# Crop-Climate Project 2012:

## Part II. Heritage Wheat and Potatoes Performance

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For the W. Garfield Weston Foundation

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Cover Graphic: Ozette potato plants (Valerie Huff)

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## Key Findings and Summary

**The principle purpose of the project in 2012 was to test the idea that citizen farmers could make high quality weather and crop growth observations for heritage varieties.** By using reliable protocols and equipment it would then be possible to develop widespread initiatives to rapidly acquire knowledge to help adapt food production to climate change. We learned important lessons about crop-climate studies and discovered interesting and useful information about some of the heritage varieties of wheat and potatoes investigated in this pilot year.

This summary includes key points from the preliminary report (Hebda 2012) and Part 1 of the final report (Huff and Hebda 2013).

**Project Design, Grower Observations, and Limitations**

- Farmer-scientists are effective in collecting crop-climate data.
- Protocols need to be simple and clearly explained and must include the full life stages of the crops.
- At times observations were not made frequently enough to track developmental stages and those stages were not always obvious to see.
- Site factors such as soil nutrients, texture, and moisture content should be assessed.
- Yield and vigour need to be included according to reliable standard ways of observation.
- Training in deployment and use of equipment (even though simple) should be carried out well in advance.
- Participants will likely require training in up-loading data to a common data bank.
- Growers made numerous made useful observations about diseases and phenomena while observing growth stages and shared information from previous experiences with crops.
- Observations should be made widely available in a standard format.

**Weather observations and stations**

- All stations experienced weather extremes including drought, high and low temperatures and heavy rainfall events.
- Both types of instruments were deployed correctly and worked well in collecting tens of thousands of data points reliably.
- Less expensive Onset Corporation HOBO's provided useful data for temperatures and RH both of which could be related to limiting factors in growth.
- HOBO's need to be either used in conjunction with either an on-site comprehensive Davis weather station or if available related to local weather station network that record rainfall and solar radiation.

**Crop observations**

- Potato varieties grew differently under different climatic conditions and responded varyingly to climatic stresses experienced during the crop year.
- Some heritage varieties outperformed more widely available standard variety Chieftain at some sites.
- Promising heritage potatoes included Corne de Mouton, Mrs. Moehrle's Yellow, Ozette and Siberian, which yielded well at some sites, often better than more widely available types.
- Potato varieties that may have some drought tolerance include Banana, Chieftain and Corne de Mouton.
- The slower growth and development of potatoes in Victoria, relative to the three other growing sites, appears to result in better performance and yields for most of the varieties tested.
- For potatoes, using Growing Degree Days as a measure of maturity gave inconsistent results, possibly because of an insufficient number of trials, inconsistent grower observations or a need to modify the method we used to calculate GDD at each phase.
- The heritage wheats grown in the study showed little variation in growth and development among variety and among sites possibly because the varieties are closely related and because the number of trials was too small.
- A trial with a wide genetic range of varieties and climatic regions is required to yield meaningful data for wheat.

**In summary:**

- This small scale project had obvious limitations in terms of scope and sample size.
- The 2012 pilot year demonstrated that crop-climate initiatives are highly feasible.
- Weather data can be reliably and continuously collected in-field in conjunction with growth data.
- Observations generate useful crop-climate information such as days to maturity, variation of development with weather conditions, differences in heritage varieties.
- Design and implementation of a larger project requires modification.
- The Project can be implemented on a larger scale.

# Introduction

## Crop-Climate Project Background

In spring 2012 The Garden Institute of BC undertook a pilot study (Project Co-Managers Richard Hebda and Sharon Rempel) to test the feasibility of using standard, field-deployed weather recording equipment to define the "climatic" characteristics of heritage varieties of wheat and potatoes. The data were to be collected by "farmer"–scientists in several different climatic zones in Canada. The idea was that such data would enable people in communities to develop their own capacity to adapt food production to climate change.

Food sustainability already challenges the globe because nearly a billion people are chronically undernourished and food production has major negative impacts on the environment. Many solutions have been proposed at the global scale such as improving yields, using resources more efficiently, and even changing human diets (Foley et al. 2011). However the extent and urgency of the potential effects of changing global climates are not adequately being factored into the development of food sustainability strategies.

Heritage varieties of agricultural crops are being lost at an alarming rate. Heritage plants may be defined in various ways, though they are generally considered to be older cultivars that have been maintained and passed down by a family or shared within a small community. They are generally grown on a smaller scale than varieties grown in industrial agriculture. For the purposes of the Crop-Climate Project, 'heritage' plants include many garden-variety and locally developed varieties that are grown on a small scale, regardless of how old a cultivar is, as well as landraces of wheat.

The rich genetic diversity held within heritage varieties is the product of thousands of years of plant breeding and seed saving by farmers around the world. Locally adapted crops are an important part of our agricultural heritage; they are also critical to our future food sustainability.

Conserving heritage varieties helps Canadian farmers prepare for climate change in several ways. These varieties contain vital traits needed for adaptation to different climatic characteristics and they have important genetic variation that may protect them against emerging diseases. They also have the potential be used in breeding programs to improve non-heritage varieties and increase crop resilience to a range of stress factors.

