known for producing large amounts of berries, and Nero, a shorter growing variety that reaches heights of around one meter. Morton is a native variety from Michigan. According to some researchers, variety performance is very similar and as such it doesn't matter which variety is used.

Requirements

The planting requirements of Black Chokeberry are similar to most fruit shrubs and trees. Often cultivated in greenhouses prior to planting, seedlings should be shallow planted in spring once the threat of frost is over. Controlling invading weeds and grasses through appropriate use of cover crop or fallowing the ground is critical, especially during establishment. Once planted, Black Chokeberry bushes should be mulched to control weeds and conserve soil moisture. Some pruning may be required.

The effect of fertilization on Black Chokeberry showed increased growth and higher yield with increased fertilizer application. While some studies recommend yearly fertilizer rates of 50-60 kg nitrogen/hectare (~45-

[20] Source: John Orlowsky, UNBC Greenhouse Curator/Horticulturalist.

55 lb/acre), 70-110 kg phosphorous/hectare (~60-100 lb/acre), and 135-225 kg potassium/hectare (~120-200 lb/acre), optimal soil nutrient levels have yet to be agreed upon.[21] Labour estimates are 50-75 hours for establishing 0.4 hectares (1 acre) of Black Chokeberry, with annual labour estimates are 300-750 hours/hectare (~120-300 hours/acre) for production, harvesting, and packing/grading.

Black Chokeberry appears to have very few disease and pest problems, and as such insect control measures are often unnecessary. Leaf spot or rust will rarely develop, while mildew is only a problem when plants do not receive adequate sunlight and air circulation. As a close relative to the apple[22], Black Chokeberry may be susceptible to the same pests (including apple maggot, grasshoppers, Japanese beetle and spotted winged drosophila). Furthermore, despite the name 'Chokeberry', purportedly because many birds avoid this berry until all other fruit sources are gone, Black Chokeberry are eaten by deer, some birds, and rabbits. The degree of wildlife damage, and therefore need for wildlife control, is highly variable between locations.

Technology & Infrastructure

Black Chokeberries can be harvested by hand or using mechanical harvesting equipment. Machine harvest is generally more efficient for areas >0.4 hectares (1 acre). Berries are not prone to mechanical damage during transport, can be easily stored in a cool place (like a refrigerator) for up to two weeks, and processing to juice can be carried out using conventional juicing technology.

Estimated Yield

Reported yields vary dramatically on bush age, variety, and growing conditions (soil, water, and nutrients). In the first year, some berries can be expected, but bushes often have weak branches that fall to the ground. Berry production in the second year, while still low, has been reported at around 1 kg/bush (~2 lbs). By year three berry production increases to 2-4 kg/bush (~4-9 lbs), and in years four and five berry production is estimated to level off at 5-7kg/bush (~11-15 lbs). Yields of up to 10kg/bush (~22 lbs) have been reported.

Depending upon spacing and berry production, Black Chokeberry generally has average commercial yields of 7-12 tonnes/hectare (~6,300-10,500 lb/acre). When processed to juice, Black Chokeberry berries should yield ~0.6 l/kg (~0.075 gal/pound) after processing losses. Although little information is available regarding years of useful life, most suggest that Black Chokeberry plants live for at least 20 years, and as one plant starts to decline a suckering plant can be established as replacement.

Market Opportunity

The Black Chokeberry has been grown as a commercial berry crop in most Eastern European countries since the 1950s. In 2005 for example, there were an estimated 4,850 hectares (12,000 acres) planted in Poland. In North America, reports suggest Iowa will have a $21 million Black Chokeberry industry within the next 5 years. Commonly used in different parts of Europe as an ingredient for fruit syrups, fruit juices, soft spreads, jellies, teas, wines, liqueurs and spirits, the strong natural colour of Black Chokeberries is also useful as a natural food colourant in the food industry.

The Black Chokeberry is rich in antioxidants, vitamins, and phytonutrients. Often touted as the healthiest fruit, the high content of micronutrients in Black Chokeberries seem responsible for the wide range of medicinal and therapeutic effects, including prevention of cancer and cardiovascular diseases. Evidence of the health benefits of Black Chokeberries is accumulating from large population studies, human feeding studies, and cell culture studies. Consequently, the Black Chokeberry is often called a superfood.

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[21] Actual fertilizer/target soil nutrient levels will depend upon current soil levels. As such, these and other levels identified below will only be appropriate in certain locations/circumstance.

[22] Unlike apples Black Chokeberry is self-pollinating and doesn't require a pollinator for fertilization and fruit set.

Demand for Black Chokeberry has increased rapidly over the past decade with discovery of its nutritional profile coupled with recent rebranding to overcome its reputation as a tart fruit. In Europe, business start-ups that use Black or Red Chokeberry as an ingredient increased from two in 1997 to over 100 in 2007. More than 440 new products containing Black Chokeberry (mostly juices, wines and other drinks) have been introduced worldwide in the last five years; about 60 of these are in Canada and the US. Example include Leading Brands, a Vancouver company which uses it in their True Black Blackberry Juice, Dairyland Alive Stirred Yogurt, and Wildland Aronia Juice Blends (apparently selling well in Costco on the U.S. West Coast).

Future Considerations

Projected climate change within the BNRD (a warmer climate, slight change in precipitation and more varied climate) will likely have a positive impact on Black Chokeberry production. The frost free-period required for Black Chokeberry is 80-120 days. Currently, average frost free days in the BNRD are 90-110. A warming climate with greater number of frost free days will therefore benefit the Black Chokeberry and most likely result in greater berry production.

Black Chokeberries have a chilling requirement of at least 800-1,000 hours, and berries are best harvested after they have been through at least one frost. A warmer climate in the BNRD is unlikely to be an issue for the Black Chokeberry's chilling requirement. However, later frosts could jeopardize harvest as once ripe (late August through mid-September) Black Chokeberries should be picked as soon as possible to avoid berries falling on the ground or wildlife damage.

Sources of Information

As a crop suitable for many climates and with rapidly growing interest there are many sources of information on Black Chokeberry. Examples of just a few of these sources include:

- USDA Plant Guide. Available at https://plants.usda.gov/plantguide/pdf/pg_arme6.pdf
- Iowa State University Extension and Outreach. Available at www.agmrc.org/commodities-products/fruits/aronia-berries/
- Aronia Berry Services of Northeast Iowa. Available at http://aroniaberryservicesofneiowa.com/how-to-plant-aronia-berries.html
- Midwest Aronia Association. Available at http://midwestaronia.org/

Camelina

About Camelina

Camelina (*Camelina sativa*) is a heavily branched herbaceous annual and member of the mustard family (a distant relative to canola). Originated in Northern Europe and called by many names, including Gold-of-Pleasure, False Flax, Wild Flax, German Sesame, and Siberian Oilseed, Camelina grows to 30-90cm tall with long, arrow shaped pointed leaves and small pale yellow or greenish-yellow flowers. Camelina produces small, pea-sized round pods with over a dozen seeds in each. These small pale yellow-brown seeds (timothy seed size) typically contain 35-45% oil and 27-32% protein.

Camelina (Photo credit: AAFC).

Due to exceptionally high level of omega-3 fatty acids, Camelina oil is used for many different purposes, including as a food supplement/food product for humans, as an input for bioplastics/biolubricants, or as an alternative to petroleum-derived products (biodiesel and aviation biofuel). The meal remaining after oil extraction can be used as a protein-rich feed source for livestock, and has been approved by the Canadian Food Inspection Agency for feeding to broiler chickens.

Climate & Soil

Camelina is a hardy, short-season, fast-growing annual crop that only takes 85-100 days to mature and requires as little as 35 cm (~14 inches) of precipitation over its lifecycle (spring planting to fall harvest). Germinating at low temperatures and frost tolerant, Camelina seedlings have shown no damage at temperatures as low as -10°C. By maturing earlier than most other crops and performing well in drought stress conditions, Camelina isn't dependent on rainfall in later summer months.

Known to grow best in light or medium well-drained soils, Camelina has shown suitability for all types of soil; from light (sandy) to heavy (clay) soils. Despite this, research shows Camelina performs poorly under water-logged conditions. With no known preference for soil pH and able to grow with minimal fertilizer application, Camelina can grow on acid, neutral, or alkaline 'marginal' agricultural lands that are considered nutritionally poor and unsuitable for most other oilseed crops.

Varieties

Since limited breeding has been done, few commercial varieties exist. Of the few named varieties Blaine Creek, Suneson (Montana State University), Platte (Blue Sun Biodiesel), and SO-40, SO-50 and SO-60 (Sustainable Oils Company) seem to be the most promising in North America. Varieties from Europe include Celine, Calena, and Epona. As breeding work continues, more Camelina varieties will become available.

Requirements

Most often seeded at rates of 3-9 kg/hectare (~3-8 lb/acre) in early spring (when soil temperatures reach 2°C) and harvested in late July or early August,[23] Camelina requires minimal seedbed preparation as it is well adapted to no-till in soybean or small grain stubble, and seeds can be drilled or broadcast. Camelina also requires minimal (if any) pre-emergence weed control as it has good weed competitiveness, especially when plant stands are dense. Reasons for this are likely due to the early emergence, rapid growth, and cold tolerance of Camelina, which allows it to be planted and established early.

While often said that Camelina can grow without fertilizer application, with research from Colorado showing no yield response to phosphorus, potassium of sulphur additions, this ultimately depends upon nutrient levels in the soil. Most studies and research recommend that soil nitrogen levels should be 60-100 kg/hectare (~55-90 lb/acre). Other studies also recommend application of phosphate to increase levels to >12 ppm, and application of 65 kg/hectare sulphur (~60 lb/acre) may also improve yield. Despite these recommendations, optimal soil nutrient levels have yet to be agreed upon.

Few or no insects appear to cause damage to Camelina, and as such insect control measures are likely unnecessary. Flea beetles and common aphids, which can be pests for canola, don't seem to affect Camelina. Downy mildew has been observed in Camelina in the Pacific Northwest and Montana. It may also be susceptible to Sclerotinia stem rot and Rhizoctonia fungus (although reports of major outbreaks are uncommon). Camelina is highly resistant to blackleg, a major disease of canola and other Brassica crops.

Although a small handful of studies have suggested that Camelina might have allelopathic traits, there is little evidence to support this. Instead most research suggests Camelina performs well as a companion crop. To

[23] Some success has been had with fall or dormant seeding, when planting is carried out as late as possible but before the soil freezes or a killing freeze (to minimize opportunities for seed germination). This enables an even earlier start to the growing season. However, in most cases spring seeding has shown higher yields.

reduce potential disease problems, Camelina (as with other brassicas) should be rotated and grown no more than once every three to four years in a field. As such, Camelina has a possible rotation fit with existing crops grown in the BNRD, such as grass and alfalfa hay, grains, and pastures, especially in fields with less than optimal irrigation and fertility.

Technology & Infrastructure

Seeding and harvesting equipment used for canola and mustard crops are suitable for Camelina. Camelina can be harvested with unmodified combines (with settings similar to those used for canola or alfalfa seed) and may be direct combined standing or swathed. Camelina seed is susceptible to moisture; recommended moisture storage is < 9%. Camelina seeds are also very small, thus cracks in truck beds and storage bins should be filled prior to harvest.

Processing Camelina requires cold pressing to extract the oil without destroying natural antioxidants, vitamins, and flavour. Cold pressing involves crushing the seeds inside a cylinder with a rotating screw and forcing out the oil through small holes in the bottom. Presses come in a range of sizes, from small sizes for home use to huge commercial presses. Once pressed the oil can be bottled and sold.

Estimated Yield

Sowing rates of 3-9 kg/hectare (~3-8 lb/acre) are recommended to achieve stand densities of 125-200 plants/m^2. Data on crop production is limited. U.S. studies suggest seed production ranges from 1,000-2,000 kg/hectare (~900-1,800 lb/acre) with low precipitation of 30cm (~12 inches), 2,000-2,250 kg/hectare (~1,800-2,000 lb/acre) with moderate precipitation of 45cm (~18 inches), and as much as 1,900-2,700 kg/hectare (~1,700-2,400 lb/acre) with high precipitation of 55cm (~22 inches).

Canadian research demonstrated seed yields of 1,600-3,100 kg/hectare (~1,450-2,800 lb/acre) in the Saskatoon area, 2,000-3,300 kg/hectare (~1,800-2,900 lb/acre) in Beaverlodge Alberta, and 1,100-1,700 kg/hectare (~1,500-2,100 lb/acre) in the Maritimes. Because Camelina seeds typically contain 30-35% oil, one tonne of seed contains 300-350 kg (~660-770 lb) of oil. Therefore, when cold pressed one tonne of Camelina seeds produces around 250 kg of oil and 750 kg of high-protein meal.

Market Opportunity

Camelina oil is relatively high in omega-3 fatty acids and low in saturated fatty acids. It also contains gamma tocopherol (vitamin E), which acts as an antioxidant and increases oil stability compared to other omega-3 rich oils. Camelina oil has good potential as an edible oil. In early 2010, Health Canada approved Camelina oil as a novel food in Canada, thereby allowing sale of Camelina oil into the human food market. One good example is Three Farmers in Saskatchewan where Camelina is grown to produce a high-end cooking oil.

Although high in protein, the meal market for Camelina is currently limited as it was only recently approved for feed. In 2015 the Canadian Food Inspection Agency approved 12% inclusion of cold pressed Camelina meal to broiler chicken feed. Approval for inclusion in layer feed is currently under consideration. Despite this, and because Camelina meal is used in the U.S., it seems likely that Camelina meal will be approved soon for all livestock in Canada.[24] If approved, Camelina meal could compete as a substitute for flax.

Camelina also has promising properties for high-value uses as a bio-based product or biofuel feedstock. The U.S. Navy successfully used Camelina oil as the biofuel feedstock for a static F414 engine as far back as 2009,

[24] In 2009 the US-FDA allowed Camelina meal as a feed ingredient for beef cattle and swine. The US-FDA also expressed no objection to feeding Camelina meal to broiler chickens and laying hens up to 10% of their final diet.

and the U.S. Air Force began testing with Camelina oil in its aircraft in 2010. However, using Camelina oil for bio-based products and biofuels is still a developing and experimental market.

Future Considerations
As a hardy, short-season, fast-growing crop, projected climate change within the BNRD (a warmer climate, slight change in precipitation and more varied climate) will likely have little positive impact on Camelina. However, as the growing season lengthens in the BNRD there may be opportunities to grow Camelina with a second crop. For example, mixtures of Camelina and clover have been tested. Camelina grows rapidly and suppresses the clover until harvest, after which the clover grows and produces a fall harvest. Climate change is also likely to have limited impact on potential competition from other possible Camelina growing regions in Canada (such as Alberta and Saskatchewan) and the U.S. (such as Montana, Pennsylvania, Idaho and Oregon).

Federal funding is now being directed towards Camelina development. In 2013 a $5 million initiative was launched to increase the value of Camelina oil and co-products for industrial uses. A number of companies are also developing Camelina varieties with improved agronomic traits. As this work continues, there may be greater potential for growing Camelina for bio-based products and biofuel feedstock.

Sources of Information
As a crop suitable for many climates and with rapidly growing interest, there are many sources of information on Camelina. Examples of just a few of these sources include:

- Camelina Production and Potential in Pennsylvania. Available at http://extension.psu.edu/plants/crops/grains/small/production/camelina-production-and-potential-in-pennsylvania
- Camelina: Effects of Planting Date and Method on Stand Establishment and Seed Yield. Available at http://cru.cahe.wsu.edu/CEPublications/PNW661/PNW661.pdf
- USDA Plant Guide. Available at https://plants.usda.gov/plantguide/pdf/pg_casa2.pdf

Garlic

About Garlic (Gourmet)
Garlic (*Allium sativum*) is a well-known herbaceous perennial member of the Amaryllidaceae family, grown as an annual or perennial for thousands of years for use as a spice, and its bioactive properties. Closely related to other domesticated Allium species, including onion, chive, and leek, Garlic is a low bulbous herb, growing to 30-60 cm tall (~12-24 inches) with 4-12 narrow grass-like leaves. The Garlic stem is surrounded by cloves covered in paper-like skin. When mature, these cloves comprise the highly aromatic bulb which is cured before storage or value-added processing.


Gourmet Garlic (Photo credit: garlicseed.ca).

Domesticated early in human culinary history and native to Central Asia, global Garlic production is over 10 million tonnes/year. Consumption and the diversity of uses continue to increase, and today Garlic is used as flavouring, a food ingredient, a natural health product or phytomedicine, and as a natural pesticide.

Climate & Soil
In colder temperate climates, such as the BNRD, Garlic is planted in the fall. All Garlic varieties are cold-tolerant (some down to -45°C) and require a chilling period before growth. Garlic requires 70-160 cm (~28-63 inches)

precipitation over its lifecycle (from fall planting to late summer harvest). Precipitation is most important during early growth, whereas dry conditions are optimal for the final stages of bulb maturation. Garlic also requires a minimum of 60 growing days at > 10°C. Although Garlic grows best in fertile medium sandy loam soil, it can tolerate a wide range of soils if drainage is sufficient. Garlic is also tolerant of a range of soil pH, performing best in slightly acidic soils of 6.2-6.8.

Varieties

Extensive global breeding has produced over 650 sub-varieties of Garlic, with at least 100 suitable for Canada. The widely cultivated commodity Garlic is usually a white softneck variety such as Silverskin. Hardneck Garlic varieties, often referred to as 'Gourmet Garlic', are hardier, grown in smaller quantities, have stronger colours and more intense, diverse flavour profiles, and have greater value. Growers in south and southeast B.C. grow hardneck varieties such as Spanish Roja, Yugoslavian, and French.

There are many Gourmet Garlic varieties potentially suitable for the BNRD, including the Tibetan, Northern Quebec, Susan Delafield, Chesnok Red, and Red Rezan. Furthermore, the hardneck varieties of Music, Red Russian, Metechie, Zemo, and Baba Franchuk's are already successfully grown in the BNRD. Because hardneck varieties have a shorter shelf-life post-harvest than softneck varieties, variety selection should be based on planned end-use.