Good information about heritage varieties is not widely available, and many standard characteristics, such as the number of days to maturity, are unknown. Growers need this basic information to decide which varieties will grow well in their local soils and climate as well as to help determine cultural practices (when to plant, how to amend the soil, how to minimize pest outbreaks) to optimize yield. Even less is known about the influence of climatic stressors (heat, humidity, drought, rainfall) on heritage varieties.

Knowing such crop traits is especially important in an era of shifting climatic zones and the development of new climatic regimes. Suitable or optimal areas for growing potatoes and wheat will certainly shift northward in general and upward in mountainous regions. Local site conditions such as the optimal soil type for a particular variety may change as new climates and weather patterns develop.

To be clear the project in 2012 was intended as a pilot, a proof of principle and approach, rather than a strict agronomic trial. Such tightly controlled replicated trials are best undertaken in established institutional facilities, but such is not the case for heritage varieties and landraces. We strongly encourage governments and agricultural institutions to do so. Our premise is that many growers making many observations with reliable equipment, growing and observing crop varieties in a standard manner may be able to rapidly generate useful and critical data. With the anticipated quickening pace of climate change, the sooner such information is widely available the better.

A report and analysis of weather observations in 2012 and instrument use were provided in Huff and Hebda (2013) (Part 1 of the final report).

## Project Implementation

The project was implemented at four sites across Canada in April and May of 2012: Victoria Farm Victoria, BC; Heritage Organic Farm, Tompkins, Saskatchewan; Caledon, Ontario; and Ironwood farm, Gananoque, Ontario (Figure 1). Two types of weather recording equipment were deployed at the sites, to allow for comparisons between sophisticated and expensive equipment with relatively simple and less expensive sensors. (Results from the Weather Station monitoring are found in Part 1.)

**Figure 1. Locations of the four sites participating in the 2012 Crop-Climate Project.**


Crops were planted on a small scale in a standard manner using organic methods in association with weather recording equipment. Participants recorded standard growth stages in potato and wheat and the data were compiled on a regular basis.

Weather data were recorded on continuous basis and compiled in Victoria. Preliminary summary analyses were carried out on weather observations and on crop-weather relationships

and reported to the growers. Surveys of participants were undertaken to obtain their impressions and suggestions on how best to implement and run the project and were presented in a preliminary report (Hebda 2012).

# APPROACH AND METHODS

## Weather and Climate Monitoring

Weather and climate observations for each of the growing locations were described in detail in Part 1 of this report, along with general implications for crop growth. During 2012 all sites participating in the project experienced one or another form of weather stress ranging from drought to heavy rainfall, and including extreme heat (Table 1). Growing conditions varied widely from site to site providing an opportunity to at least in a general way look at differences in the responses of varieties.

## Monitoring Growth and Development

As noted earlier we chose mostly "heritage" varieties, those generally considered to be older cultivars that originally were maintained and passed down by a family or shared within a small community. They are generally grown on a smaller scale than varieties grown in industrial agriculture. For the purposes of the Crop-Climate Project, we use the term 'heritage' to include many garden-variety potatoes that are grown on a small scale, regardless of how old the cultivar is. In the case of potatoes for comparison we also included the standard variety 'Chieftain'.

A series of standard developmental stages was chosen for both potato and wheat observations. For potatoes these included emergence from soil, two leaves horizontal, appearance of flower buds, leaf yellowing and the drying out of plants. For wheat, growers monitored emergence, third-leaf stage, fourth-leaf stage, tillering, boot, heading out, milk stage, yellowing heads and ripe heads. Many of these stages are relatively easy to recognize, whereas other as we found out were somewhat ambiguous to observe (Hebda 2012). We also provided general guidelines for the interval of observation (every few days) however participants were at liberty to make the observations in accordance with the demands of their schedules.

Data were collected using standard forms and a technical bulletin was provided for planting and observations (with e-mail up-dates as required). Suggested observation time was based on anticipated rate of change of growth. Participants were encouraged to make additional observations about vigour diseases and pests and other unusual phenomena. We were interested in tapping into the broader experience and knowledge of growers to help develop improved observation methods and criteria for future years.

## Heritage Potatoes

Potatoes were first domesticated in the Andes of what is now Peru and Bolivia. They are now a staple crop in many countries, including Canada. Early European settlers brought different varieties with them, which over time have been selected for local conditions and taste.

There is a lack of information about Canada's heritage varieties of potatoes because they are usually grown on a small scale for personal consumption or a local market. The Crop-Climate Project hopes to bring together grower observations to make standardized descriptions widely available. In addition, we hope to learn how the varieties perform under different climatic conditions in various locations across Canada, and will contribute information about maturity, response to diseases and agricultural features, as reported by growers in the project. The entries in the appendix provide examples of variety profiles.

Eleven potato cultivars in a variety of colours, shapes and maturity dates, were tested by the Crop-Climate Project (Table 1). Four heritage varieties were grown at all four sites: Banana Fingerling, Chieftain, Russian Blue and Sieglinde. These varieties were readily available from a standard stock provided by a reputable commercial supplier of organic seed tubers West Coast Seeds, Delta, British Columbia. A further seven less common heritage varieties were grown only at Victoria and Caledon because of limited availability: Congo, Corne de Mouton, Mrs. Moehrle's Yellow, Ozette, Pugh's Purple, Siberian, and Slovenian Crescent. Tubers for Ozette were supplied by Richard Hebda. The remaining seed potatoes were supplied by project participant Garrett Pittenger who maintains an extensive heritage potato collection.

**Table 1: Maturity, skin colour, flesh colour and tuber shape of 11 potato varieties used in the Crop-Climate project 2012.**

| Variety Name: | Maturity: | Skin colour: | Flesh colour: | Tuber Shape: |
|---|---|---|---|---|
| Banana | late | light yellow | pale yellow | banana |
| Chieftain | mid-season | red | white | oval to oblong |
| Congo | late | blue | blue | Long to oval |
| Corne de Mouton | early to mid-season | white to yellow | creamy yellow | oval to very long |
| Mrs. Moehrle's Yellow | mid-season | tan | yellow | round |
| Ozette | late | pale gold | creamy yellow | fingerling |
| Pugh's Purple | mid-season | light purple | purple | Long oval |
| Russian Blue | late | dark purple | blue | round to oblong |
| Siberian | very late | white | red | round to oval |
| Sieglinde | early | clear yellow | pale yellow | Oval to round |
| Slovenian Crescent | early | pale yellow to white | pale yellow brown to pale brown | crescent |

Most of these varieties are not registered under the *Seeds Act and Regulations* of Canada. Two more common varieties, Banana and Chieftain, however are registered. The Canadian Food Inspection Agency (CFIA) has plant descriptions available on-line for many varieties including these two, presented in a standard manner. As the project proceeds, it is our intention to use the CFIA descriptions as a template and compile the information on potato varieties in the project for access on the internet.

The development of potatoes through critical growth stages (phenological phases) is influenced by many factors, some of which are climate-related and some of which are more strongly influenced by soil type and the cultivation practices. In this study it is assumed that primary control over the basic stages of development depends on what are loosely termed "climatic" factors. These factors vary year to year according to the weather but more or less fall within a typical range for a region. The most important weather-related factors are temperature and intercepted solar radiation (IBSNAT 1993), with precipitation, relative humidity and wind also playing a role. (For a more in-depth discussion on how each of these impacts plant development, see Part 1 of this report (by Huff and Hebda 2013).

Yield was not one of the key attributes to be observed at the outset because it is affected by non-climate factors such as soil fertility and field practices (weed or not, water or not). These were beyond the scope of this pilot project. Because of the interest of the participants and its obvious economic value, yield of potato tubers was measured or estimated at the end of the project. However it was not uniformly observed at all sites: three observed weight, one observed number and size. We recognize that yield needs to be integrated into observations in a standard way without requiring a lot of extra work by the project participants.

The number of tubers planted and observed varied from site to site partly because of limited supply of some varieties. Participants were asked to plant and observe 10 potato tubers for the four principal varieties grown.

## Heritage Wheats

Wheat is a cereal grain that is a staple food source throughout the world. It originated in the 'fertile crescent' in what is now Iran, Iraq and Turkey. The domestication of wheat, between 8,000 and 10,000 years ago, was a key factor in the development of civilization. Wheat has since spread around the world and it is currently grown in a wide variety of climates and conditions.

Canada has an important wheat heritage of landraces, adapted to our particular climate and soils. This heritage survives today in the seeds of locally adapted wheats, often grown, maintained on and exchanged by a handful of dedicated farmers who understand the importance of maintaining the security of our seed supply. The characteristics of these varieties are not well known, and many are being lost.

In Canada, new settlers brought wheat seeds with them from their country of origin. The first recorded planting of wheat dates to 1605 in Nova Scotia (Campbell, A.B. n.d.). Many of these varieties were not well adapted to Canadian growing conditions and climate. In 1842, Red Fife became the first wheat developed in Canada, and it was distributed and grown across the country (Symko 1999). While it was gradually replaced by other wheat varieties, its genetic lineage is carried on in most of the bread wheats in Canada.

Traditional varieties, such as Red Fife, almost disappeared from farmers' fields, and only a few varieties, bred for uniformity and consistent performance, are grown commercially. The loss of heritage varieties, and the plant genetic diversity they contain, is of great concern. The need for the conservation of plant genetic resources is of paramount importance, particularly in the face of rapidly changing climates.

Three heritage varieties of wheat (Canus, Hard Red Calcutta and Marquis) were grown at two locations (Gananoque, Ontario and Tompkins, Saskatchewan). All three Climatic parameters of these locations are discussed in Part 1 of this report and are incorporated here for their influences on heritage wheat growth and development under two very different climatic regimes.

The wheat varieties for this trial were chosen based on the recommendations of Sharon Rempel. All three are hard red spring wheats with a long history of cultivation in Canada. Hard red spring wheats are excellent bread wheats with a higher percentage of protein than winter wheats. They are the main wheats grown on the Canadian Prairies.

# RESULTS

## Weather and Climate Stresses

The Crop-Climate Project aims to identify varieties of potato and wheat that tolerate weather stresses and still yield well, as a hedge against future climate changes. The 2012 growing season was a pilot to test the feasibility of the approach, including analyzing two separate types of weather monitoring equipment, and different protocols for monitoring growth. Nevertheless, the weather data and patterns when compared with crop growth observations revealed some emerging patterns in need of further investigation.

During 2012 all sites participating in the project experienced one or another form of weather stress ranging from drought to heavy rainfall, and including extreme heat (Table 2). Part I of this report (Huff and Hebda 2013) discusses in detail the weather and climate variables tracked and/or calculated at the four project locations. Growing conditions varied widely from site to site providing an opportunity to at least in a general way look at differences in the response of varieties.