Required Inputs

Recommended soil preparation is repeated tilling to ensure a loose-textured, well-draining soil to a depth of 15 cm (~6 inches). Gourmet Garlic is often hand-planted 7.5-15 cm (~3-6 inches) below the surface. Seeding rate is about 700-1,000 kg/hectare (~630-900 lb/acre). Approximately 35,000 cloves can be planted in 0.3 hectares (0.7 acres). Recommended spacing between plants and rows is 17.5-20 cm (~7-8 inches) or more depending on the variety bulb size. Mulching is recommended before the first snow to moderate soil temperature, conserve moisture, and inhibit weed growth. Irrigation will likely be required in the BNRD as precipitation is insufficient to meet Garlic's needs.

Soil nitrogen levels of 142 kg/hectare (~128 lb/acre), phosphorus levels of 24 kg/hectare (~20 lb/acre) and potassium levels of 105 kg/hectare (~95 lb/acre) are recommended for maximal yield. Micronutrient levels of 9 kg/hectare (~8 lb/acre) for magnesium and 57 kg/hectare (~50 lb/acre) for calcium are also considered ideal. Cover crops such as brassicas (e.g., *Camelina sativa*) can improve compacted soils, adding organic matter deeper into the soil. For certified organic production, the use of manures, compost or alfalfa meal are options to increase soil fertility.

To reduce potential disease problems, Gourmet Garlic should be grown no more than once every three to four years in a field. Complete removal and disposal of seasonal crop residues is also important. Major Gourmet Garlic fungal diseases found in B.C. include white rot, downy mildew, and rust. The major insect pests for Gourmet Garlic are onion thrips and maggot. Registered fungicides, biofungicides, and pest control products are available. Prevention is best as once a pest is detected, the Gourmet Garlic crop is usually lost.

In early spring hardneck Gourmet Garlic varieties bolt to produce a flowering stem called a scape. Removal of the scape is recommended for maximal bulb growth. Scapes can be harvested and sold fresh, similar to fresh chives. Alternatively, the scapes can be left to produce bulbils which can be used for propagation; this may become necessary as finding sufficient bulbs for large-scale production is often challenging. However, scapes require two to three years of growth before a substantive bulb is produced.

Technology & Infrastructure

Gourmet Garlic is typically manually planted and harvested. For larger areas, the use of a dimpler for seeding is recommended (hand-push type or attached to tractor and used concurrently with last till before planting). Gourmet Garlic requires frequent shallow weeding. Labour needs estimates are 60 hours/hectare (~25 hours/acre) for planting and 400 hours/hectare (~162 hours/acre) for harvest and packing.

When bulbs are ready for harvest, the entire plant is carefully pulled out after loosening the soil with a narrow-blade shovel or fork. For larger areas, a tractor-mounted cutter bar can be used; however, great care must be taken as fresh Gourmet Garlic bulbs bruise easily. After careful removal of soil from the roots, the Gourmet Garlic plant is cured in bunches of 4-15 plants in drying sheds, out of direct light at 27°C for two weeks, or longer at lower temperatures.

Good ventilation during curing and storage is critical. Once cured, the leaves and roots are trimmed off the plant, leaving a short length of stem. Surface soil and the minimal amount of the outer wrapper are also removed. Cleaned, sorted bulbs should be stored with some air circulation at 0-4°C and 60-70% relative humidity. Gourmet Garlic bulbs can be stored for up to 8 months at 15-18°C. High humidity or temperature fluctuations will produce mold, stimulate root growth and sprouting, resulting in rapid spoilage.

Estimated Yield

Gourmet Garlic yield is highly dependent on variety used, seed clove size, planting density, soil type, nitrogen levels, and weather. A 5 kg planting in optimal conditions will yield 100-145 kg (~220-320 lb) of Gourmet Garlic. Typical conventional garlic yields in B.C. range from 5-10 tonnes/hectare (~5,000-9,000 lb/acre). A planning calculator for specialty organic garlic bulb costs specific to B.C. is available.[25]

Market Opportunity

Garlic consumption in Canada and the U.S. is close to 1 kg/person/year. With annual production of 20 million tonnes/year at an estimated value of $10 billion, China dominates global Garlic production. The extent of this dominance has made it challenging for profitable white softneck Garlic production in Canada. Other areas that produce large volumes of commodity Garlic include California. Some commodity Garlic is grown commercially in several Canadian provinces; Ontario and Quebec are by far the largest producers.

In contrast to commodity Garlic, Gourmet Garlic can be highly profitable for small-scale growers. Gourmet Garlic is usually sold as fresh or seed garlic. In 2016, fresh or cured Gourmet Garlic can be sold for up to $12-22/kg, and for $30-35/kg (~$1.85-4/bulb) as seed stock. Value-added Gourmet Garlic products include peeled and frozen garlic, vinegars, pickled garlic, and chutney. Most small-scale Gourmet Garlic producers sell on-line or directly to local restaurant distributors or specialty food shops. Some examples of Gourmet Garlic producers in Canada include the Garlic Box and John Boy Farms.

Future Considerations

Gourmet Garlic is a highly adaptable crop with the major limitations for cultivation being the manual labour needed for planting, weeding, harvesting, and curing. Projected climate change within the BNRD (a warmer climate, slight change in precipitation and more varied climate) is unlikely to have a major impact on the crop. However, less predictable precipitation might increase requirements for more extensive moisture control (e.g., raised beds for adequate drainage and drip irrigation), and an extended season may increase Gourmet Garlic yields, as well as the number of varieties that can be grown.

[25] Planning Your Garlic Farm spreadsheets are available at: http://www.rasacreekfarm.com/plan-your-garlic-farm

Projected climate change elsewhere may have a major impact on market potential. In 2016 commercial commodity Garlic production was significantly affected by droughts in both China, the world's largest producer of Garlic, and California. Increased temperatures and drought in southern Canada may also make Gourmet Garlic production in northern Canada more profitable.

Sources of Information
As a crop suitable for many climates and with rapidly growing interest there are many sources of information on Garlic. Examples of just a few of these sources include:

- Garlic Production. Available at: http://extension.psu.edu/business/ag-alternatives/horticulture/vegetables/garlic-production
- Crop Profile for Allium Vegetables in Canada. Available at: www.agr.gc.ca/eng/?id=1407782241822
- British Columbia Vegetable Production Guide. Available at: http://productionguide.agrifoodbc.ca/guides/17/
- Growing Gourmet Garlic guide. Available at:www.mmmgarlic.com/growing-garlic-3/
- Garlic Production - Ontario. Available at: www.omafra.gov.on.ca/english/crops/facts/09-011w.htm

Haskap Berry
About Haskap Berry
Haskap (*Lonicera caerulea)* is a deciduous fruit bearing shrub. More closely related to the potato, tomato, snowberry, and elderberry than to the blueberry or cranberry, Haskap bushes grow to 1.5-2 meters (~5-7 feet) tall, have slightly waxy, long oval leaves, yellowish-white flowers, and blue berries 1 cm (~0.4 inches) in diameter. Native to northern Japan and Russia, and naturalized in Canada, Haskap has many names, including the Blue, Edible and Sweet Berry Honeysuckle, and the Honeyberry.


Haskap Berry (Photo credit: Farm Management Canada).

Due to its flavour, often described as something between a blueberry, saskatoon berry and raspberry, the small seeds, and high nutritional value, Haskap berries are attracting great interest. Predominantly eaten fresh, Haskap berries are increasingly being used in drinks, jams, ice-cream, and other value-added products.

Climate & Soil
Recently grown in Burns Lake and with successful commercial production in Salmon Arm, Haskap is known as a hardy, short-seasoned perennial crop. Most varieties are cold hardy to -45^{o}C, while flowers have been known to survive and set fruit after spring temperatures as low as -11^{o}C. Haskap is also suited to long daylight hours. Required precipitation for Haskap varies from 40-75 cm (~16-30 inches) based on plant age (younger plants require more moisture, whereas established plants are mildly drought-tolerant) and soil type. Low moisture levels are ideal in the late summer and fall to induce dormancy, reducing the potential for winter damage.

A key advantage Haskap has over blueberries is its adaptation to a wide range of soil pH; Haskap can grow in acidic or alkaline soil with a pH of 5.4-7.9. Most research recommends a soil pH of 5-7. In the wild Haskap is often found in wetlands and boggy areas, thus it can be successfully grown in heavy, clay soil where water sits for a few weeks each spring. Haskap also grows well in well-drained soils.

Varieties

The University of Saskatchewan has developed a series of licenced Haskap varieties by crossing tastier Japanese varieties with more winter hardy Russian varieties. Examples include the Tundra (firmer skin and bleeds less), the Borealis (sweeter and larger berry, softer skin), the Aurora (selected as companion pollinator for the Borealis), the Honeybee (selected as pollinator for the Borealis and Tundra), the Boreal Beauty (firm, mostly oval berries that fully ripen a month after most varieties), and the Boreal Blizzard (larger berries with good taste).

Requirements

Most recommendations suggest planting bushes 1-1.5 m (~3-5 feet) apart in rows 2- 5 m (~6-17 feet) apart, in tilled soil devoid of weeds. Row spacing is heavily dependent upon how the berries will be harvested (if picked by hand row spacing requirements are much less than if done with machinery). Planting is most often recommended in the fall as cooler, wetter weather means less watering and weeding, while also allowing more time for root development (spring plantings of dormant plants can also be successful). All Haskap varieties require a pollinator variety to optimise growth, and bees and other insects are key to pollination. Irrigation may be required during establishment and possibly during the spring and summer.

Being a relatively new crop, little is known about Haskap's fertilizer requirements. As it is more closely related to potatoes and tomatoes than other fruit crops, it is often suggested fertilizer recommendations for tomatoes or potatoes be used. As such, required soil nutrient levels are likely in the region of 125-175 kg/hectare nitrogen (~110-160 lb/acre), 100-150 kg/hectare phosphorous (~90-130 lb/acre), and 200-300 kg/hectare potassium (~180-270 lb/acre). Other suggested nutrients include calcium, magnesium, and sulphur. Fertilization should be done in spring, as growth later in the season is prone to winter injury.

During the first few years after planting, watering may be necessary to promote deep root growth. In heavy clay soils that hold moisture irrigation may not be necessary. Established plants may need no water other than that provided through rainfall. If irrigation is required, it is generally better to water less frequently with large volumes than frequently with small amounts, as this promotes a deeper root system. In the establishment years, protection from prevailing winter winds may also be necessary to minimize injury.

Haskap shrubs should be kept free of grass and weeds. Although most herbicides are not recommended for use (as the berries are highly susceptible to damage), weeding is fairly simple. Some pruning may also be required. Well-tended Haskap plant should stay productive for > 20 years. Haskap has few pest worries given it fruits so early in the season (earlier than strawberries by a few weeks). It also doesn't appear to be a favorite of deer. Birds, however, particularly Cedar Waxwings, love Haskap and as such some method of bird control is necessary. The only common Haskap disease currently reported is powdery mildew. This is usually seen later in the fall season and is therefore not an issue as it occurs well after harvest is complete.

Technology & Infrastructure

Haskap should be planted by hand. As many Haskap varieties have uniform harvesting (all fruit is mature at once), berries can be harvested by hand or using mechanical equipment. If picked by hand, it is estimated that 20 pickers working 8 hours a day for 5-10 days are required to pick one hectare (2.5 acres). Hand picking costs an estimated $2-3/kg (~$1-1.5/lb). Mechanical harvesters, which can cost $75,000-150,000, harvest about 4 hectares/day (~10 acres) and generally become economically feasible at 4 hectares (~10 acres). Harvesting can be done over several weeks because berries will keep on the bush for weeks. This means there may be potential for farmers to share harvesting equipment. Once harvested, the berries should be kept at below 2^{o}C and > 95% humidity.

Estimated Yield

Recommended planting densities of 1-1.5 m (3-5 feet) between bushes and 3-5 m (10-17 feet) between rows results in an estimated 1,600-2,500 bushes/hectare (~650-1,000/acre). Haskap will fruit after the first year; however, bushes do not produce significant amounts of berries until three to four years after planting, when they are able to yield 2.5-4 kg/bush (~4.5-9 lb/bush). Newer varieties are claimed to yield upwards of 5-7 kg/bush (~11-15 lbs/bush) after four or five years. Once established, Haskap is a long-lived crop. Well-tended bushes are expected to stay productive for 20 years.

Market Opportunity

Haskaps have been popular in Japan for many years and market demand is significant. Markets for Haskap berries are also growing in the U.S., Saskatchewan, and Nova Scotia (last year Sobeys began stocking Haskap juice, chutney, jam and relish in 20 stores in the Atlantic region). This growth is likely in part due to work carried out by Haskap industry associations, such as the Haskap Canada Association, a non-profit created to find national and international market opportunities for Canadian grown Haskap, Haskap Canada, and the Haskap Growers Association of Nova Scotia.[26]

Stored and processed like other berries, most Haskap berries are currently eaten fresh. One reason for the growing interest in Haskap berries is their nutritional value. Several studies claim Haskap berries are superior to blueberries, specifically because Vitamin C and A, potassium, and fibre are high. Haskap berries also have an extremely high Oxygen Radical Absorbance Capacity (which indicates a high antioxidant capacity), and high levels of anthocyanins, polyphenols and bioflavanoids, which have demonstrated ability to protect against a myriad of human diseases.

As well as eaten fresh, Haskap berries can also be used in processed products, such as pastries, jams, juice, wine, ice cream, yogurt, sauces, etc. Haskap seeds aren't noticeable when eating (they are similar in shape to those in kiwi fruit), and the berry's skins disintegrates easily. These characteristics are causing some excitement amongst ice cream and smoothie makers. Dried Haskap berries are also widely sold in Japan; the size, colour, texture, and flavour are similar to raisins. Despite these potential market opportunities, Haskap berries are a newly produced crop in Canada and as such market development will take time.

Future Considerations

As a short-season perennial crop cold hardy to -45°C and able to survive spring temperatures as low as -11°C, projected climate change within the BNRD (a warmer climate, slight change in precipitation and more varied climate) will likely have little positive impact on Haskap. However, climate change within the rest of B.C. may impact the supply of other berries. For example, blueberry farmers in the Lower Mainland face greater crop risks as warmer winters result in early blooms that are dried out by temperature drops and strong winds.

Sources of Information

As a crop suitable for many climates and with rapidly growing interest there are several sources of information about Haskap. Examples of just a few of these sources include:

- University of Saskatchewan: Growing Haskap in Canada. Available at www.fruit.usask.ca/articles/growinghaskapinCanada.pdf
- LaHave Farm in Nova Scotia. Available at http://lahavenaturalfarms.com/
- Haskap Canada Association. Available at http://haskap.ca/
- Phytocultures Ltd. Available at http://cameriseberries.com/

[26] A new Haskap Grower Association of B.C. is in the process of forming, and should be started by mid-year 2017. This will likely be an asset to new growers.

Hemp (Industrial)

About Industrial Hemp

Industrial Hemp (*Cannabis sativa*) is an annual, herbaceous plant used worldwide to produce a variety of food, beverage, cosmetics, fabric, textile, paper, construction, and insulation products. Low in active tetrahydrocannabinol, the main psychoactive ingredient in marijuana, Industrial Hemp plants consist of a spindly, furrowed, and usually branched hollow main stem covered with leaves. Plant height varies enormously depending on genetic constitution and environment, typically reaching 1.5-3 m (~5-10 feet) in height.

Industrial Hemp (Photo credit: ransmissionsmedia.com).

In Canada, where commercial production of Industrial Hemp was legalized in 1998, the focus is seed production; with Canadian farmers selling most of their seed to the U.S. Within B.C., a study carried out by the District of 100 Mile House found that climate conditions made seed production inconsistent, Industrial Hemp in the region should be grown for fibre and not seed production. There is no evidence to suggest that the primary focus of Industrial Hemp in the BNRD should be any different.

Climate & Soil

Currently grown in some BNRD back gardens on a small-scale for chicken feed, Industrial Hemp is a fast-growing annual crop that requires 70-90 days between planting and harvesting and 40-70 cm (~16-28 inches) of precipitation. Industrial Hemp is well adapted to growing in the Canadian prairies; however, young plants are often stunted by heavy rain and killed by late frosts. Once established, Industrial Hemp can tolerate frosts with little damage. It is also day-length sensitive; longer days result in increased vegetative and reduced flower development. As such, it is always advised to plant Industrial Hemp as early in spring as possible.

Known to grow in a wide variety of soil types, Industrial Hemp grows best in well-drained, loamy soils with high levels of organic matter and a pH of 6-7.5. Industrial Hemp does not grow well in poorly drained, heavy, compacted clays soils. This is because young plants are very sensitive to wet soils during the first few weeks of growth and Industrial Hemp is also very sensitive to soil compaction. Water-damaged Industrial Hemp plants will remain stunted, resulting in a weedy, uneven, poor crop. Research suggests that the higher the level of soil compaction, the lower the seed germination and seedling emergence.

Varieties

The Canadian hemp industry initially grew European varieties; however, in recent years Canadian plant breeding programs developed a number of high-yielding cultivars suitable for a wide range of growing conditions. In 2014 over 20 Industrial Hemp varieties were grown in Canada. Of these, the four grain type cultivars of Finola, CFX-2, X59, and CRS 1 accounted for 90% of national acreage because economic returns are much greater for seed than fibre production. In recent years, several new fibre varieties were bred, including Alyssa, Carmen, and Anka. Of these Anka was the best performer according to the District of 100 Mile House's Industrial Hemp study.[27]

Requirements

Field preparation for Industrial Hemp is similar to traditional grain crops (corn, wheat, etc.), and planting can be done using a traditional grain/seed drill. Industrial Hemp planted for fibre is usually sown in 15-20 cm (~6-7 inch) rows, and optimum final stand is around 200-375 plants/m^2 (for seed production recommended hemp

[27] Project in Motion: Preparing for 100 Mile House Industrial Hemp Pilot Project (2010) www.100milehouse.com/files/1313/9268/1644/Project_In_Motion.pdf

stand is 100-150 plants/m^2). Dense stands of Industrial Hemp are required to ensure stems are tall and slender with a higher percentage of fibre.

Early seeding (as soon as soil conditions are appropriate) is recommended. The recommended seeding rate for hemp fibre production is 45-70 kg/ha (~40-60 lb/acre). Industrial Hemp should only be sown once the risk of hard frost has passed. Furthermore, irrigation systems for fields are also required to avoid poor crop performance due to weather related stresses.