Extreme high and low temperatures occurred at all four sites, with Caledon and Gananoque experiencing regular high temperature stresses, and all but Victoria receiving frost or severe

cold in the early part of the season. All regions experienced low rainfall, resulting in drought during different parts of the growing season.

Relative Humidity can stress growing crops at different growth stages in various ways (Huff and Hebda 2013), depending on the crop and in interaction with other climatic and cultural factors. Caledon and Gananoque were both extremely humid for most of the growing season; Tompkins had long periods of very low relative humidity; and Victoria experienced optimum levels of humidity throughout the season.

**Table 2: Summary of weather conditions during the growing season at four participating sites in the Crop-Climate project in 2012 (from Huff and Hebda 2012)**

| | **Caledon** | **Gananoque** | **Tompkins** | **Victoria** |
|---|---|---|---|---|
| **AIR TEMPERATURE** | | | | |
| **Highs**<br>*Over 30 C stresses potato plants, may stress some wheat varieties.* | Regularly above 30$^{o}$ | Regularly (26 days) above 30$^{o}$C | Rarely above 30C | Rarely above 30C |
| **Lows**<br>*Frosts may kill emerging potato shoots, low temps delay emergence in wheat and potatoes*. | Below zero temperatures in May | Below zero temperatures in May | Below zero temperatures in May and June | No freezing temperatures during growing season |
| **RAINFALL** | | | | |
| **Growing Season Total** | 208 mm | 155 mm | 179 mm | 78 mm |
| **Seasonal distribution** | More than half of rain came from July 16-Aug 15. | Drought in June and July, followed by heavy rains in August | Spring rain, very little rain after July 1. | Some spring precipitation, July and August were droughty |
| **RELATIVE HUMIDITY (RH)**<br>*Optimal range is approximately 40 to 80; high and low values suppress growth and yield.* | | | | |
| **Season Average** | 76% | 72% | 64% | 74% |
| **Low RH**<br>(percent readings below 40%) | 5% | 7% | 15% | 2% |
| **High RH**<br>(percent readings above 80%) | 52% | 41% | 27% | 31% |
| **Seasonal distribution** | Highest in late June | High RH in early July and again in early August | Low RH at beginning and end of growing season. | Within or near optimum range all growing season |
| **POTENTIAL EVAPOTRANSPIRATION** | 389 mm | 452 mm | 475 mm | 426 mm |
| **CLIMATIC MOISTURE DEFICIT** | -114 mm | -244 mm | -267 mm | -278 mm |

Using weather data from the Davis WeatherStations, we were able to calculate two important composite variables: Potential Evapotranspiration (PET) and Climatic Moisture Deficit (CMD). PET uses temperature, rainfall, relative humidity, solar radiation and wind to calculate the amount of evaporation and transpiration (passage of water through the plant during plant growth) that would occur if sufficient water was available. The lowest PET value was at Caledon while the highest was at Tompkins for the growing season, meaning that Tompkins had the greatest theoretical potential for plant growth in the presence of adequate rain and good crop management techniques. The CMD is the cumulative difference between Potential Evapotranspiration, Precipitation and residual soil moisture through the growing season. Victoria experienced the highest deficit of all locations, more than double that at Caledon. It is important to note that these are theoretical values that can be influenced by soil conditions, the crop being grown, and the stage of the crop. Nevertheless, they provide a practical comparison of differences between locations which likely influence crop growth, development and yield.

# Potatoes

## Growth and Development

The development of potatoes under different climates has important practical applications as mentioned earlier. The rate of progression through stages reveals whether or not varieties behave in standard manner when it comes to the key variables such as number of days and accumulated heat, as represented by Growing Degree Days (GDD)[1] to reach a particular level of development. Varieties that require a specific number of either days or GDD to advance from stage to stage may be highly adapted to a local climatic environment, but may not perform as well under a different climatic regime. Other varieties may be more widely adapted and grow well under a variety of weather conditions and climates.

### Observation limitations

In this pilot year, we discovered that in general grower observations were not frequent enough at some sites at the start of season. Potatoes went from one stage to the next within a week partly because of unseasonably warm weather. Later in the season observations may have been unnecessarily frequent largely because there were no standard growth stages to observe. Instead participants made notes on what they saw (See Disease and Insect Observations).

As might be expected, observers sometimes recorded certain kinds of data in various ways making it difficult to interpret by the data compiler and difficult to carry out statistical analyses. For example in the case of potatoes the percent of plants at a specific stage was recorded rather than the number. The recognition of a standard growth stage also varied. The 'two-leaf

[1] For a discussion on the importance of Growing Degree Days and the specifics of how GDD was calculated for the Crop-Climate Project, see Part 1.

horizontal' stage proved particularly difficult to interpret. Leaf yellowing is used as a standard point of reference in potatoes, yet three of four participants did not specifically note it. Also weather monitoring stations were turned off and crops harvested in mid-August in three of four locations. Crops may have not reached maturity by this time.

### Cross-variety comparisons: Rate of development at different sites

People choose crop varieties to plant for a range of reasons including yield, taste, harvesting and processing properties, disease resistance and even tradition. A key consideration is matching the variety to the length to the growing season or desired harvest time to take advantage of good market prices. In this section we compare the progression of trial varieties through unambiguously observed growth stages in the context of climatic factors (Table 3).