In research studies, Industrial Hemp has shown a significant yield response to applied fertilizers when levels of plant-available nutrients in soil were low and soil moisture conditions were adequate. Industrial Hemp requires approximately the same fertility as a high-yielding crop of wheat. Depending upon soil fertility, 100-150 kg/hectare (~90-135 lb/acre) nitrogen and 40-90 kg/hectare (~35-80 lb/acre) potassium are recommended. Some growers add 20-30 kg/hectare (~19-27 lb acre) sulphur; however, research has shown minimal benefit from additional sulphur or phosphorous fertilizer when soils are not deficient in either.

When planted in well-drained, fertile soil with optimum moisture conditions, Industrial Hemp will grow quickly, providing >80% ground shade in 3-4 weeks, effectively suppressing weed growth. Under less ideal growing conditions, problem weeds include Hemp Nettle, Wild Buckwheat, Wild Oat, Pigweed, Lamb's Quarters, and Canada Thistle. Although more than 50 different viruses, bacteria, fungi, and insect pests are known to affect Industrial Hemp, its rapid growth and vigorous nature allows it to overcome most diseases and pests. To avoid disease build-up, a four-year crop rotation is recommended. Industrial Hemp should not be grown after canola, soybeans, or sunflowers.

Technology & Infrastructure

Industrial Hemp is normally sown using a standard grain drill. Harvesting, ideally done in the early flowering stage for maximum fibre quality and quantity, can be done using a sickle-bar mower or hay swather. Once harvested, the fibre is baled using any kind of baler after some in-field retting has taken place. Retting begins to separate the bast from the core fibre. In the field, the chosen method and length of time required for retting depends upon climate (from 14-28 days) and fibre use. Bales must be stored indoors under dry conditions.

Once bailed, bast fibres are separated from core fibres at or near the production area using decortication equipment. This equipment uses mechanical forces to separate the fibres and can be transportable to farms for primary processing. With a price range of $1-3 million tonne/hour capacity, decortication equipment could be shared by a local producer group. Primary processed Industrial Hemp bast and core fibre can be sold to the green building industry. Primary processed Industrial Hemp core fibre can also be sold for animal bedding.

Secondary processing of Industrial Hemp fibre and core into value-added products involves expensive large scale technology. An industrial-scale hemp processing facility has been discussed for 100 Mile House. This facility could manufacture a variety of products using Industrial Hemp grown by a large network of agricultural producers. Discussions on such a facility have been positive; however, currently there is no secondary fibre processing equipment in B.C. This may be due to the high capital investment required (~$10-30 million).

Estimated Yield

Fibre yield depends on both the stalk yield per hectare and the fibre content of the stalk. Varieties differ in the amount of actual fibre, and on the ratio of bast to core fibre. Industry estimates indicate one hectare of Industrial Hemp can yield an average of 4-10 tonnes of dry retted stalks (~4,500-12,500 lb/acre). Approximately one tonne of bast fibre and 2-3 tonnes of core material can be decorticated from 3-4 tonnes of good quality, dry retted Industrial Hemp straw.

Market Opportunity
Industrial Hemp fibre has some of the best mechanical properties of all natural fibres. Today it is mainly used for speciality pulp and paper, insulation material, and bio-composites (interior press moulding) in automotive applications. Other growing applications for the fibre include for use in clothing, as a high-performance bedding material for livestock, and in construction and gardening.

Canadian Industrial Hemp cultivation is concentrated in the three Prairie Provinces where the driver for this production is the demand for hemp grain (seed, oil, and meal) for food and the nutraceutical market. Since the reintroduction of Industrial Hemp in Canada during the late 1990's, hemp fibre processing has not developed to the same extent as the hemp grain industry. As such, credible market prices have not yet been established for the fibre and prices can vary greatly with end use. In the 100 Mile House Hemp Study it was recommended that the target market for Industrial Hemp fibre should be focused on the B.C. and U.S. Pacific Northwest green building industry, at least initially.

Future Considerations
Projected climate change within the BNRD (a warmer climate, slight change in precipitation and more varied climate) could have a positive impact on Industrial Hemp as the young plants are often killed by late frosts. Currently, average frost free days in the BNRD are 90-110, so a warming climate will reduce the risk of late frosts, benefiting Industrial Hemp and most likely resulting in less loss. Furthermore, if the District of 100 Mile House secures the capital investment required to build a large secondary processing facility for Industrial Hemp, opportunity will increase for agricultural producers in the BNRD to grow industrial Hemp.

Sources of Information
As a multi-purpose crop with rapidly growing interest there are many sources of information on Industrial Hemp. Examples of just a few of these sources include:

- District of 100 Mile House Industrial Hemp Pilot Project 2009-2010 Report. Available at www.100milehouse.com/files/9213/4731/1178/ind_hemp_report.pdf
- Alberta Ministry of Agriculture and Forestry: Industrial Hemp Enterprise. Available at www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex126
- OMAFRA: Growing Industrial Hemp in Ontario. Available at www.omafra.gov.on.ca/english/crops/facts/00-067.htm
- WSU: Industrial Hemp Opportunities and Challenges for Washington. Available at http://ses.wsu.edu/wp-content/uploads/2015/02/WP2014-10.pdf

Hops

About Hops
Hops (*Humulus lupulus*) is a vigorous, perennial vine in the Cannabaceae family. Indigenous to North America and other temperate regions, Hops plants can grow up to 9 m (~30 feet) in one season. Hops' broad leaves are lobed, similar to maple leaves, the square-stemmed shoots grow and twine clock-wise around any available support, and the yellow flowers become pale green cones. The highly resinous female cones are mainly used for brewing beer.


Hops (Photo credit: Grit City Photography).

Hops is also a medicinal plant used traditionally for over 2,000 years to treat sleep disorders, anxiety, improve digestion, and is used for its antimicrobial properties. Today, Hops are studied for human health benefits, veterinary medicines, animal feeds, and industrial applications.

Climate & Soil

Hops is a hardy, fast-growing perennial that requires direct sunlight, long days (>15 hours of light), and 120 frost-free growing days for flowers to develop and mature. Hop are grown between 30-55 degrees latitude North and South. Although Hops can withstand frosts and be productive with as little as 30 cm (~12 inches) of precipitation, timing is critical. Frosts or drought during establishment, early shoot growth, flower development or cone maturation can affect survival, yield, and quality. Once established, Hops are very hardy and the overwintering crowns, rhizomes, and roots can withstand -30^oC. Commercial Hops production typically requires 75 cm (~30 inches) precipitation annually. Site microclimate and soil are very important.

Hops are most productive in fertile, well-drained sandy loam soils with acidic pH from 6-6.2. However, Hops can tolerant a wider range of soil types and pH up to 6.5 if drainage is good and other needs are met, including lots of direct sunlight, long day length, adequate water, and a dry climate.

Varieties

Hops breeding is active to develop different flavour and aroma profiles, and increase hardiness, yield, and disease and pest resistance. Key considerations for variety selection are site microclimate, intended market (e.g., organic, direct sales, wholesale, etc.) and specific market needs. Hops quality and sensory characteristics also vary significantly with terroir - the unique combination of geography, soil, and climate. The Hops variety Willamette has been grown in back gardens in Prince George. Bulkley Canyon Ranch grows commercial Hops for beer production. Evaluation of several varieties is recommended to determine which grow well and produce the desired qualities, and to minimize risk of losses and market changes.

Required Inputs

Hops yard sites should be weed-free, plowed, and disked. Smother crops and green manures for at least one year before planting is recommended. Suggested soil organic matter content ranges from 3-10%. Hops varieties are propagated by rhizome or tissue culture from plugs because only the female plants are used. Rhizomes are planted in moist soil in early spring as soon as the ground can be worked, then mulched to minimize risks of frost damage. The distance between beds is often 2.25 m (~7 feet), but varies with type of machinery used for tilling, mowing, and harvest. Frequent watering is needed during establishment.

In spring, the crowns of established Hops need to be pruned to remove rhizomes (which can be used for propagation). Ongoing rhizome production can be pruned by tilling. Once the growing vines (or bines) are 1 m (~3 feet) high they must be pruned and the remaining shoots trained to grow on twines attached to a trellis system. New shoots emerging from the crowns also need to be pruned over the season and, after harvest, long stems should be removed and new mulch added.

The nutrient requirements of Hops are complex, varying with plant age, developmental stage, and variety. Generally, Hops require soil nitrogen levels of 180-225 kg/hectare (~160-200 lb/acre), phosphorus levels of 120 kg/hectare (~110 lb/acre), potassium levels over 500 kg/hectare (~450 lb/acre), and a range of other micronutrients. Terroir is also very significant. For example, citrus and floral flavours are most desirable, but Vancouver Island-grown Hops are known for less desirable earthy, herbal flavours.

Hops have many known pests and fungal, bacterial, and viral diseases that can result in significant losses. Aphids and spider mites must be controlled. Hops powdery and downy mildews and Verticillium wilts are the most significant diseases in the Pacific Northwest. Removal of the lower leaves, any diseased or damaged tissue, and rigorous water control are suggested as routine practice. Although Hops are classified as a very invasive weed in Southern BC[28], they are very shade intolerant and can be controlled with pre-emergent and post-emergent herbicides.

Technology & Infrastructure

Establishment of a Hops growing operation requires investment in trellis systems, harvesting equipment, and, at a minimum, a drying facility for post-harvest processing. Good drainage is important; however, subsurface improvement using drainage tiles or pipe isn't advised as the large roots of Hops can penetrate 1.5-4.5 m (~5-15 feet). Selection of a sloped site, planting on hills, or carefully ditching between rows to prevent water pooling are options for poorly drained soils. Most trellis systems are >5 m (~16 feet) in height. Trellis type and layout vary with microclimate, scale, variety, weeding, pruning, and harvesting systems. If required, drip irrigation is recommended as overhead watering can result in mildews and other diseases.

Hops harvesting is done manually, using a ladder or cherry-picker, or mechanically, using specialized equipment. Harvested cones are dried immediately after harvest, reducing water content from 80% to 8% using even heat below 60^{o}C and good ventilation. Once dried, Hops are compressed, packaged and frozen to protect quality losses from exposure to light, oxygen, and warmth. Hops quality testing must be done by a qualified analytical lab.[29] At minimum, brewers require information on Hops' alpha and beta acid percentages, and storage index. Oil content and volatile oil profiles are also assessed.

Estimated Yield

At recommended planting rates of 1,000-1,200/hectare (~400-500/acre), Hops yields in the Pacific Northwest range from 1,000-2,800 kg/hectare (~900-2,500 lb/acre).

Market Opportunity

Germany and the U.S. are the major producers of commercial Hops. Global demand for conventionally grown Hops is decreasing, but demand for specialty, organic Hops is increasing. There are suggestions that the B.C. Hops market is saturated; however, recent research indicates that this is not yet the case. A 2014 survey found over half of the local brewers interviewed didn't have access to a source of locally grown B.C. hops and would be interested if desired varieties, quality, and quantities could be provided[30]. Furthermore, demand for organic hops in the rest of Canada and the U.S. continues to grow.

Biochemicals in Hops have neuropharmarcological, estrogenic, anti-inflammatory, antifungal, antibacterial, and anti-viral properties. Hops have also shown promise for use as antimicrobials in animal feed, decreasing mortality and improving feed use efficiency in fish, poultry, rabbits, and cattle. Hops-derived chemicals can replace antibiotics in ethanol production, and spent Hops from brewing can be used as an industrial source of flavours, pectins, and organic acids.

Future Considerations

Projected climate change (a warmer climate, slight change in precipitation and more varied climate) will likely have a positive impact on Hops in the BNRD. Hops requires 120 frost free days. Currently, average frost free days in the BNRD are 90-110. A warming climate with greater number of frost free days will therefore benefit Hops and most likely result in greater productivity. Changes in precipitation and greater climate variability could negatively impact Hops growers in southern B.C. and the U.S. Ongoing research into Hops' components and bioactives may provide additional market opportunities.

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[28] See Northwest Invasive Plant Council at http://nwipc.org/plants/common-hops.

[29] Commodity Lab Vancouver (http://www.clvancouver.com) is the first B.C. to offer Hops' testing. Test prices start at $40.

[30] Available at www.persephonebrewing.com/wp-content/uploads/2015/07/TM1Appendix2.pdf

Sources of Information

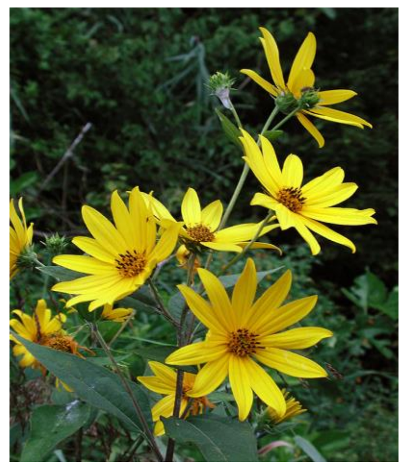
With the rapidly growing interest in cultivation there are many sources of information on Hops. Examples of just a few of these sources include:

- Small Scale and Organic Hops Production. Available at: www.crannogales.com/products/small-scale-organic-hops-production-manual?variant=14857172422
- Nova Scotia Hop Growers' Guide 2013. Available at: http://0-nsleg-edeposit.gov.ns.ca.legcat.gov.ns.ca/deposit/b10680536.pdf
- Calendar of Hops Field Work. Available at: http://thehopyard.com/wp-content/uploads/2012/06/COState_Soil.pdf
- Open Demonstration Hop Yard and Business Resource Centre. Information available at: www.persephonebrewing.com/open-demo-hop-yard-2/

Jerusalem Artichoke

About Jerusalem Artichoke

Jerusalem Artichoke (*Helianthus tuberosus*) is a vigorous herbaceous perennial in the Asteraceae family. Originating in the prairies and plains of North America, Jerusalem Artichoke is naturalized in most U.S. states and all Canadian provinces, and is cultivated as an annual in Northern Europe and Asia. Related to other sunflower species grown as ornamentals or for their oil, Jerusalem Artichoke is primarily grown for its edible tubers. Variously known as Sunroot, Sunchoke, Earth Apple, and Topinambur, Jerusalem Artichoke grows to 1-3 m (~3-10 feet) in height with broad thick leaves, robust stems, and yellow flowers. The knobby tubers, 7.5-10 cm (~3-4 inches) long and 3-5 cm thick (~1-2 inches), grow from rhizomes.



Jerusalem Artichoke (Photo credit: www.discoverlife.org).

Domesticated by First Nations in North America and established in Northern Europe in the 1600s, Jerusalem Artichoke is receiving renewed interest as a commercial crop. Jerusalem Artichoke's major storage carbohydrate, inulin, is an indigestible soluble carbohydrate that is converted to fructose by cold temperature (e.g., after a frost), during storage, or by processing (such as cooking). Fresh Jerusalem Artichoke tubers are primarily used as a specialty food and animal feed. However, as a prebiotic functional ingredient, the tubers are also consumed fresh or processed (dried and powdered) and incorporated into baked and dairy products. Tubers can also be used to produce industrial chemicals (e.g., fructose, ethanol, and butanol).

Climate & Soil

Grown widely by gardeners in the BNRD and sold as seedlings by the David Douglas Botanical Society, Jerusalem Artichoke requires 80-125 frost free days from planting in early spring to late summer harvest. Frost and drought-tolerant, Jerusalem Artichoke requires as little as 40 cm (~16 inches) precipitation. Often grown in regions too dry for potato cultivation, Jerusalem Artichoke grows best in full-sun and requires a long photoperiod for tuber development and to flower (> 9 and 13 hour days, respectively).

Environment has a strong influence on Jerusalem Artichoke growth and tuber characteristics (i.e., size and shape). As such, although the Jerusalem Artichoke is known for its tolerance of marginal soils and can be grown in hard-clay soils, the greatest yields and best tuber quality are in well-drained, moist fertile sandy loam soils with a slightly alkaline pH.

Varieties
Jerusalem Artichoke breeding has generated several varieties, primarily selected for smoother skinned uniform tubers because the gnarled, knobby, highly variable tuber shapes affect its appeal as a root crop. There is a least one early-maturing variety called Stampede, which grows quickly to produce round tubers. White-skinned tuber varieties include French White Mammoth, Clearwater, and White Fuseau. Red-skinned tuber varieties include Red Fuseau and fingerling-type varieties, such as Red Rover and Walspinel.

Natural vegetative propagation from Jerusalem Artichoke tubers is so prolific that once a field is planted there is sufficient planting stock available for the following year. This characteristic has positive and negative consequences. Once established Jerusalem Artichoke is very persistent. Careful selection of the initial variety is therefore important for growth rate, tuber yield, and shape. Breeding of Jerusalem Artichoke interspecific hybrids (i.e., Jerusalem Artichoke and the common sunflower) shows potential value as a perennial commercial crop for both oilseed and tuber production[31].

Required Inputs
Recommended soil preparation for Jerusalem Artichoke is similar to potato needs, i.e., plowing just before planting to produce loose-texture and good drainage. Jerusalem Artichoke seed is expensive with limited availability as most varieties are sterile. Despite this, Jerusalem Artichoke is readily established from tubers. Whole tubers or tuber pieces with two to three buds are used for planting. The recommended planting density depends on variety and climate, but it is usually about 20% lower than potatoes. For example, Jerusalem Artichoke tubers are often planted 1,100-1,800 kg/hectare (~980-1600 lb/acre) in rows 50-60 cm (~2 feet) wide, with 70-130 cm (~2-4 feet) between rows Depending upon climate and soil characteristics. This planting density is reported to yield between 10,000-15,000 plants.

Although Jerusalem Artichoke is reported to grow readily in poor soils, tuber yield is improved by increased soil fertility. For some Jerusalem Artichoke varieties, addition of 50-130 kg/hectare (~45-120 lb/acre) nitrogen and 50-168 kg/hectare (~45-150 lb/acre) potassium are reported to increase productivity to 18-38 tonnes/hectare (~16,000-34,000 lb/acre). Depending upon soil pH, addition of lime to increase alkalinity may also be beneficial. Spraying plants with inorganic selenium can enhance the nutritional value of tubers.

Jerusalem Artichoke is vigorous, dense, and able to compete effectively with weeds after initial growth. As such, weed control after establishment is minimal. Although Jerusalem Artichoke has no significant insect pests that might impact tuber production, losses to fungal diseases, such as rusts and rot, during production and post-harvest can be significant. Jerusalem Artichoke should be grown no more than once every three years in a field. Jerusalem Artichoke is best rotated with cereals and grasses.

Technology & Infrastructure
Jerusalem Artichoke planting and harvesting is done manually for small areas; however, both can be carried out with care using modified potato equipment. Cost of production is estimated to be 20% greater than for potatoes. When harvesting Jerusalem Artichoke tubers, the woody shoots must be removed and equipment must be adjusted to accommodate the smaller, less uniform tuber size. Manual tuber separation, sorting, and washing to remove soil and stones is required to avoid bruising and minimize disease.

Because spoilage during storage is a significant problem, prompt tuber processing (i.e., washing, boiling, dehydrating, and/or freezing) is recommended. Ideal storage conditions for Jerusalem Artichoke tubers are 0-2^{o}C and 90-95% humidity. Under these conditions, Jerusalem Artichoke tubers can be stored for up to 12

[31] Researchers at University of Minnesota developed interspecific hybrids of *H. tuberosum x H. annuus* (oilseed or common sunflower) demonstrating tuber and seed production are not linked traits and suggested potential for a commercial crop producing both.

months. However, during storage the carbohydrate profile of the Jerusalem Artichoke tubers changes as inulin depolymerizes to fructose and glucose. This must be considered when assessing potential markets and value.

Estimated Yield

Each Jerusalem Artichoke plant produces 1-2.5 kg (~2-3 lbs) fresh weight of tubers. However, as mentioned previously, yield is highly dependent on variety and growth conditions, and can range from 10-80 tonnes/hectare (~9,000-72,000 lb/acre). Commercial production in both Northern Europe and the U.S. Northwest is typically 30-60 tonnes/hectare (~27,000-54,000 lb/acre).

Market Opportunity

Jerusalem Artichokes were cultivated by First Nations in North America and continue to be grown commercially for food, forage, and feedstock chemicals in Northern Europe and China. Commercial scale production of Jerusalem Artichoke goes in and out of favour, in part because it is highly persistent and occasionally described as invasive because small pieces of tuber can readily re-establish a stand. Currently, the global market for Jerusalem Artichokes is small. France consumes more than any other country.

As food, Jerusalem Artichoke tubers require extensive cooking or treatment to convert the inulin content to fructose. Without this, some people experience gastric distress (flatulence). Plant tops can be used as animal fodder; however, this reduces tuber yield. The most promising commercial opportunities appear to be as functional foods, e.g., as prebiotics, because Jerusalem Artichoke tubers have low starch content and a high inulin concentration (10-20% fresh matter). Inulin is recognized as a natural soluble fibre by Health Canada.

Commercial interest and research on Jerusalem Artichoke as a functional ingredient for low glycemic index food products for heart health, weight-loss and diabetes increased in the past five years. Jerusalem Artichoke can be grown alternatively as an industrial crop for carbohydrate (e.g., fructose) or ethanol production. Its potential use for industrial chemicals such as succinic acid has also been evaluated. Currently Jerusalem Artichoke is not cost-competitive with chicory for inulin production and, in the Pacific Northwest, its use for ethanol and fructose production isn't economically viable.

Future Considerations

The production of Jerusalem Artichoke, a hardy, vigorous crop with low input requirements, is likely to be positively impacted by projected climate change within the BNRD (a warmer climate, slight change in precipitation and more varied climate). Some Jerusalem Artichoke varieties require up to 125 frost free days (although other sources suggest as few as 80 days). Currently, in the BNRD the average number of frost free days is 90-110, so a warming climate with more frost free days would benefit Jerusalem Artichoke and most likely result in greater tuber production.

Sources of Information

As a crop suitable for many climates and with rapidly growing interest there are many sources of information on Jerusalem Artichoke. Examples of just a few of these sources include:

- Jerusalem Artichoke Factsheet. Available at: www.omafra.gov.on.ca/english/crops/facts/94-077.htm
- Oregon Vegetables, Artichoke, Jerusalem. Available at: http://horticulture.oregonstate.edu/content/artichoke-jerusalem
- Alternative Field Crops Manual - Jerusalem Artichoke. Available at: www.hort.purdue.edu/newcrop/afcm/jerusart.html
- Growing Jerusalem Artichokes (Sunchokes). Available at: https://www.growveg.com/guides/growing-jerusalem-artichokes-sunchokes

Quinoa

About Quinoa

Quinoa (*Chenopodium quinoa*) is a broad-leaf annual crop in the Amaranthaceae family, grown for its highly nutritious grain-like seeds. Quinoa, often referred to as an ancient grain or 'pseudo-cereal', originated in the Andes Mountains where it has been used for over 8,000 years as a staple food. Quinoa grows to 0.5-2 m (~2-6 feet) tall with broad goose-foot-shaped leaves, and clusters of small flowers. The black, red, pink, orange, yellow, or white Quinoa seeds are small (1.5-2mm in diameter) and contain 12-22% protein.

Quinoa (Photo credit: Biodiversity International).

Quinoa has a number of nutritional advantages for food products. The seed contains all nine amino acids essential for human health, and more calcium, phosphorus, iron, fiber, and B vitamins than most other cereal grains. Quinoa does not contain gluten so the seeds are used for gluten-free pastas, baked goods, and other products. Bioactive and industrial products are made from the saponins, the bitter, soapy componds that coat the grains. Whole Quinoa plants can also be used as green forage and harvest residues are used as cattle, horse, pigs, sheep, and poultry feed.

Climate & Soil

Grown around the BNRD in gardens, Quinoa is a cool season, annual crop that takes from 90-125 days to mature, requiring as little as 25cm (~10 inches) of precipitation. Although adequate soil moisture is critical for germination, limited water availability appears to have little impact on seed yield once plants are established. Quinoa plants are tolerant of light frosts (down to -5^{o}C) and require cool temperatures for growth. During flowering and early seed development, temperatures below -2^{o}C and above 35^{o}C can reduce seed set. Heat sensitivity has restricted Quinoa production in the U.S. and southern Canada.

Noted for its ability to be grown on marginal land with low fertility, salinity, and high acidity (pH 4.6) or alkalinity (pH 8.5), Quinoa is highly tolerant of a range of soil types. Despite growing best in medium well-drained sandy loam soils with pH of 5.5-8, Quinoa is also frequently cultivated in clay-loam soils.

Varieties

Quinoa breeding has accelerated recently with growing worldwide recognition of its value for cultivation in diverse climates, the significant genetic diversity available for breeding, and its use for high-value food and industrial products.[32] Most Quinoa breeding is focussed on improving heat tolerance, disease resistance, and yield. Although Bolivia and Peru dominate global Quinoa production, over 95 countries in Europe, Asia, Africa, and the Americas now actively grow selected varieties suited to specific climate and market needs.

For production in northern regions, early maturing, day length insensitive (flowering can be inhibited by long day length) cultivars are recommended, such as the University of Wageningen's Atlas and Pasta varieties. Two registered Danish varieties, Puno and Tiicaca, and a Chilean variety, La Regalona, may also be suitable for northern B.C. An American variety, Linares, has produced good yields in Colorado, Oregon, and Washington State. The company Northern Quinoa in Saskatchewan has grown Quinoa since the 1990's using their own registered variety NQ94PT which they license to growers in Saskatchewan and Alberta.[33]

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[32] Despite extensive global breeding, commercial seed availability for registered varieties is limited due to required compliance with country-specific regulations on sharing plant genetic resources and phytosanitary certification requirements.

[33] Notably, Northern Quinoa will not contract Quinoa growers in Manitoba, Saskatchewan, and Alberta south of latitude 52^{o}N because of heat-caused yield reductions. The BNRD is situated between latitude 53-56^{o}N.

Required Inputs

Quinoa seed is direct-sown (drilled) in spring (late April to early June) at soil temperatures of > 2°C and harvested in August or September. Required soil preparation is minimal; tilling to produce a level seedbed. The small seeds are vulnerable to dehydration and waterlogging. Soil moisture is key for determining planting depth; recommendations range from 0.5-2.5 cm (~0.2-1 inches). Alternatively, Quinoa can be sown indoors and then transplanted to fields. Increased plant density results in earlier seed maturation. Quinoa plants grow slowly at first and weed growth must be managed by mulching or row cultivation. Rotary hoeing to 10-15 cm (~4-6 inches) depth is effective to reduce competition and seed contamination from weeds, such as redroot pigweed and lamb's quarters. Once Quinoa plants reach 30 cm (~12 inches) high, growth is rapid and weeds are outcompeted. Quinoa seed is ready for harvest once it turns yellow and starts to fall out of the seed head.

Although renowned for its productivity on marginal land, Quinoa responds well to nitrogen fertilization of 80-200 kg/hectare (~70-180 lb/acre). For low fertility soils, the addition of 50-200 kg/hectare (~45-180 lb/acre) phosphate and 88 kg/hectare (~80 lb/acre) calcium are recommended. Insect larvae, flea beetles, grasshoppers, and sugar beet root aphids can cause damage. In Canada, the most significant insect pest is the Lygus bug, while the most significant disease globally is downy mildew. Other diseases include leaf spot, grey mold, and bacterial blight. There are no registered pest or disease control products for Quinoa. Birds can damage young plants and eat up to 60% of seeds, particularly if low saponin varieties are grown.

A three-year rotation of Quinoa is suggested. Quinoa performs well after potatoes or legumes (e.g., clover or medic), so it may work in rotation with existing crops grown in the BNRD, particularly in low water, low fertility areas. Quinoa is not recommended to follow a canola or wheat crop as seed types are difficult to separate.

Technology & Infrastructure

Once seed is no longer green and plants are dry, Quinoa can be manually or mechanically harvested using a combine with a sorghum or standard platform/header. Screen sizes must compensate for small seed size. Pre-harvest sprouting can be a significant problem in rainy conditions; seeds must be dry before storage. In addition to cleaning by threshing to remove chaff, Quinoa seed must be treated to remove the bitter, soapy saponins before processing or consumption. Saponins can be removed by repeated washing, or using a grain dehuller followed by washing. Treatment with a rice polisher is also used. Low saponin varieties require less post-harvest processing. Water and oil content is comparable to sunflower seed, so similar storage conditions can be used (-3-4°C and <70% relative humidity).

Estimated Yield

Quinoa sowing density is 20-30 kg/hectare (~18 lb/acre) with rows 30 cm (~12 inches) apart to produce stand density of 150-500 plants/m^2. Seed yields range from 500-5,000 kg/hectare (~450-4,500 lb/acre) depending on variety, cultivation and weather. Weed control and nitrogen fertilization have greatest impact on seed yield. In the Canadian prairies seed yield is typically 700-1,000 kg/hectare (~625-900 lb/acre).

Market Opportunity

In 2015 Canada was the 4th largest exporter of Quinoa. Its popularity continues to grow because Quinoa has an excellent nutrient profile as a complete protein source and good source of dietary fibre, carbohydrates, lipids, and vitamin C and E. It can be marketed as a whole grain and labelled gluten-free if it meets processing guidelines. Quinoa can be milled into flakes or flour, and used in a wide range of food products, including pastas, baked goods, snacks, and beverages. It can also be used as animal feed. Well-established in the organic food market, Quinoa products are often marketed as health foods[34].

[34] Evidence suggests Quinoa can be beneficial in prevention and treatment of risk factors related to metabolic, cardiovascular, and gastrointestinal disease. Research as a bioactive for uses as diverse as cosmetics, antimicrobials, and pesticides is also growing.

Quinoa starch has good characteristics for food processing - excellent freeze-thaw properties, a low gelling point and stability at low temperatures. It can be used as a thickener for frozen foods, sauces and soup, and provide a creamy, smooth texture similar to fats. It has potential use in biodegradable films and flavour carriers. Quinoa proteins are being evaluated for foaming, emulsifying, and gelling properties. Evidence to date suggests that Quinoa's protein properties are similar or superior to soy and milk proteins.

Future Considerations

Quinoa is a rapidly developing crop with broad potential for cultivation in a range of marginal climates. Climate change related variability in precipitation in the BNRD is likely to have little or no effect on Quinoa cultivation. A warmer climate with a longer growing season increases the opportunities for production in the BNRD. Canadian Quinoa production is more cost effective than in the U.S. Active research in breeding, agronomy, health benefits, processing methods, and industrial products indicate sustained market interest.

Sources of Information

As a crop suitable for many climates and with rapidly growing interest there are many sources of information on Quinoa. Examples of just a few of these sources include:

- Keen-what? Quinoa: things to consider for quinoa production. Available at: www.omafra.gov.on.ca/english/crops/organic/news/2013/2013-10a2.htm
- Quinoa cultivation in the Netherlands. Available at: www.wur.nl/en/article/Quinoa-cultivation-in-the-Netherlands.htm
- Quinoa...The Next Cinderella Crop for Alberta? Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/afu9961/$FILE/quinoa_final_report_june_05.pdf
- Working Quinoa into a Prairie Crop Rotation. Available at: www.realagriculture.com/2014/07/working-quinoa-prairie-crop-rotation/

Saskatoon Berry

About Saskatoon Berry

The Saskatoon Berry, *Amelanchier alnifolia*, is a deciduous, fruit-bearing shrub in the Rosaceae family. Also known as Pacific or Western Serviceberry, Alder Leaf, Dwarf Shadbush and Juneberry, the Saskatoon Berry is native to North America and grows widely across Western Canada. The Saskatoon Berry shrub grows to 1-2 m (~3-10 feet) in height, with oval to circular leaves, and white flowers. The round blue-purple fruit is similar to a blueberry but seedier.

While Canadians have consumed fresh and dried Saskatoon berries for centuries, and have grown Saskatoon bushes as ornamental plants and windbreaks, interest in Saskatoon Berries as a comercial crop is relatively recent. Saskatoon Berries are rich in antioxidants and have high nutrient density. They contain more energy, protein, fibre, carbohydrates, vitamin C, iron, potassium, and calcium than blueberries, strawberries, or raspberries. Saskatoon Berries are sold fresh, dried, canned, frozen, and are used in baked goods, beverages, confections, and snack foods.

Saskatoon Berry (Photo credit: Manitoba Agriculture).

Climate & Soil

Growing in the wild and locally by U-pick berry operations in the BNRD, the Saskatoon Berry is a hardy shrub, tolerant of -50°C winter temperatures. The Saskatoon Berry has a minimum chilling requirement of 3 months

<4^{o}C, and requires 30-75 cm (~14-28 inches) precipitation. Although Saskatoon Berry shrubs are shade tolerant, full sun is recommended for highest berry yield. Water is critical for initial establishment, as well as during flowering and fruit filling. After three years of growth Saskatoon Berries are produced, requiring 90-100 frost free days from the onset of flowering to berry ripening. Flowers are vulnerable to spring frosts.

Adaptable to a wide range of soil types, including fine clay, the Saskatoon Berry grows best on deep, moist, well-drained, acidic (pH 6-7.5) sandy loam soils with organic matter content of 2-3%. Site selection is important; planting on a northeast or east slope of 1-5% can provide good drainage and avoid frost pockets during flowering. Protective shelterbelts perpendicular to the prevailing winds are also advantageous.

Varieties

Several Saskatoon Berry varieties currently exist; some of which have been trialled in the BNRD.[35] Variety selection depends on whether the crop is for a U-pick operation, in which uneven blooming and ripening can be tolerated, or for mechanical harvesting, in which uniform ripening is required. For U-picks, Honeywood and Theissen varieties are suggested. However, Thiessen is earlier flowering and is therefore more vulnerable to frost. For mechanical harvesting, Northline, Smoky, JB30 and Martin are recommended. JB30 grows quickly, has large fruit, and once established, is among the highest-yielding varieties.

Requirements

Saskatoon Berry shrubs can be planted in spring, after the risk of frost but before plants lose dormancy, or planted in the late fall. Before planting Saskatoon Berry stock fields should be well-tilled, ideally cultivated for several years before planting to control perennial weeds, and soil nutrient levels should be adjusted to 70 kg/hectare (~60 lb/acre) nitrogen, 100 kg/hectare (~90 lb/acre) phosphorous, and 400 kg/hectare (~360 lb/acre) potassium. Annually, it is recommended that 33-55 kg/hectare (~30-50 lb/acre) more nitrogen and 22-44 kg/hectare (~20-40 lb/acre) more phosphorous are added in early spring.

Deep planting in row furrows is recommended to reduce frost damage. Irrigation will likely be required during establishment, and possibly during flowering and fruiting. Organic or plastic mulching also helps to reduce soil moisture loss and reduces growth of weeds. Proactive weed control is essential as young plants are not very competitive. Recommended pre-planting herbicides to control annual grasses and broadleaf weeds include glyphosate or trifuraline products. No herbicide should be applied during establishment. After fruiting begins in the third year, herbicides can be used in early spring and fall.

Grasshoppers and western flower thrips are known pests for the Saskatoon Berry. Other insect pests require active monitoring. Diseases include juniper rusts and powdery mildew. Planting Saskatoon Berry at least 2 km away from native junipers is advised. Actions to deter deer, mice, rabbits and birds may be needed to avoid berry loss. Pruning is strongly recommended to control bush height, size, shape and suckering, and to remove diseased or damaged branches. For mechanical harvesting, annual pruning is required as well.

Technology & Infrastructure

Saskatoon Berry planting can be manual or mechanized, using traditional methods or deep planting. Dripline irrigation can be set up during planting if required. Overhead irrigation is not advised because it increases the risk of disease. Irrigation can be very important to ensure adequate moisture for shrub establishment, flowering, and berry production.

Saskatoon Berries are harvested mid-July to mid-August, depending upon the variety and weather. Equipment options include over the row/upright harvesters for tall plants with narrow rows, or side row harvesters for shorter plants or more densely planted orchards. Post-harvest handling includes immediate heat removal,

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[35] Varieties tested in a demonstration trial from 2001-2006 in the BNRD included Honeywood, Thiessen, Northline, and Smoky.

elimination of debris using a blower or destemmer, and berry sorting. Fresh berries have a very short shelf life and must be kept at 0-5°C with high humidity. Freezing or processing is recommended.