The length of time from planting the tuber until the emergence of the first shoots from the soil is strongly influenced by soil temperature and moisture. It is also influenced by factors controlled by the grower, including the source and age of the mother seed tubers, how and if they are cut, whether or not they have been pre-sprouted ("chitted") and depth of planting.

The mother tubers were all presumably identical having come from the same source and were planted at a standard depth. Planting date varied, however, due to local conditions, leading to differences in degree of pre-sprouting development in potatoes from the same source. For example, because of the milder climate in Victoria, planting was earlier for many varieties. However, soil temperatures were cooler and emergence took longer for almost all varieties than at all other locations (Table 3). Tompkins potatoes emerged fastest, after an average of 10 days, Caledon after 12 days, Gananoque after 14, and Victoria after 25 days. Rapid emergence in Tompkins, Caledon and Gananoque may be partially explained by later planting, where the mother tubers, although from the same source, would have been further along in the pre-sprouting process when they were planted. Another factor may involve the cumulative heat in the soil, represented by GDD. On this basis the values among sites for the four standard varieties were closer than for the date after planting (Table 3), nevertheless tubers planted at Victoria still required more GDD's than those planted at other sites. There were also differences among varieties in emergence, with Sieglinde and Banana emerging in an average of 14 days at all four sites, while Chieftain, Ozette and Russian Blue took 18 days.

The appearance of flower buds is an important marker in the phenological development of plants and is easily observed. Of the varieties grown at all 4 sites, Sieglinde was the fastest to reach the first flower stage (an average of about 40 days) and required the fewest accumulated amount of warmth, an average of 363 GDD. The slowest to produce visible flower buds was Ozette , 55 days and 526 GDD. The Siberian variety, which was grown only in Victoria, took 72 days to reach this stage and needed 709 GDD. At that site, by comparison, Ozette, which was planted later, took 72 days to flower at the same location, after being exposed to only 594.3 GDD.

**Table 3: Days from Planting and Growing Degree Days to Break, First Flower and Dried Plants at all sites for all potatoes.**

| | Break (Days) | Break (GDD) | First Flower (Days) | First Flower (GDD) | Dried Leaves (Days) | Dried Leaves (GDD) |
|---|---|---|---|---|---|---|
| **Banana** | 14 | 110 | 54 | 517 | 106 | 1159 |
| Caledon | 11 | 118 | 50 | 621 | | |
| Gananoque | 10 | 55 | 58 | 568 | 85 | 1034 |
| Tompkins | 7 | 58 | 36 | 295 | | |
| Victoria | 27 | 209 | 72 | 582 | 127 | 1284 |
| **Chieftain** | 18 | 152 | 45 | 386 | 102 | 1102 |
| Caledon | 14 | 158 | 35 | 397 | | |
| Gananoque | 14 | 115 | 41 | 316 | 76 | 915 |
| Tompkins | 17 | 127 | 40 | 326 | | |
| Victoria | 27 | 209 | 63 | 502 | 127 | 1290 |
| **Congo** | 22 | 226 | 55 | 607 | 117 | 1294 |
| Caledon | 14 | 158 | 55 | 703 | | |
| Victoria | 30 | 294 | 54 | 510 | 117 | 1294 |
| **Corne de Mouton** | 19 | 197 | 50 | 520 | 124 | 1361 |
| Caledon | 14 | 158 | 42 | 504 | | |
| Victoria | 24 | 237 | 58 | 537 | 124 | 1361 |
| **Mrs. Moehrle's Yellow** | 20 | 202 | 54 | 570 | 109 | 1190 |
| Caledon | 14 | 158 | 50 | 621 | | |
| Victoria | 25 | 246 | 57 | 519 | 109 | 1190 |
| **Ozette** | 18 | 158 | 55 | 525 | 127 | 1189 |
| Caledon | 10 | 104 | 54 | 692 | | |
| Gananoque | 18 | 180 | 46 | 408 | | |
| Tompkins | 14 | 110 | 46 | 407 | | |
| Victoria | 30 | 240 | 72 | 594 | 127 | 1296 |
| **Pugh's Purple** | 34 | 329 | 51 | 492 | 109 | 1221 |
| Victoria | 34 | 329 | 51 | 492 | 109 | 1221 |
| **Russian Blue** | 18 | 149 | 44 | 388 | 97 | 1026 |
| Caledon | 13 | 144 | 46 | 563 | | |
| Gananoque | 14 | 115 | 41 | 283 | 73 | 828 |
| Tompkins | 17 | 127 | 40 | 328 | | |
| Victoria | 27 | 209 | 49 | 380 | 121 | 1223 |
| **Siberian** | 23 | 226 | 72 | 709 | 124 | 1358 |
| Victoria | 23 | 226 | 72 | 709 | 124 | 1358 |
| **Sieglinde** | 14 | 117 | 48 | 429 | 98 | 1087 |
| Caledon | 11 | 118 | 35 | 397 | | |
| Gananoque | 14 | 115 | 51 | 476 | 76 | 997 |
| Tompkins | 7 | 58 | 40 | 333 | | |
| Victoria | 24 | 175 | 66 | 509 | 119 | 1177 |
| **Slovenian** | 25 | 256 | 59 | 661 | 104 | 1165 |
| Caledon | 18 | 209 | 50 | 634 | | |
| Victoria | 31 | 303 | 68 | 688 | 104 | 1165 |
| | | | | | | |
| **Average** | **18.4** | **168.9** | **51.3** | **496.6** | **107.9** | **1175.6** |

The dried-leaves stage marks the end of the year's growth in potatoes, and is generally considered the time when the potato tubers have reached their maximum size and the skins are cured for good storage (IBSNAT 1993). Heritage varieties exhibited considerable differences in reaching this phase, and not all varieties died off. The mid-August harvest date by three of the growers also meant that this stage was not reached for several of the varieties shown in Table 3 as blank.