Estimated Yield

Recommended Saskatoon Berry planting density is 2,000-3,000 plants/hectare (~800-1,200/acre). For mechanical harvesting, the recommended bush spacing is 5-6 m (~16-20 feet) between rows and 1-1.5 m (~3-5 feet) between plants. Crop yields range from 2-8 tonnes/hectare (~0.8-3.2 tonnes/acre). Productivity is most affected by water availability. Depending on the chosen variety and weather, Saskatoon Berry production after 3-4 years of establishment averages 3-6 kg/plant (~7-13 lb/plant). The four varieties grown in the BNRD demonstration trials have produced upwards of 3.4-4.6 kg/plant (~7.5-10 lb/plant) in trials in Saskatchewan. Saskatoon Berry shrubs can produce berries for over 30 years.

Market Opportunity

Globally, Canada is the largest producer of Saskatoon Berries. In 2010, over 300 tonnes of berries were produced from 1 million hectares. In 2014, total Canadian production was 393 tonnes. Manitoba, Saskatchewan, and Alberta all grow Saskatoon Berries on a commercial-scale. In 2010, 22 tonnes of berries were produced in B.C. Food product development using Saskatoon Berries is also very active.

Saskatoon Berries have great potential for use in health food and natural health products, and research into their health benefits is ongoing. Traditionally used for diabetes management by First Nations is supported by scientific evidence. The nutritional and antioxidant values of Saskatoon Berries are superior to blueberries, strawberries, and raspberries. In Canada, Saskatoon Berries can make nutrient content claims for fibre, some minerals and micronutrients, and two health claims. The health claims are that Saskatoon Berries can help to reduce the risk of heart disease, and they can help to reduce the risk of some cancers.

Future Considerations

As a hardy berry crop, the projected climate change within the BNRD (a warmer climate, potentially more or less precipitation, and more varied climate) may have a positive impact on Saskatoon Berry production especially if the risk of frost is reduced and water availability is maintained during establishment, flowering and fruit development. As with the Black Chokeberry, Saskatoon Berries have a minimum chilling requirement. Although a warmer climate in the BNRD will reduce the number of days below 4°C, it is unlikely that this number will fall below that required by the Saskatoon Berry (approximately 90 days).

Sources of Information

As a specialty Canadian crop suitable for commercial production in northern climates, there are several sources of information on Saskatoon Berry production. Some examples of these include:

- Saskatoon Berry Production Manual. Available at: www1.agric.gov.ab.ca/$Department/deptdocs.nsf/all/agdex14362/$FILE/238_20-2.pdf
- Saskatoon Berry Production Alberta Farm Fresh School 2014. Available at: www.agric.gov.ab.ca/crops/hort/bv2014/saskatoon-berry-production.pdf
- Saskatoon. Manitoba Agriculture. Available at: www.gov.mb.ca/agriculture/crops/production/fruit-crops/saskatoon-berries.html#diseases

Sugar Beet

About Sugar Beet

The Sugar Beet (*Beta vulgaris L. subsp. vulgaris*), from the same species as Swiss chard, fodder beet and the red beet, is a root vegetable with a conical, white, fleshy root, and a rosette of leaves. Developed in the 1700s by the Prussians and inedible when harvested, the Sugar Beet grows to about 30 cm (~1 foot) in length, weighs about 1-1.5 kg (~2-3 lbs), and has up to 20% sugar content.

Sugar Beet (Photo credit: politicsoftheplate.com).

Typically cultivated in the Northern Hemisphere at latitudes of 30-60°N, the Sugar Beet is grown commercially for the sugar that can be refined from the root. Because the sugar percentage of a Sugar Beet varies depending upon variety, climate, soil, and crop management, producers are generally compensated for the amount of sugar delivered to processing facilities, rather than for the tonnes of Sugar Beet they deliver.

Climate & Soil

The Sugar Beet is a short-seasoned annual crop that takes only 70-90 days to mature from planting. Adapted to a wide range of climatic conditions, Sugar Beet grows until harvested or growth is stopped by a hard freeze. Optimal daytime and nighttime temperatures for the Sugar Beet are 15-25°C and 5-10°C respectively, and areas with long day lengths are most suitable. With a tolerance for mild frosts and known to survive temperatures as low as -5°C, the Sugar Beet requires upwards of 50cm (~20 inches) precipitation over its lifecycle (spring planting to fall harvest).

Sugar Beet are grown in a wide range of different soil types, from coarse textured sandy soils to high clay content, silty clay or silty clay loam soils. Soils with few stones are desirable as they can cause problems for Sugar Beet planting, thinning, and harvesting equipment. Soils with high water holding capacity are also beneficial, especially in areas with limited precipitation. Sugar Beet grow best in soils with a pH of 6.0-8.0.

Varieties

In both Europe and the U.S., commercial Sugar Beet variety improvement and seed production has been primarily carried out by private companies. Consequently, today there are hundreds of different Sugar Beet varieties to choose from depending upon local growing conditions. Varieties have been developed to have the highest yield, require the lowest inputs, have the lowest potential for bolting, produce the greatest consistency, or have the greatest disease resistance. Within North America, all Sugar Beet varieties grown are GMO. As the Regional District of Bulkley-Nechako generally does not support the use of GMO's for agricultural purposes, although opinion is divided both within and outside the agriculture sector, non-GMO seed would need to be sourced.

Requirements

Planted with precision row planters and seeded at rates from 1-3 kg/hectare (~1-3 lbs/acre), optimum planting dates for Sugar Beet in northern climates is from April 15th to May 10th. Harvest begins late-September or early-October, before the soil freezes. Land preparation for Sugar Beet generally begins late summer or early fall of the previous year, with plowing or disking to reduce soil clots (if the soil has clots seeds may remain bare, resulting in poor germination). Sugar Beet are a rotational crop, planted once every three or four years to minimise potential disease problems.

As profitable Sugar Beet production often depends upon high sugar content, soil fertility must be managed effectively. Somewhat unique in their nitrogen requirement (too little results in reduced yields, while too much leads to reduced sugar content), Sugar Beet research has shown that soil nutrient levels should be 110-135 kg/hectare (~100-120 lb/acre) nitrogen, 90-110 kg/hectare (~80-100 lb/acre) phosphorous, and 50-70 kg/hectare (~45-60 lb/acre) potassium.

Emerging Sugar Beet are small and take approximately two months before their leaves shade the ground. Until shading occurs, Sugar Beet are poor competitors with weeds. To avoid yield loss, weeds should be controlled throughout the spring with a combination of cultural, chemical, and mechanical methods (poorly timed weeding can affect the growth of crop and reduce yield). Most common diseases of the Sugar Beet are rhizomania, cercospora leaf spot, powdery mildew, and downy mildew. Sugar Beet are also susceptible to several insect pests, including the Sugar Beet root maggot, cutworm, and beet webworm. Chemical applications used to control insects and disease are effective and relatively inexpensive.

Technology & Infrastructure
Sugar Beet are a root crop that require specialized cultivation and harvesting equipment. Use of Sugar Beet drills to plant seeds saves time and labour, and can produce higher economic efficiency over manual sowing (especially if seeds are planted in cover crops without spring tillage). Depending upon seeding rates, thinning may be required. For harvesting, a mechanical defoliator is used to remove foliage from the Sugar Beet prior to lifting. Immediately following defoliation, Sugar Beet lifter-loader harvesters pull the beet from the soil and load them onto trucks.

Once harvested, Sugar Beet are piled on the ground or over forced air ventilation/aeration systems. Other storage options include climate controlled storage buildings. More specialised storage minimizes sugar loss caused by storage rot and root respiration.[36] Sugar Beet refining involves washing, slicing, and soaking to remove the juice. This juice is then purified, filtered, concentrated, and dried to create refined sugar.

Estimated Yield
Sugar Beet yield varies greatly depending upon climate, soil, chosen variety, and fertilizer application rates. Ideally, Sugar Beet plant density should be 70,000-100,000/hectare (~30,000-40,000/acre) at harvest. Typically Sugar Beet yields average anywhere from 35-60 tonnes/hectare (~15-25 tonnes/acre). One tonne of Sugar Beet can produce roughly 130-60 kg of refined sugar.

Market Opportunity
Approximately 35% of global sugar production is from Sugar Beet. Within the U.S., Sugar Beet production occurs primarily in California, Colorado, Idaho, Michigan, Minnesota, Montana, Nebraska, North Dakota, Oregon, Washington, and Wyoming, where > 400,000 hectares (1 million acres) are planted annual to produce > 36 million tonnes of Sugar Beet. Sugar Beet by-products include molasses and beet pulp, which are generally sold to local livestock and dairy operators. Within Canada, although Sugar Beet have been grown in Quebec and Manitoba, today the only remaining provinces to produce Sugar Beet are in Alberta and Ontario, which plant ~20,000 hectares (~50,000 acres) annually.

The greatest issue for most Sugar Beet farmers is market access. Sugar Beet processing facilities are large (daily capacity is generally > 3,000 tonnes) and expensive (estimated cost to build an average size facility is > $100 million). As such, if no Sugar Beet processing facilities are nearby, or if nearby processing facilities are at full

[36] Once a Sugar Beet is harvested, the plant begins to burn sugar as it decays. However, if temperatures remain below freezing, the sugar content of Sugar Beet stored outside remains constant.

capacity, farmers are unable to get their Sugar Beet refined into sugar. Lack of processing is why many Sugar Beet farmers in the U.S. have formed cooperatives to purchase and/or operate local facilities.

Sugar Beet in the U.S. are also used for ethanol production in place of corn or sugar cane. Technically, conversion of sugar to ethanol is a simpler process that conversion of corn to ethanol (which first requires enzymes to convert starch to sugars). Although estimates vary, the cost of Sugar Beet ethanol is approximately $0.8-1.5/l (~$3-5/g) depending upon feedstock, processing, and transportation costs. As with other ethanol processing facilities, Sugar Beet ethanol plants are large. Even a relatively small plant processing 1,000 tonnes/day for 150 days/year requires 3,000 hectares (~7,400 acres) Sugar Beet production.

Anaerobic digestion of Sugar Beet is an alternative to ethanol production.[37] Whole Sugar Beet, including the foliage, decompose well inside digesters. Anaerobic digesters can be built to any size depending upon local supply of Sugar Beet, and other available feedstocks, such as agricultural and food processing waste. The digestate from anaerobic digesters (the material left after digestion) can be used as fertilizer. For Sugar Beet to be used for anaerobic digestion throughout the year, suitable storage is required. Two common storage methods are liquid ensiling in a silo tower or lagoon, and ensiling of whole beet in plastic tubes.

Future Considerations

As a frost tolerant, short-season crop, projected climate change within the BNRD (a warmer climate, slight change in precipitation and more varied climate) will likely have little impact on Sugar Beet cultivation. Although projected climate change will have minimal impact, potential policy changes could be supportive. Over the past few years the B.C. government has taken greater interest in carbon neutral fuels, such as renewable natural gas. If policies were implemented to drive renewable natural gas production, such as higher prices, the economic feasibility of renewable natural gas from Sugar Beet could change significantly.

Sources of Information

As a crop suitable for many climates and with rapidly growing interest there are many sources of information on Sugar Beet. Examples of just a few of these sources include:

- University of Wisconsin, Alternative Field Crops Manual. Available at https://hort.purdue.edu/newcrop/afcm/sugarbeet.html
- Michigan Sugar Company Grower's Guide. Available at www.michigansugar.com/wp-content/uploads/2014/02/Growers-Guide-2014.pdf
- BBRO Sugar Beet Reference Book. Available at http://bbro.co.uk/media/1049/bbro-sugar-beet-reference-book-2016.pdf

5. Equipment & Infrastructure

When assessing crop suitability for a specific area, an important consideration is the necessary equipment and infrastructure to grow, harvest, process, and store the crop. Because the ten specialty and alternative crops identified in this study aren't widely grown in the BNRD, very little specialised equipment and infrastructure for these crops currently exists locally. Therefore, research was undertaken to determine the type of equipment and infrastructure required, and whether existing equipment and infrastructure in the BNRD could be used for the specialty and alternative crops identified.

[37] Anaerobic digestion is a naturally occurring process where micro-organisms breakdown organic waste in the absence of oxygen to produce a methane-rich gas. This gas can be burnt to produce renewable electricity or upgraded to a natural gas substitute.

5.1 Field Preparation

Most non-livestock farming equipment within the BNRD is for growing and harvesting forages and cereals. The most common type of field preparation is done using a moldboard plow; the second most common is discing. Some farmers also use chisel plows, which can be used on previously worked fields (e.g., a grain field sown with an annual crop, versus a perennial hay field). Chain and diamond-toothed harrows are also available and could be used, and equipment also exists locally for no-tillage (e.g., no-till seed drills).

5.2 Planting, Harvesting & Processing

The necessary equipment exists locally for field preparation; however, specialised planting, harvesting, and processing equipment is also required. Below is a general overview of the type of equipment and infrastructure within the BNRD that could be suitable for each of the identified specialty and alternative crops. This research used information gathered from Regional Agrologists, farmers, farm managers, and agriculture extension resources.

Berries: Saskatoon, Black Chokeberry & Haskap

There are some greenhouses in the BNRD that could be used to start berry plants prior to field planting.[38] There was a mechanical berry harvester located in Red Rock but this piece of equipment was for sale in 2015 and may have left the region. A local fruit winery harvests all of its berries manually. Because manually harvested berries have very little debris, the winery doesn't use a blower or destemming equipment. There is no known berry processing equipment within the BNRD.

Camelina & Quinoa

There are some combines in the BNRD that could be used for harvesting of both camelina and quinoa. These combines are primarily set-up for barley or wheat, and as such may need modification. Some farmers in the BNRD grow canola, and adjusting this equipment is not expected to be a problem. There is very little existing equipment in the BNRD for cleaning seed (all canola is shipped out of the region for processing) and any that does exist is very old and likely unable to be adapted for cleaning smaller seeds. It is also likely that there is no equipment to dehull or wash quinoa seed, nor any cold press system for processing camelina.

Garlic

There is no known specialized equipment in the BNRD for planting or harvesting garlic. However, local farmers have adapted other machinery to make the process more efficient. For example, a local garlic farmer used a cabbage transplanter to plant garlic. This transplanter planted 135 kg (~300 lbs) of garlic in four hours (compared to 55 kg (~125 lbs) manually in two days). Any equipment that opens a trench, drops the bulb and closes the trench could also work. Any larger-scale vegetable farm is likely

Left: Garlic planting using a cabbage transplanter (Photo credit: N. Touchette). Right: Garlic planting equipment (Photo credit: K Kellett)

[38] Alternatively, the young plants could be purchased from a credible supplier.

to have equipment that could be used for planting garlic, as long as spacing between plants and depth of planting can be adequately controlled.

Although garlic harvesting in the BNRD is primarily done by hand, available machinery could be used to help break up the soil. For example, a small rototiller or chisel plow could be used to loosen the soil, making it easy to pull the garlic bulbs by hand. It is believed most BNRD farmers have equipment that could be used to make garlic harvesting more efficient. For curing/drying garlic some farms have existing buildings (e.g., open sheds) that could be used, provided the buildings are well ventilated.

Hemp

Grain farmers in the BNRD generally have hay swathers to harvest their crop, whereas hay farmers have mowers with and without conditioning rollers to cut hay. Most grain and hay farmers also have the necessary equipment to make round or square bales. Although this technology could be used to harvest hemp, a local farmer who grew hemp experienced difficultly using traditional baling equipment (hemp fibre quickly tangled in the equipment and was difficult to remove). There is no existing decortication equipment in the BNRD.

Hops

There are very few, if any, existing trellis systems available in the BNRD for hops. Appropriate mechanical harvesting equipment is also extremely limited as very few (if any) farmers have cherry pickers. There are a few hops drying facilities in the BNRD (e.g., two or three private facilities have been built by local hops farmers); however, these are unlikely to have excess capacity. The two hay compression plants in Vanderhoof might be able to dry hops with excess available heat from compression, but this is as yet unconfirmed.

Jerusalem Artichoke

Larger scale vegetable farmers are likely to own potato or other planting and harvesting equipment that could be modified for Jerusalem Artichoke. Unfortunately, there are very few larger scale vegetable farmers in the BNRD. Furthermore, any existing vegetable equipment is likely to be older models and may not be in regular use. There is no existing local equipment or infrastructure for large-scale washing, boiling, or dehydrating that would be required to meet the needs for tuber processing.

Sugar Beet

It is expected that there are some precision row crop planters amongst vegetable farmers in the BNRD, and that some farmers may have equipment that could be adapted for direct seeding. It is also possible that there may be some mechanical defoliators in the BNRD, although these would be fairly uncommon. There is no Sugar Beet harvesting equipment or processing refineries in the BNRD.

5.3 Storage

There is very little existing storage infrastructure in the BNRD. In Prince George, the Northern Lights Winery has a walk-in freezer (capacity: 10,000 lbs fruit), and there is a local producer in the Giscome area with cold storage infrastructure capable of freezing. Local tree nurseries could also have the capacity to provide freezer storage during specific times of the year (e.g., a tree nursery in Telkwa has small, individually temperature-controlled rooms that could be used for temporary storage). There are some larger cold storage facilities owned by vegetable farmers throughout the BNRD, but these are unlikely to have excess capacity. In Smithers, there is an old Dairyland building, but it’s current use and capacity is unknown. There are several grain and silage storage silos and two hay-compression plants in the Vanderhoof area.

For the use of crops and crop residues for bioenergy production (as discussed below), dry storage is required. This storage, which can range from permanent steel and concrete to temporary fabric buildings, is necessary to prevent crop or crop residues (herein referred to as biomass) taking on moisture; which reduces net calorific value (also known as lower heating value). Biomass with high moisture content may require pre-storage drying to prevent fermentation/rotting, or more specially designed storage facilities. If biomass storage facilities are to be built, they should be established in Smithers (or between Smithers and Houston) and Vanderhoof, as these communities access the largest agricultural regions and highest population densities.

6. Bioenergy

Of the ten specialty and alternative crops identified in this study, five are suitable for bioenergy production. These are Camelina residues (stalk minus seed), Industrial Hemp, Jerusalem Artichoke residues (stalk minus tuber), Quinoa residues (stalk minus seed), and Sugar Beet. The most important characteristics when assessing biomass suitability for bioenergy production are net calorific value, ash content, moisture content, and yield (Table 10). Unfortunately, and because stalks are commonly plowed into the soil rather than used for bioenergy production, limited information exists for Quinoa.

Table 10: Bioenergy Characteristics for Bioenergy Suitability

Crop	Bioenergy Portion	Net Calorific Value (GJ/ODT)	Ash Content (%)	Moisture Content (%)	Yield (Tonnes/Ha)
Camelina	Stalk	18.43	N/A	Oven dried	~5.7*
Hemp	Entire plant	18	4	12.0 - 14.0 (field dried)	4.0 -12.0
Jerusalem Artichoke	Stalk	16.1 - 16.3	5.4 - 5.6	Oven dried	5.0 - 6.8
Quinoa	Stalk	N/A	N/A	13.42	3.33 - 5.32
Sugar Beet	Entire plant	16.1 - 17	6.9	77.5 - 81	35 - 65

GJ: Gigajoules. ODT: Oven dry tonnes. Ha: Hectare. Note: Only one source found (Steppuhn et al. 2010. Emergence, Height, Grain Yield & Oil Content of Camelina & Canola Grown in Saline Media. Can. J. Soil. Sci. Can. J. Soil. Sci.).*

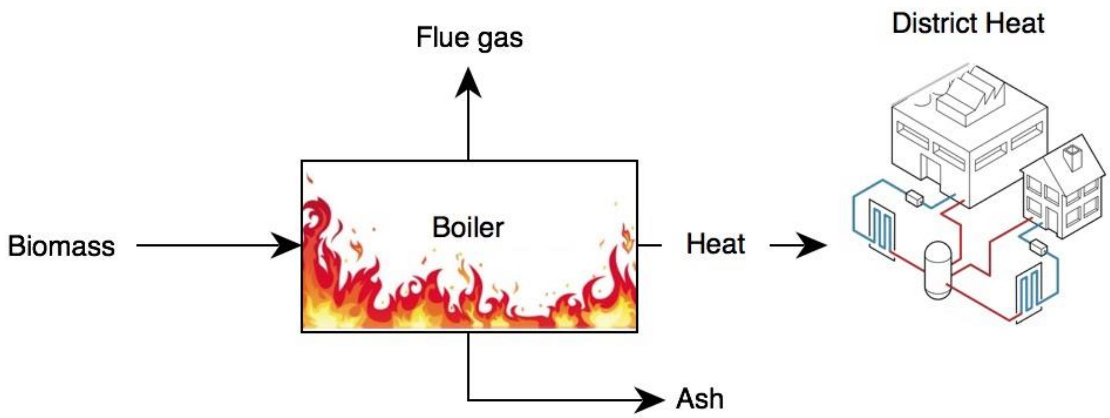
6.1 Bioenergy Opportunities

Bioenergy opportunities depend upon the type, volume, and location of available biomass, as well as crop economics, community needs and opportunity, and economic feasibility. For this study, and based on the five types of biomass identified above, the bioenergy opportunities assessed were biomass boilers, anaerobic digesters, and bio-coal production. Other bioenergy opportunities, such as ethanol, biodiesel, and syngas, were not assessed because they are incompatible with the size of communities found in the BNRD.

Biomass Boilers

Biomass boiler systems can be designed for small-scale individual use, or large-scale community use such as multi-building district heating systems (Figure 3). In both scenarios, biomass is fed into a boiler and used to run a hot water heating loop. Of the five types of biomass identified, Camelina, Industrial Hemp, Jerusalem Artichoke, and Quinoa are suitable for biomass boilers because of their lower moisture content. Sugar Beet are unsuitable due to their high moisture content.

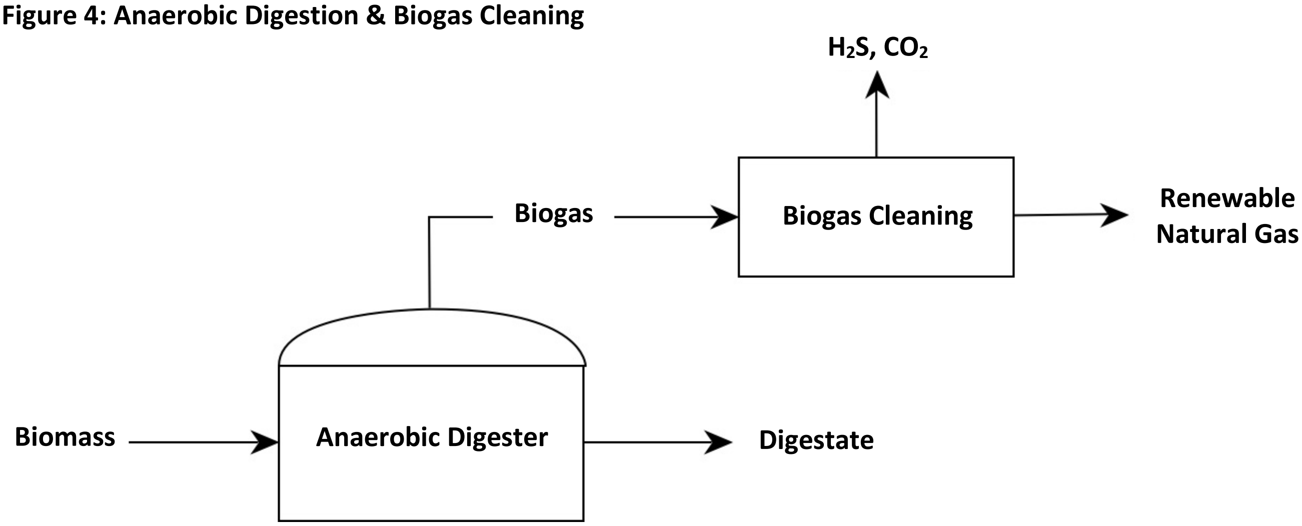
Figure 3: Biomass Boiler Combustion & District Heating System



Anaerobic Digestion

Although anaerobic digestion plants can be built any size, economies of scale greatly favour larger plants. Regardless of plant size, biomass is fed into an oxygen free tank where bacteria digest the feedstock to produce a methane-rich gas, called biogas. Biogas can be burned for heat, heat and electricity (this is known as combined heat and power), or cleaned of contaminants and carbon dioxide to produce renewable natural gas (biomethane). Renewable natural gas can be injected into the gas distribution system (Figure 4).

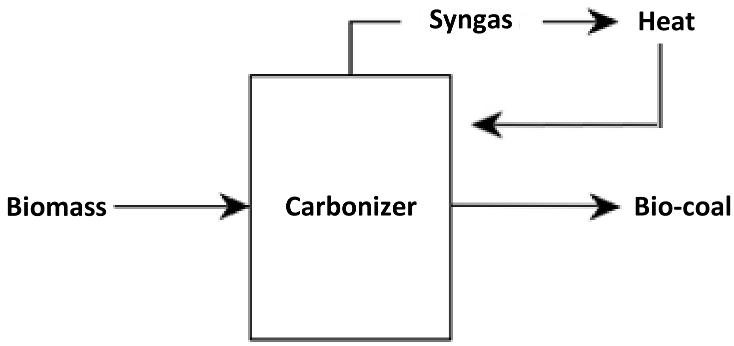
Figure 4: Anaerobic Digestion & Biogas Cleaning



Bio-coal

Bio-coal is a solid fuel made by heating biomass in an inert atmosphere to produce charcoal or torrefied wood (depending upon process temperature). Bio-coal differs from the starting biomass as all moisture is removed and the energy density is increased. The properties of bio-coal are very similar to fossil coal, enabling it to be very easily used to displace coal without the need for process handling changes.

Figure 5: Bio-coal Production & Opportunities



6.2 Bioenergy Assessment

There is steady and growing demand for bioenergy in B.C. Today, the feedstock most commonly used for bioenergy production is wood (wood pellets, wood chips, wood waste, and hog fuel). The lowest-cost source of wood supply is sawmill wood waste (including residual wood chips, sawdust, shavings, and bark), followed by roadside logging residues (including tree tops, branches and other non-saw log material derived during logging operations), and then standing timber (Table 11).

Table 11: Wood Biomass Sources & Prices

Biomass Source	$/tonne	$/GJ
Sawmill residue (Fort St. James)	12	0.7
Sawmill residue (Prince George)	40 to 60	2 to 3
Roadside slash (grinding and transportation)	55	3
Standing timber (harvest and transportation)	>110	> 6

One challenge facing B.C.'s bioenergy industry, particularly within the BNRD, is the availability of affordable biomass. For example, a large decrease in the annual allowable cut in the Prince George Timber Supply Area (which includes Vanderhoof and Fort St James) is predicted to decrease available forestry residue from 1.8 million to < 0.2 million m^3/year.[39] A similar situation is predicted for the East Prince Rupert Timber Supply Area (which includes Burns Lake, Houston, and Smithers). This drastic reduction in forestry biomass could present an opportunity for agricultural crops and crop residues, especially if these feedstocks are targeted towards the most appropriate energy sources and communities.

Currently, natural gas is substantially cheaper than any other energy sources in the BNRD, indicating that bioenergy will have a difficult time competing with this energy source. Instead, bioenergy should be targeted towards replacing heating oil or propane, as these energy sources are more expensive (Figure 6). The one exception to this is production of renewable natural gas. Through its green natural gas program, FortisBC currently pays upwards of $15/GJ for renewable natural gas. This price, anticipated to increase over the next few years, means renewable natural gas production should also be considered.

[39] BC Hydro 2013. BC Hydro. Integrated Resource Plan, Appendix 3A-25 Wood Based Biomass Potential Report. Available at www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/regulatory-planning-documents/integrated-resource-plans/current-plan/0300a25-nov-2013-irp-appx-3a-25.pdf

Figure 6 Current Energy Prices in BNRD as of December 2016

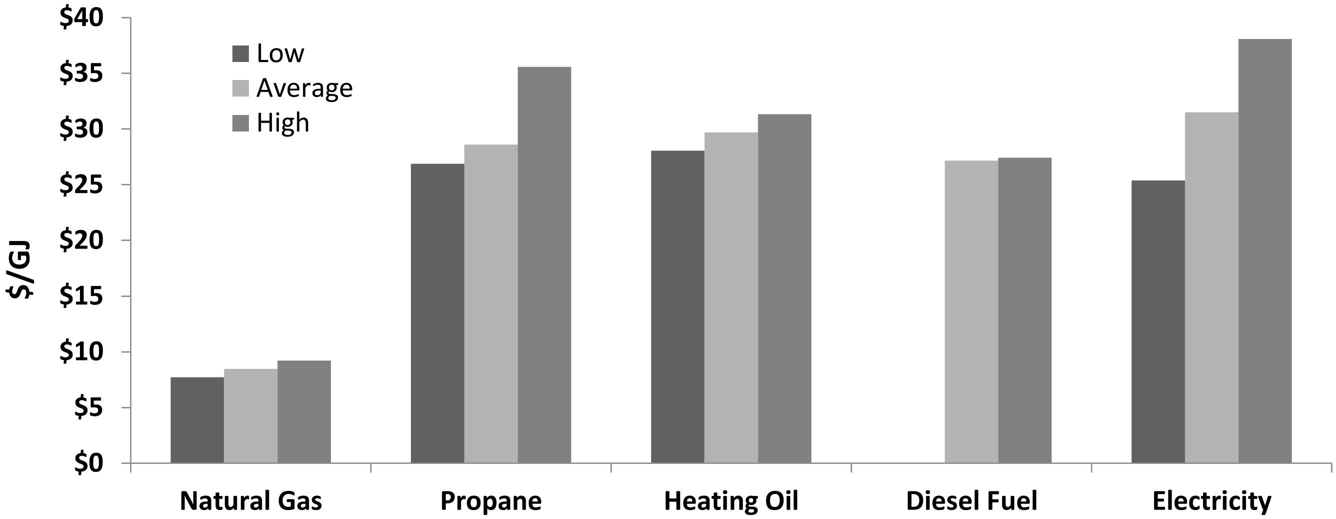


Table 12, which summarises BNRD community profiles, can be used to inform a regional strategy for bioenergy development. The largest communities in the BNRD, located along Highway 16, all have access to natural gas. It is only in the smaller communities, those that are more remote, where natural gas is not available. The application of natural gas and propane are typically the same; however, propane is more expensive than natural gas and is therefore a better fuel to replace from an economic feasibility basis. Consequently, bioenergy projects should be focused on opportunities in the more remote communities in the BNRD, on facilities in the larger communities that use propane (not natural gas), or for renewable natural gas production.

Table 12: Summary of BNRD Community Profiles

Municipality	Government Type	Population	Prox to Hwy 16	Existing Fossil Fuel Sources*
Smithers	Town	5,404	0 km	Natural Gas, Propane, Heating Oil
Vanderhoof	District municipality	4,480	0 km	Natural Gas, Propane, Heating Oil
Houston	District municipality	3,163	0 km	Natural Gas, Propane, Heating Oil
Burns Lake	Village	2,107	0 km	Natural Gas, Propane, Heating Oil
Fort St. James	District municipality	1,355	50 km	Natural Gas, Propane, Heating Oil
Telkwa	Village	1,295	0 km	Natural Gas, Propane, Heating Oil
Fraser Lake	Village	1,113	0 km	Natural Gas, Propane, Heating Oil
Granisle	Village	364	50 km	Propane, Heating Oil
Fort Babine	Village	~200	100 km	Propane, Heating Oil
Fort Fraser	Unincorporated	~500	0 km	Natural Gas, Propane, Heating Oil
Smithers	Town	5,404	0 km	Natural Gas, Propane, Heating Oil

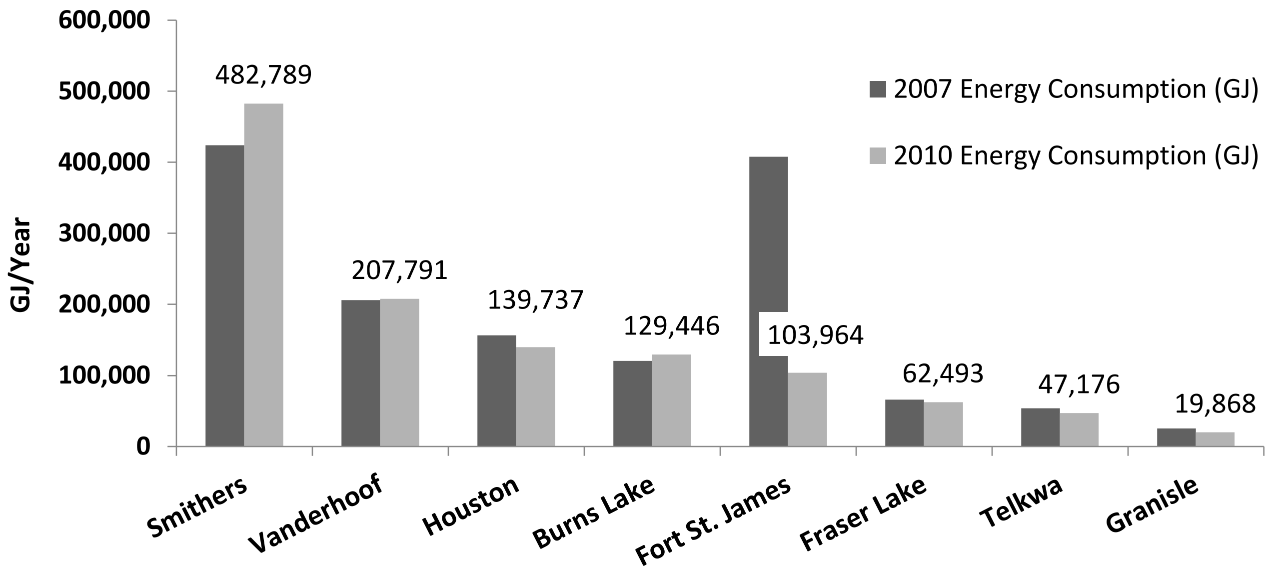
*Note: *All communities listed in the above table are connected to the BC Hydro electricity grid.*

Figure 7 shows potential market size for agricultural crops and crop residues to displace fossil fuel in residential, industrial, and commercial applications in the BNRD. Annual energy consumed is shown for both 2007 and 2010 to demonstrate potential trends in energy use.[40] Although Smithers and Vanderhoof present

[40] Data obtained from the B.C. Community Energy & Emissions Inventory. B.C. Government, Ministry of Environment. Available at http://www2.gov.bc.ca/gov/content/environment/climate-change/reports-data/community-energy-emissions-inventory

the largest overall opportunities, the ability of agricultural crops and residues to displace fossil fuels in these or any other communities in the BNRD will depend upon access to sufficient feedstock, local adoption of required bioenergy technology, and economic feasibility.

Figure 7: Potential Market Size Based on Energy Consumption



7. Economic Feasibility

7.1 Specialty & Alternative Crop Economic Feasibility

Assessing the net present value (NPV) for one hectare of land for the ten selected specialty and alternative crops over 25 years using production costs (including planting, cultivation, harvesting, processing, and distribution), yields, and market values, helps to better understand crop economic feasibility (Table 13). NPV was estimated by subtracting start-up costs (negative) from yearly profit for 25 years (profit in future years was converted to a present value using a discount rate of 2-6% to account for inflation and the time value of money). For crops requiring several years for establishment, such as Black Chokeberry, Haskap Berry, Hops, and Saskatoon Berry, saleable yields were assumed to only occur five years after planting.

Production costs vary greatly with individual circumstances, including total acreage, required inputs, and cost of equipment. Crop yield is heavily affected by variety and conditions during cultivation, whereas crop value varies according to quality, current market demand, and end use. Because of this, a range of values for production costs, yields, and market values were used, and NPV calculations were repeated 1,000 times using different, randomly selected input values for each calculation. These input values were varied according to a triangular distribution, as a triangular distribution is most likely to have a value near the center of the range.[41]

[41] This is called a Monte Carlo economic analysis and provides an output range for the most likely NPV.