The differences in the rate of development are clearly evident at the two most thoroughly observed sites Victoria and Gananoque and having the most differences in weather during the growing season (Table 4). Emergence look consistently longer in Victoria for all varieties, and the plants grew for a much longer period of time and required more GDDs. The extended progression of growth could be linked to lower mean temperatures, particularly at the start of the growing season. It is possible that a different method of calculation would yield different results[2]; alternate calculation methods are discussed by Francl (1989) and IBSNAT (1993). Fine-tuning of our calculation may be necessary going forward.

**Table 4. Growth and development by days and Growing Degree Days for Banana, Chieftain, Ozette, Russian Blue and Sieglinde grown in Gananoque and Victoria.**

| Variety | Location | Days to Break | GDD to Break | Days to First Flower | GDD to First Flower | Days to Dried Leaves | GDD to Dried Leaves |
|---|---|---|---|---|---|---|---|
| Banana | Gananoque | 10 | 55 | 58 | 568 | 85 | 1034 |
| Banana | Victoria | 27 | 209 | 72 | 582 | 127 | 1284 |
| Chieftain | Gananoque | 14 | 115 | 41 | 316 | 76 | 915 |
| Chieftain | Victoria | 27 | 209 | 63 | 502 | 127 | 1290 |
| Ozette | Gananoque | 18 | 180 | 46 | 408 | Never yellowed | never dried |
| Ozette | Victoria | 30 | 240 | 72 | 594 | 127 | 1296 |
| Russian Blue | Gananoque | 14 | 115 | 41 | 283 | 73 | 828 |
| Russian Blue | Victoria | 27 | 209 | 49 | 380 | 121 | 1223 |
| Sieglinde | Gananoque | 14 | 115 | 51 | 476 | 76 | 997 |
| Sieglinde | Victoria | 24 | 175 | 66 | 509 | 119 | 1177 |

This point is further illustrated by simply comparing maturity time as reported in the literature to our observed growing degree days (Table 5). For example the reportedly late maturing Russian Blue and early maturing Sieglinde required on average the same number of days and

[2] See Huff and Hebda 2013 for in-depth discussion on our calculation parameters.

GDD's to reach the dried leaf stage. On the other hand the very late maturing Siberian variety took much more time to reach the dried leaf stage than the very early Sieglinde using both days and Growing Degree Days as measures. The differences in reported maturity times compared to our observations may be linked to the practical definition of maturity which to a grower may be defined as the time required for a harvestable crop rather than the time to reach an above ground growth stage.

The issue of time to maturity in a region needs to be better observed and understood because it influences grower choices and financial return. There may indeed be varietal differences in the maturation of tubers underground in relation to above-ground stages. If so a strict protocol of observing tuber development in relation to above ground development needs to be part of the observations. On the other hand there may simply be a lack of good data about maturity of heritage varieties. As noted earlier, the limitations of this study need to taken into consideration.

**Table 5. Potato varieties grown in the Crop-Climate Project, maturity as reported in the literature, Days to dried leaves average GDD and in 2012 growing season**

| Variety | Maturity | Days to Dried Leaves | GDD to Dried Leaves |
|---|---|---|---|
| Russian Blue | Late | 97 | 1026 |
| Sieglinde | Early | 98 | 1087 |
| Chieftain | Mid-season | 102 | 1102 |
| Slovenian Crescent | Early | 104 | 1165 |
| | | | |
| Banana | Late | 106 | 1159 |
| Mrs. Moehrle's Yellow | Unknown | 109 | 1190 |
| Pugh's Purple | Unknown | 109 | 1221 |
| Congo | Late | 117 | 1294 |
| Corne de Mouton | Early to mid-season | 124 | 1361 |
| Siberian | Very late | 124 | 1358 |
| Ozette | Late | 127 | 1296 |

Relative humidity and Climatic Moisture Deficit differed from site to site, as noted earlier in Part 1 of the report. The relationship of these factors to development is difficult to understand or even describe without a much large samples size. Nevertheless, it is curious to note that in Victoria with the greatest moisture deficit potatoes took the longest time to progress through stages. These two factors are further discussed in the section on yield.

## Disease and Insect observations

The development of disease and insect infestations in crops is influenced by numerous factors, including the planting history at a site, varietal resistance, heat and humidity. In potatoes,

diseases can be spread from site to site through infected potatoes. Maintaining clean, disease-free tubers is challenging. Many potato diseases overwinter in the soil, and organic growers are required to follow a strict rotation period to minimize disease stress and maximize yield.

Grower observations across sites over numerous years can help identifying different influences, as well as which varieties are likely to have resistance to pests which may be more common as the climate warms.