Table 13: Crop Economic Input Parameters and Net Present Value per Hectare

Crop	Start-up Cost ($/ha)	Annual Cost ($/ha)	Yield (T/Ha)	Value ($/T)	NPV ($/Ha)
Black Chokeberry	13,000 - 24,000	10,000 - 14,000	7 - 12	1,000 – 3,000	20,000 – 95,000
Camelina		300 - 450	1 - 3	200 - 500	3,000 - 7,000
Garlic	50,000 - 100,000	25,000 - 37,000	4 - 8	12,000 - 22,000	800,000 - 1,250,000
Haskap Berry	20,000 - 35,000	12,500 - 24,000	4 - 10	5,000 - 12,000	290,000 - 550,000
Hemp		1,000 - 1,800	4 - 12	70 - 180	(9,500) – (3,000)
Hops	43,000 - 60,000	10,000 - 27,000	0.8 - 1.65	15,000 - 35,000	16,000 - 140,000
Jerusalem Artichoke		6,750 - 7,850	3 - 6	4,420	160,000 - 230,000
Quinoa		1,000 - 1,500	0.75 - 1.5	2,000 - 10,000	62,000 - 110,000
Saskatoon Berry	12,000 - 17,000	600 - 1,000	4.5 - 6	5,000 - 10,000	350,000 - 475,000
Sugar Beet		2,000 - 3,000	35 - 65	35 - 55	(8,500) – 1,000

Table 13 and Figure 8 show Garlic, Haskap Berry, Saskatoon Berry, and then Jerusalem Artichoke have the highest NPV. Hemp has the lowest, negative, NPV, followed by Sugar Beet, negative to positive, and Camelina slightly positive. Shaded values in Table 13 indicate the parameters that most strongly influence NPV. For example, for Haskap Berry the parameters that most strongly influence NPV are yield and value. Therefore, although Haskap Berry is estimated to have a positive NPV, it is significantly higher if yield is 10 tonnes/hectare (rather than 4 tonnes/hectare), or if the value is $12,000/tonne (instead of $5,000/tonne). NPV for Haskap Berry isn't as greatly impacted by start-up or annual costs (i.e., start-up and annual costs have a smaller impact on NPV than yield and value).

Figure 8. Selected Specialty & Alternative Crop Net Present Value

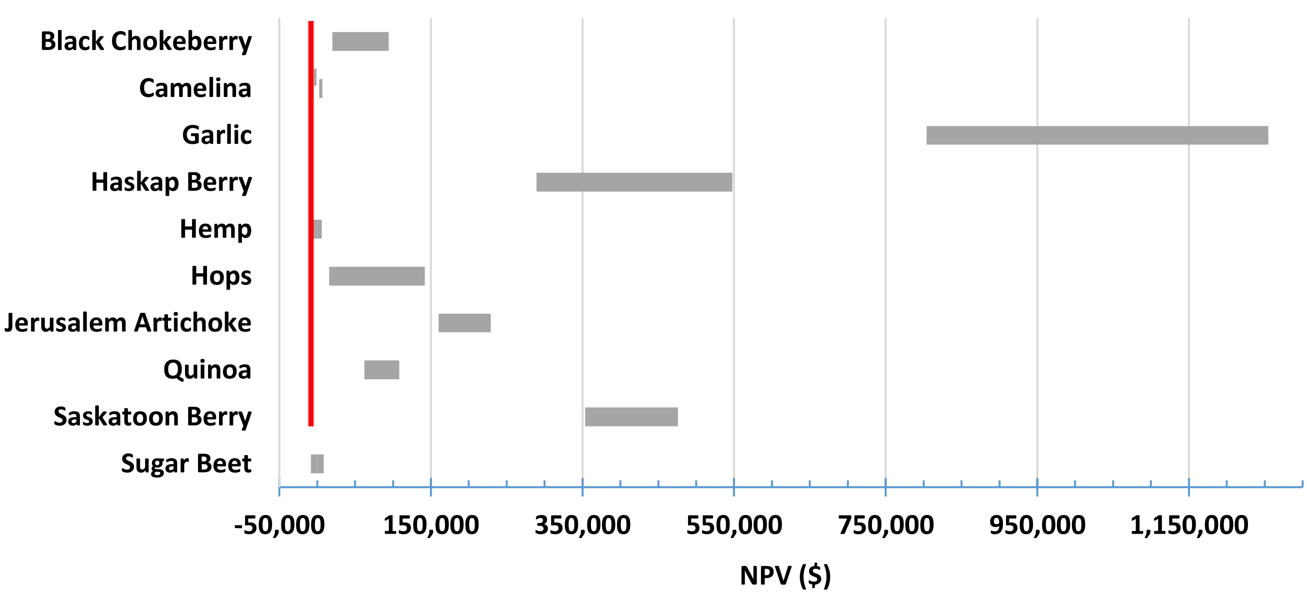
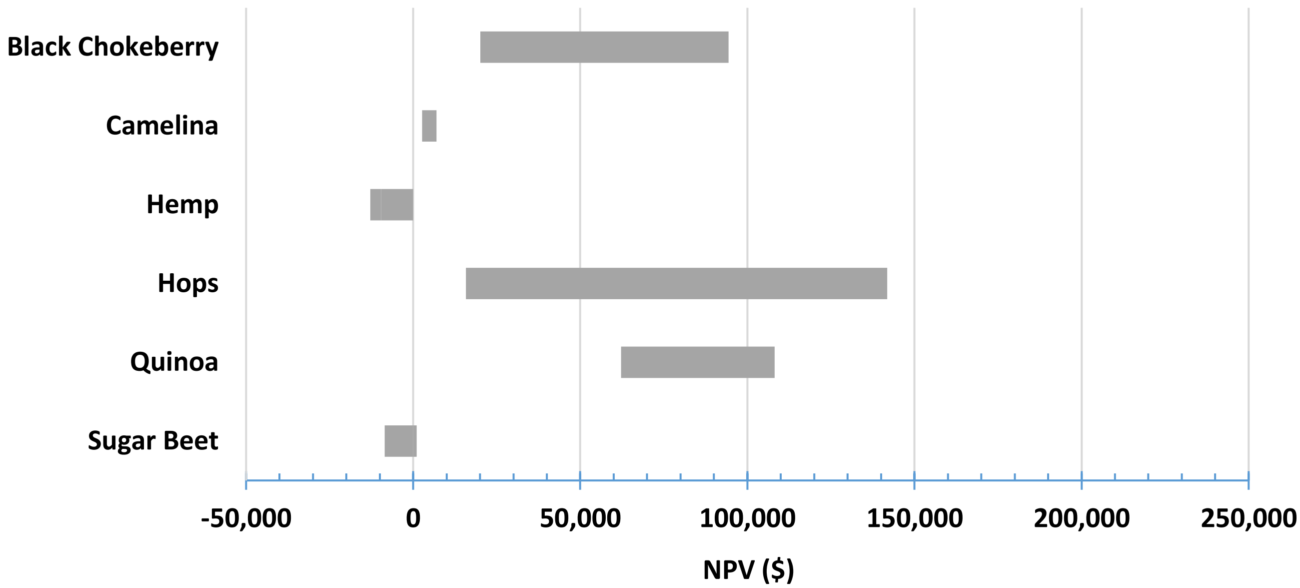


Figure 9: Selected Specialty & Alternative Crops With Lowest Net Present Values



7.2 Bioenergy Economic Feasibility

Bioenergy economic feasibility depends on the cost of obtaining the biomass, savings on displaced fuel, and cost of required equipment. For biomass costs, Hemp and Sugar Beet costs were taken from the above economic assessment, and Camelina, Jerusalem Artichoke, and Quinoa residue costs were estimated based on typical biomass storage and pre-processing costs (Table 14). Given the highly variable nature of fuel prices and the fact that bioenergy projects have a lifetime of 20 years or more, a range of prices for displaced fuels were estimated (Table 15). Equipment costs were estimated using available industry data. Using these factors, the NPV for bioenergy using Camelina, Industrial Hemp, Jerusalem Artichoke, Quinoa, and Sugar Beet crop or crop residue were calculated (Figure 10). As before, NPV was calculated per hectare over a 25-year time frame.

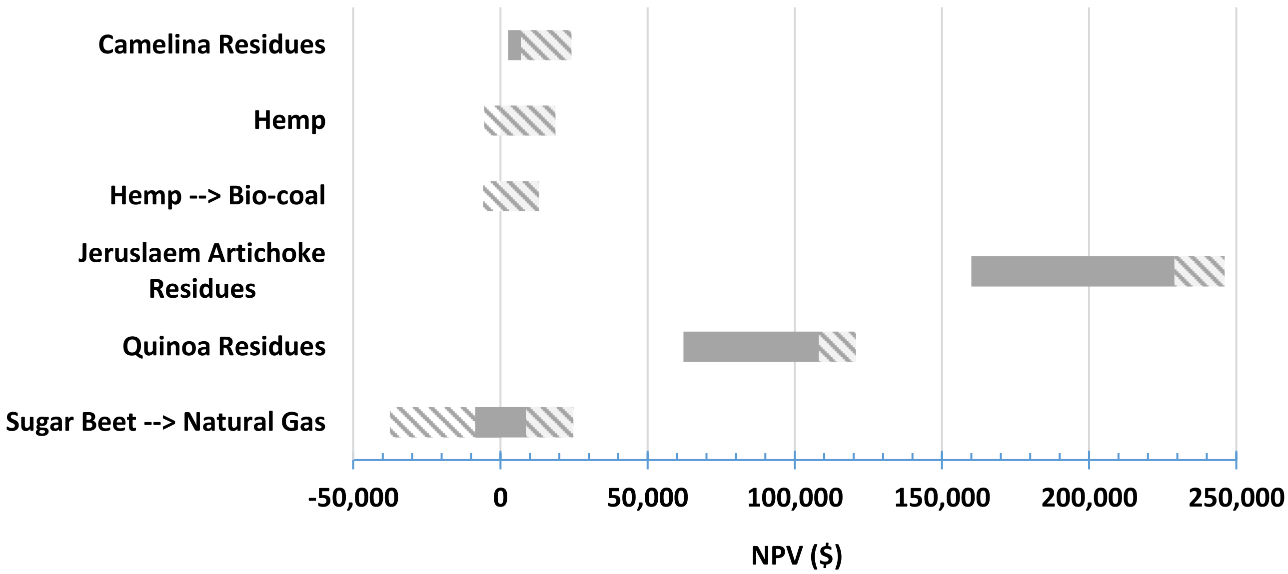
Table 14: Biomass Costs per GJ

Crop/Residues	$/GJ
Hemp	4.50 – 11.50
Sugar beet	10.50 – 16.50
Residues	3.00 – 10.00

Table 15: Current and Forecasted Fuel Price Ranges

Fuel	Current Fuel price ($/GJ)	2020’s Fuel price ($/GJ)
Natural gas	7.73 – 9.2	13.0 – 14.5
Propane	26.9 – 35.6	26.9 – 35.6
Heating oil	28.1 – 31.3	28.1 – 31.3
Electricity	25.4 – 38.1	25.4 – 38.1

Figure 10: Net Present Value for Bioenergy Production*



** Unless otherwise specified, bioenergy is heat from biomass boilers.*

Figure 10 shows that bioenergy from Camelina, Jerusalem Artichoke, and Quinoa residues have potential to increase crop NPV if done in conjunction with the sale of the seeds or tubers (solid bars show crop NPV without bioenergy, shaded bars show crop NPV with bioenergy). Bioenergy systems based on Hemp and Sugar Beet increase the uncertainty of the NPV (i.e., there is more possibility for greater profit, but also more potential for greater loss). NPVs for Camelina, Industrial Hemp, Jerusalem Artichoke, and Quinoa were calculated for a 200 kW biomass boiler.[42] A 200 kW biomass boiler requires approximately 200 tonnes of dry biomass/year. If Hemp were used to supply such a biomass boiler, over 20 hectares of hemp production would be required. For Camelina, Jerusalem Artichoke, and Quinoa residues, 30-50 hectares of production would be required.

8. Crop Decision Tool

There is often little available information or local experience growing specialty or alternative crops. As such, determining which crops show potential and should be investigated further can be challenging. One way to overcome this challenge and determine crop suitability is to assess a crop using a Crop Decision Tool. A Crop Decision Tool was created to provide BNRD farmers with greater ability to assess crop suitability.

Many factors influence which crops could and should be grown in the BNRD. Unfortunately, it is not possible to include all factors. As such, the following Crop Decision Tool should be viewed as a simple, yet effective way to conduct a first level assessment of specialty and alternative crops to determine the merit for further investigation. Once a crop is assessed, and if the results look promising, more work is needed to ensure the crop is truly suitable and presents a real opportunity. This includes detailed research into the crop's agronomic requirements, potential yield, required technology and infrastructure, and a thorough market assessment.

To use this Crop Decision Tool, work through all three sections answering all questions. If you don't know the answer to any question, select the 'proceed cautiously' answer. The number of 'proceed cautiously' answers impacts assessed suitability of a crop, so every effort should be made to find answers to every question; otherwise a potentially suitable crop may be assessed as unsuitable.