### Caledon

Caledon potato grower Garret Pittenger experienced high temperatures, drought and high humidity during the 2012 growing season. He made very few notes of disease in the potatoes, other than to note that 3 plants of Slovenian Crescent had developed leaf curl virus by July 3, and that Sieglinde had brown edges on mature leaves on fully mature plants, similar to ground level ozone sensitivity in Norland potatoes. In mid-July, many varieties had begun to flower and then aborted the flower buds due to heat stress. Pittenger also planted chitted (pre-sprouted) and unchitted tubers of the same variety, and noted that the chitted potatoes emerged more uniformly than unchitted ones.

### Gananoque

Gananoque experienced drought, heat stress and high relative humidity values during the growing season.

Small holes (1 mm in diameter or less) in the leaves were reported for all potato varieties on new growth in early June. The holes are likely from red spider mites, or some small chewing insect. The grower reported that new growth later in June was healthy and free from the holes. By mid-July, all were reported to have browning leaves. This may have been a result of heat stress and drought. Ozette and Banana had the least browning through this very dry period, and the grower commented on for Banana that it was “obviously drought resistant.” Leaf curl, likely a viral infection, was reportedly severe for Russian Blue, present to a lesser degree in Chieftain and Sieglinde, but not for Banana or Ozette. In addition, Russian Blue was noted to have brown scab on the harvested tubers.

### Tompkins

Tompkins experienced serious drought through the growing season, although it had the lowest average relative humidity of all sites, and few days of heat stress.

The growers reported very few disease and insect problems with their potatoes. Several potato bugs were found on Chieftain and Russian Blue, leaf curl was found on Sieglinde. Russian Blue was reported to be still in full bloom on July 26. The ground was “hard and dry” when plants were harvested on August 15.

### Victoria

Victoria experienced abnormally dry, droughty, conditions during the summer of 2012. Temperature and relative humidity were, by and large, within the optimal range for potatoes throughout the growing season.

The most commonly reported problem was leaf curl, which was recorded for Slovenian Crescent, Congo, Russian Blue, Mrs. Moehrle's Yellow and Siberian. Insect damage was noted on Chieftain, Russian Blue and Sieglinde. Slovenian Crescent had irregular emergence and overall poor growth.

## Potato Yield

To the producer, yield of tubers is obviously most important. However it is dependent on many factors aside from the weather experienced during the growing season. Nevertheless if plants are stressed by temperature extremes or moisture excess or deficit their yield is obviously affected. At the outset when considering a site-to-site comparison we felt that yield was too variable a characteristic to observe. Nevertheless growers were willing to observe yield and there seemed to be obvious connections of yield to the weather history of each site because of the extremes experienced (see Table 2). Also because in-site conditions were relatively uniform, the comparison of yield among varieties at a single site seemed a reasonable analysis to undertake.

Potato yield varied greatly by site and by variety (Table 6). Comparative observations at one site (where soil fertility and cultivation practices are uniform) demonstrate great differences in yield among heritage varieties (Figure 2 and Figure 3). Also within limitations, across-site comparison appears to show major differences possibly related to moisture availability, growing conditions and other factors (compare Gananoque to Caledon and Haliburton yields in Figure 2).

Poor yield of all potato varieties was most obvious at Gananoque (Figure 2). For the four commonly grown varieties only Banana and Chieftain produced a comparable yield to the other two sites with weight data and the yield of the other two varieties was very poor. Simplistically, one might be tempted to say that Gananoque experienced the most extreme weather conditions during the growing season. Yet Victoria had as strong a climatic moisture deficit as Gananoque and Caledon experienced much higher relative humidities and Victoria, much lower ones (Table 2).

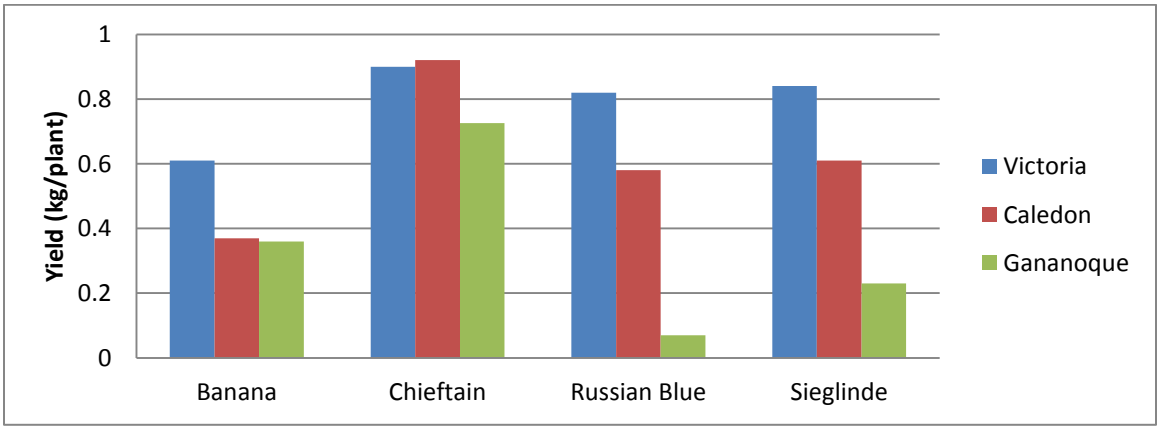
Other factors may have been involved too. For example at Gananoque, Russian Blue yield may have been severely depressed by viral diseases and scab. Gananoque yields also may have been limited by an early season pest infestation, when pinholes in the leaves, may have been caused by red spider mites.