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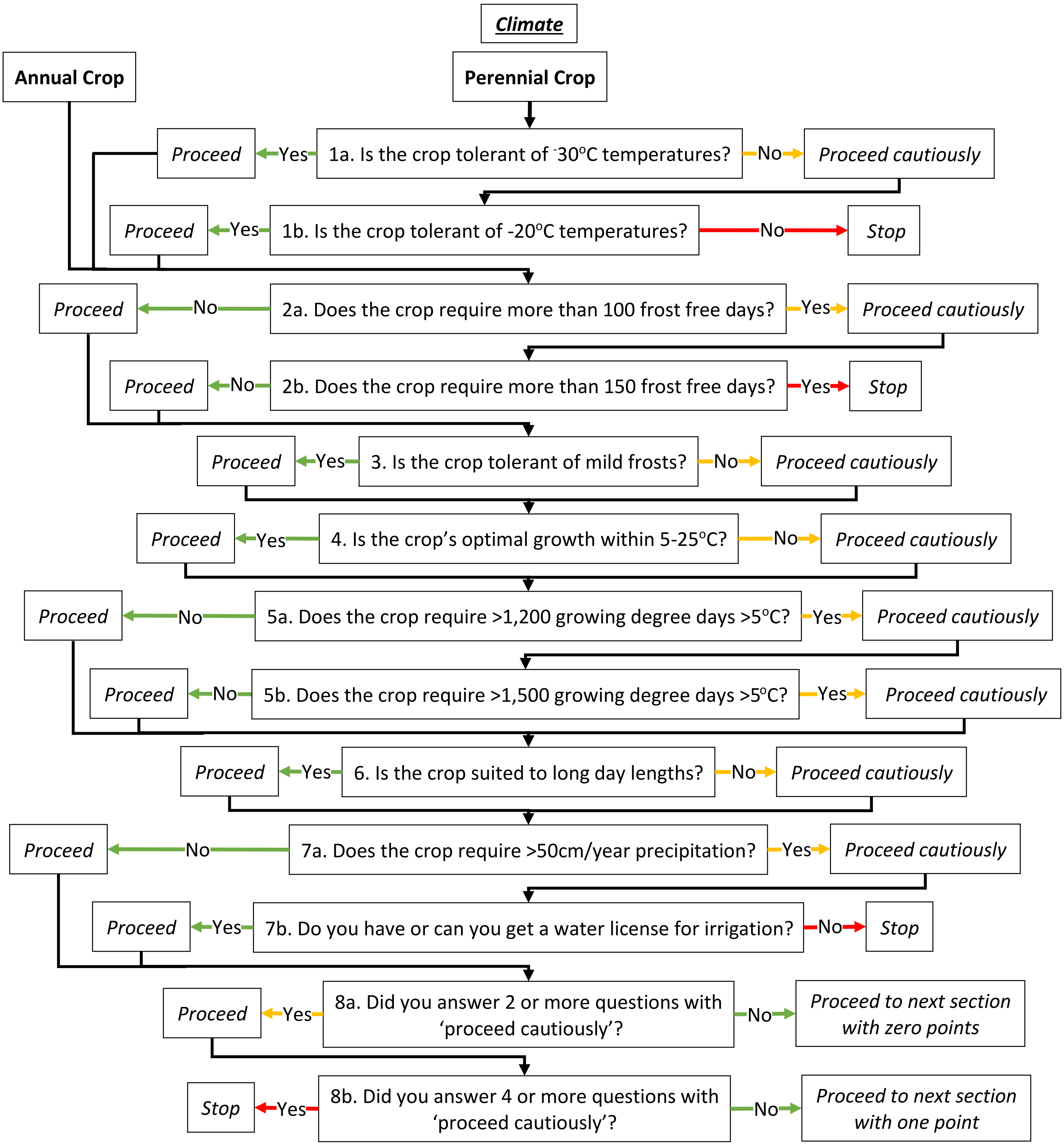
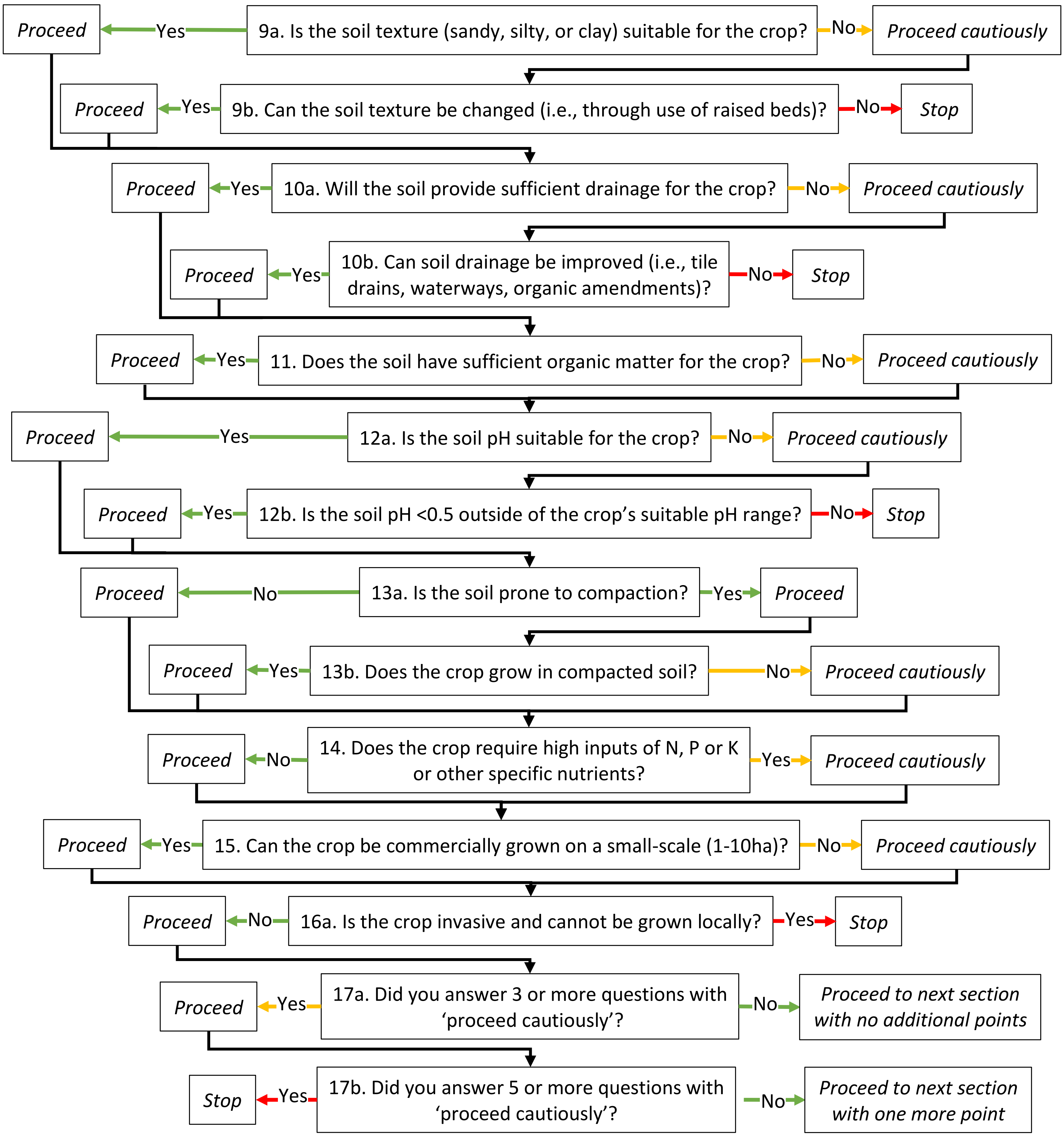
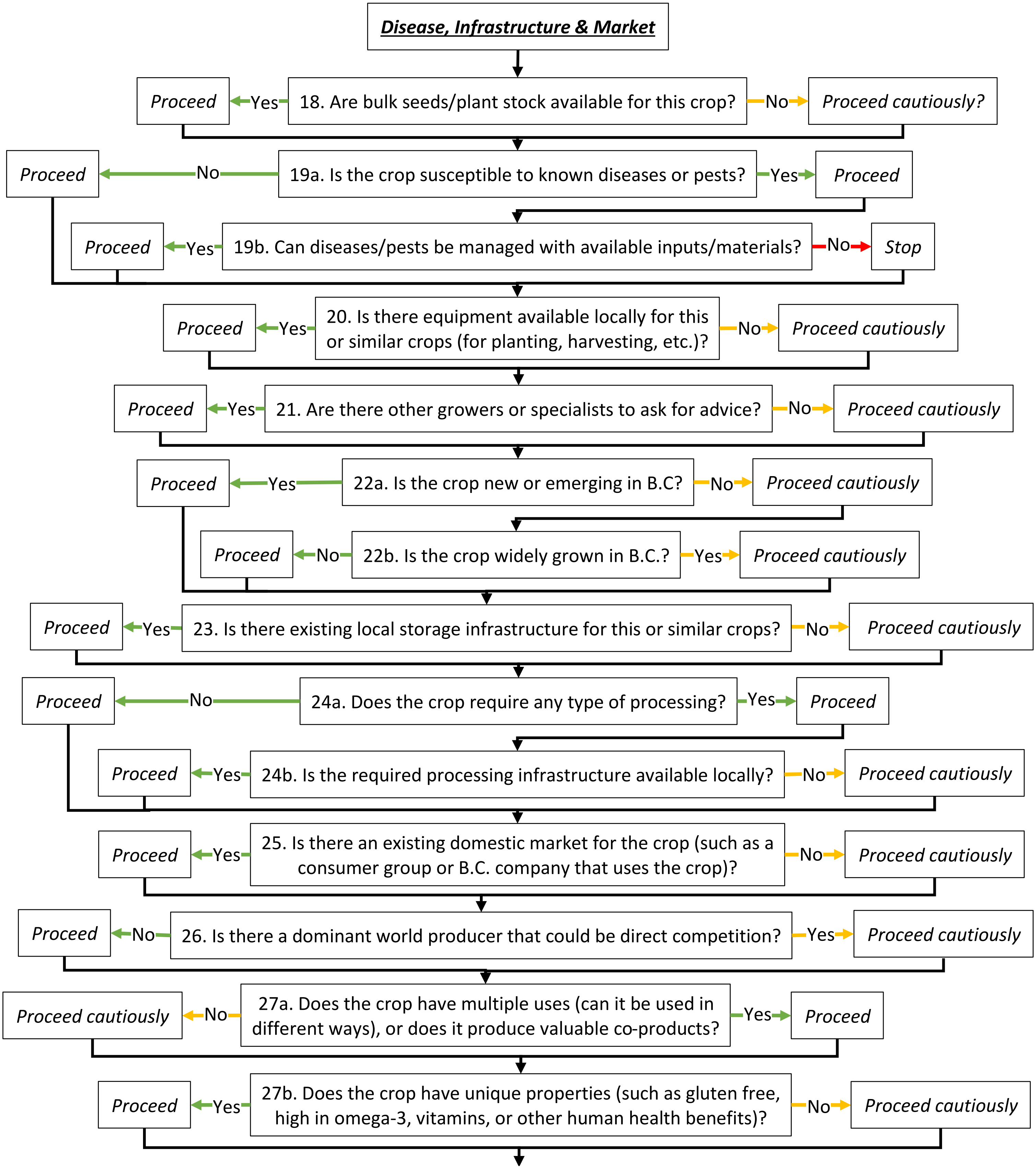
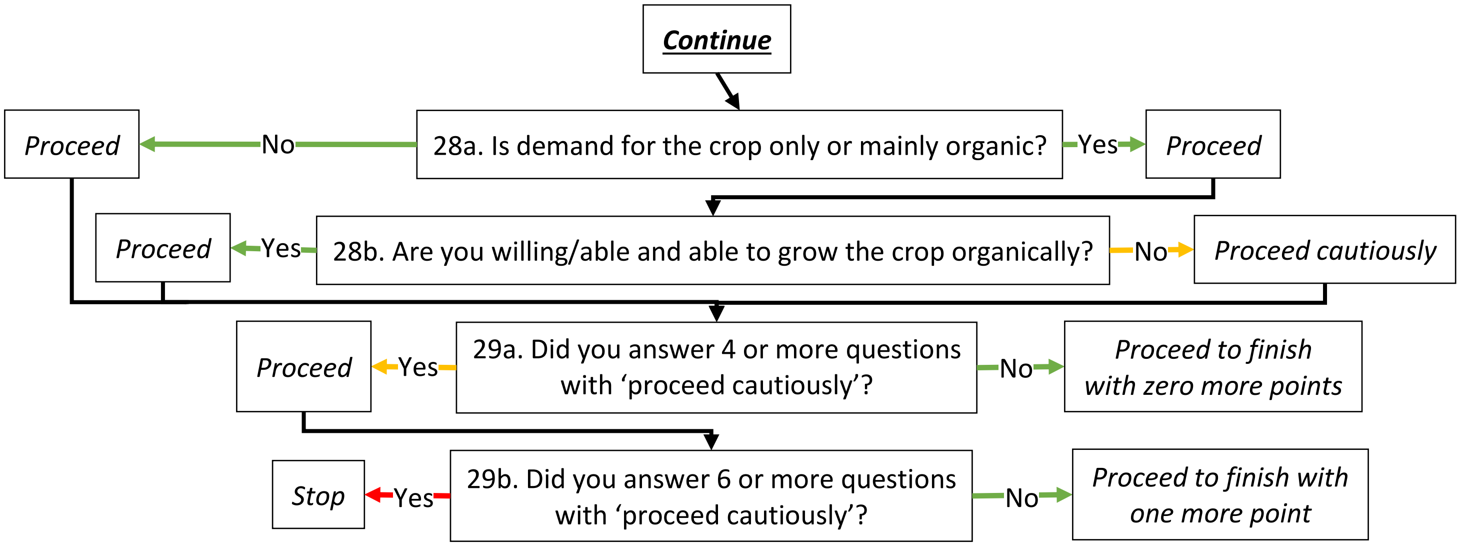
[42] A 200 kW biomass heating system is appropriate for a small school.


Climate
Annual Crop
Perennial Crop
Proceed
Yes
1a. Is the crop tolerant of -30°C temperatures?
No
Proceed cautiously
Proceed
Yes
1b. Is the crop tolerant of -20°C temperatures?
No
Stop
Proceed
No
2a. Does the crop require more than 100 frost free days?
Yes
Proceed cautiously
Proceed
No
2b. Does the crop require more than 150 frost free days?
Yes
Stop
Proceed
Yes
3. Is the crop tolerant of mild frosts?
No
Proceed cautiously
Proceed
Yes
4. Is the crop's optimal growth within 5-25°C?
No
Proceed cautiously
Proceed
No
5a. Does the crop require >1,200 growing degree days >5°C?
Yes
Proceed cautiously
Proceed
No
5b. Does the crop require >1,500 growing degree days >5°C?
Yes
Proceed cautiously
Proceed
Yes
6. Is the crop suited to long day lengths?
No
Proceed cautiously
Proceed
No
7a. Does the crop require >50cm/year precipitation?
Yes
Proceed cautiously
Proceed
Yes
7b. Do you have or can you get a water license for irrigation?
No
Stop
Proceed
Yes
8a. Did you answer 2 or more questions with 'proceed cautiously'?
No
Proceed to next section with zero points
Stop
Yes
8b. Did you answer 4 or more questions with 'proceed cautiously'?
No
Proceed to next section with one point

Soil


9a. Is the soil texture (sandy, silty, or clay) suitable for the crop?
Yes
Proceed
No
Proceed cautiously
9b. Can the soil texture be changed (i.e., through use of raised beds)?
Yes
Proceed
No
Stop
10a. Will the soil provide sufficient drainage for the crop?
Yes
Proceed
No
Proceed cautiously
10b. Can soil drainage be improved (i.e., tile drains, waterways, organic amendments)?
Yes
Proceed
No
Stop
11. Does the soil have sufficient organic matter for the crop?
Yes
Proceed
No
Proceed cautiously
12a. Is the soil pH suitable for the crop?
Yes
Proceed
No
Proceed cautiously
12b. Is the soil pH <0.5 outside of the crop's suitable pH range?
Yes
Proceed
No
Stop
13a. Is the soil prone to compaction?
No
Proceed
Yes
Proceed
13b. Does the crop grow in compacted soil?
Yes
Proceed
No
Proceed cautiously
14. Does the crop require high inputs of N, P or K or other specific nutrients?
No
Proceed
Yes
Proceed cautiously
15. Can the crop be commercially grown on a small-scale (1-10ha)?
Yes
Proceed
No
Proceed cautiously
16a. Is the crop invasive and cannot be grown locally?
No
Proceed
Yes
Stop
17a. Did you answer 3 or more questions with 'proceed cautiously'?
Yes
Proceed
No
Proceed to next section with no additional points
17b. Did you answer 5 or more questions with 'proceed cautiously'?
Yes
Stop
No
Proceed to next section with one more point


Disease, Infrastructure & Market
Proceed
Yes
18. Are bulk seeds/plant stock available for this crop?
No
Proceed cautiously?
Proceed
No
19a. Is the crop susceptible to known diseases or pests?
Yes
Proceed
Proceed
Yes
19b. Can diseases/pests be managed with available inputs/materials?
No
Stop
Proceed
Yes
20. Is there equipment available locally for this or similar crops (for planting, harvesting, etc.)?
No
Proceed cautiously
Proceed
Yes
21. Are there other growers or specialists to ask for advice?
No
Proceed cautiously
Proceed
Yes
22a. Is the crop new or emerging in B.C?
No
Proceed cautiously
Proceed
No
22b. Is the crop widely grown in B.C.?
Yes
Proceed cautiously
Proceed
Yes
23. Is there existing local storage infrastructure for this or similar crops?
No
Proceed cautiously
Proceed
No
24a. Does the crop require any type of processing?
Yes
Proceed
Proceed
Yes
24b. Is the required processing infrastructure available locally?
No
Proceed cautiously
Proceed
Yes
25. Is there an existing domestic market for the crop (such as a consumer group or B.C. company that uses the crop)?
No
Proceed cautiously
Proceed
No
26. Is there a dominant world producer that could be direct competition?
Yes
Proceed cautiously
Proceed cautiously
No
27a. Does the crop have multiple uses (can it be used in different ways), or does it produce valuable co-products?
Yes
Proceed
Proceed
Yes
27b. Does the crop have unique properties (such as gluten free, high in omega-3, vitamins, or other human health benefits)?
No
Proceed cautiously



Once you have worked through the Crop Decision Tool answering every question, and if no questions resulted in a 'stop' answer,[43] sum the total number of points. For example, if you answered one question in the Climate Section with proceed cautiously (zero points), three questions in the Soil Section with proceed cautiously (one point), and two questions in the Disease/Infrastructure/Market Section with proceed cautiously (zero points), points total is one. Alternatively, if you answered two questions in the Climate Section with proceed cautiously (one point), four questions in the Soil Section with proceed cautiously (one point), and four questions in the Disease/Infrastructure/Market Section with proceed cautiously (one point), points total is three.

Based on total points, the potential suitability of the crop is as follows:

- 0 Points = Crop shows very good potential as there seems to be very few potential barriers or issues that may need to be overcome. This crop should be investigated further.
- 1 Point = Crop shows good potential, although there are a few barriers or issues that may need to be overcome. Provided these barriers or issues aren't overly complex or expensive to overcome, this crop should be investigated further.
- 2 Points = Crop shows some potential but the number of barriers or issues that may need to be overcome is a concern. Further assessment of the complexity or cost to overcome these barriers or issues is required before this crop should be investigated further.
- 3 Points = Crops shows a little potential but the number of barriers or issues that may need to be overcome is very concerning. Unless the collective complexity or cost to overcome these barriers or issues is reasonable, this crop should not be investigated further.

9. Summary

One possibility for improving the economic viability, profitability, and resilience of the BNRD's agricultural sector is through the introduction of suitable specialty or alternative crops. The purpose of this project was to identify ten specialty and alternative crops that could be successfully grown in the BNRD, and that have the potential to provide new economic opportunities for local farmers. Of all the specialty and alternative crops

[43] A 'stop' answer indicates the crop has significant potential barriers/issues that will likely be difficult or impossible to overcome.

assessed, ten were identified. These were Black Chokeberry, Camelina, Garlic, Haskap Berry, Hemp, Hops, Jerusalem Artichoke, Quinoa, Saskatoon Berry, and Sugar Beet.

Of the ten specialty and alternative crops, each has its own advantages for growth in the BNRD. For example, with regards to climate, the precipitation requirements for Black Chokeberry, Camelina, Hops, Jerusalem Artichoke, and Quinoa are sufficiently low that these crops can likely be grown in the BNRD without irrigation. Black Chokeberry, Camelina, Garlic, Haskap Berry, Jerusalem Artichoke, Quinoa, Saskatoon Berry, and Sugar Beet are frost tolerant, while Black Chokeberry, Haskap Berry, and Saskatoon Berry are also all very cold hardy. Hemp and Sugar Beet have a short growing season.

In terms of soil requirements, Black Chokeberry, Camelina, Garlic, and Hops (assuming appropriate drainage), Haskap Berry, Jerusalem Artichoke, Quinoa, Saskatoon Berry, and Sugar Beet all tolerate a wide range of soil types. Camelina and Quinoa are also able to grow on marginal agricultural land considered nutritionally poor and unsuitable for many other crops. With regards to disease, insect pests and wildlife, Camelina, Hemp, Jerusalem Artichoke, Quinoa, and Sugar Beet seem to have few issues.

Although Black Chokeberry, Garlic, Haskap Berry, Hops, and Saskatoon Berry all require moderate or high up-front investment, these crops all have a high value, require minimal amount of land, and have significant and/or growing market opportunities. The market opportunity for Quinoa is also large. Product versatility (the ability to process the crop to make or use in many different products) is high for Black Chokeberry, Haskap Berry, Hemp, Jerusalem Artichoke, and Saskatoon Berry.

In terms of economic feasibility, estimated NPV is greatest for Garlic, Haskap Berry, Saskatoon Berry, and Jerusalem Artichoke. It is lowest for Hemp (negative), Sugar Beet (negative to positive), and Camelina (slightly positive). Estimated NPV for Black Chokeberry, Hops, and Quinoa are all positive. However, NPV is based on assumed production costs, crop yield, and crop value. These can vary greatly depending upon many variables, including total acreage, required inputs, equipment costs, climate and soil, market demand, and end use. Consequently, further site-specific research into the ten specialty and alternative crops is required to refine NPVs based on local conditions in the BNRD and actual market demand.

For crop and crop residue bioenergy, although the scale of opportunity in the BNRD is large, current economic feasibility is limited. In 2017, the greatest opportunities for using Camelina, Jerusalem Artichoke, and Quinoa residues, Hemp, or Sugar Beet are for use in biomass boilers, anaerobic digesters, or to produce bio-coal to replace energy in remote communities where natural gas isn’t available, or to replace propane facilities in larger communities. The one exception is renewable natural gas, with FortisBC currently paying upwards of $15/GJ. This price means that renewable natural gas production in the BNRD using anaerobic digestion technology with Sugar Beet, potentially mixed with other appropriate locally-available feedstocks, such as livestock manure and food waste, could be an interesting bioenergy opportunity to explore further.