The grower at Caledon noted early shriveling and drying out of plants. The most obvious cause of this appears to have been the high temperatures, high humidity and relatively low rainfall during the key early stages of potato development (Table 2).

**Table 6: Yield of Heritage potato varieties at different sites.**

| Potato variety | Victoria | Caledon (with watering) | Gananoque | Tompkins |
|---|---|---|---|---|
| Banana | 0.61 | 0.37 | 0.36 | Big yield 1-7 cm long |
| Chieftain | 0.90 | 0.92 | 0.73 | Moderate yield 1-8 cm long |
| Russian Blue | 0.82 | 0.58 | 0.07 | Moderate to large yield 1-10 cm long |
| Sieglinde | 0.84 | 0.61 | 0.23 | Moderate yield 4-12.5 cm long |
| Congo | 0.61 | 0.53 | | |
| Corne de Mouton | 1.02 | 3.04 | | |
| Mrs. Moehrle's yellow | 1.26 | 0.47 | | |
| Ozette | 0.90 | | | |
| Pugh's Purple | 0.25 | 0.53 | | |
| Siberian | 0.51 | 1.25 | | |
| Slovenian Crescent | **0.26** | | | |

**Figure 2. Yield of Banana, Chieftain, Russian Blue and Sieglinde Potato Varieties**

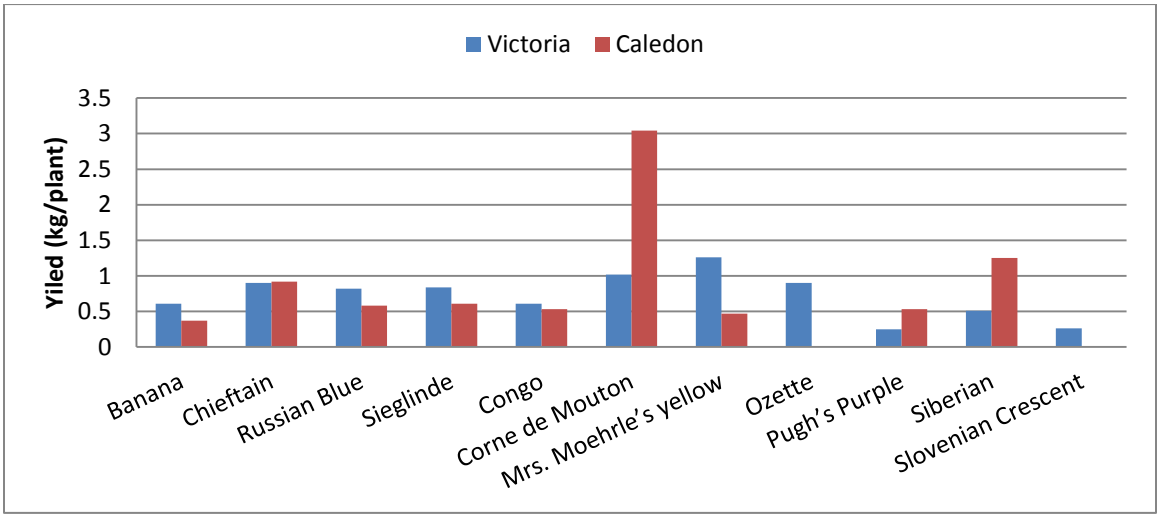



Comparing the two better yielding sites, Caledon and Victoria, a modest amount of supplemental watering was provided at Caledon mostly during the two leaf-horizontal and

flowering stages whereas no water was provided at Victoria during the long interval of drought. There were also strong differences in Relative Humidity, with Caledon regularly registering RH at values known to depress potato tuber size while Victoria rarely experienced readings outside the optimum range for potatoes. These important differences, considering the relatively good yields at Victoria, merit further investigation. They suggest that the Victoria climate with its relatively cool summer temperatures and earlier start to the growing season appears to be more amendable to potato growth of several Heritage varieties. Further years of observation are required to see if this pattern is consistent from year to year. More tightly controlled and systematic investigation is also merited.

Looking at differences among sites with respect to varieties, Victoria and Caledon which grew a total of 11 different varieties provide a comparison (Figure 3). Victoria yields were generally higher than Caledon with a couple of important differences. Corne de Mouton at Caledon had the highest yield of any variety at any site (3.04 kg/plant); Siberian also yielded very well at Caledon. Within previously mentioned limitations these observations may mean that Corne de Mouton and Siberian are well adapted to the high temperature, high relative humidity and climatic moisture deficit experienced at Caledon in 2012. In contrast, Mrs. Moehrle's Yellow was much more productive in Victoria (1.26 kg/plant) than at Caledon (.47 kg/plant) under a different set of climatic conditions whereas Corne de Mouton and Siberian did not yield well.

**Figure 3. Yield of all potato varieties grown at Victoria and Caledon.**




Notably, none of the four standard varieties from the same source (West Coast Seeds) were as productive as some of the Heritage varieties provided by Garrett Pittenger. Even considering the limitations of the study the yields of the four varieties were relatively similar at Caledon and Victoria. Much greater differences were observed for the less commonly grown heritage varieties, perhaps pointing to major variations in the climate related attribute of these varieties.

Although not explicitly recorded, there were obvious differences in the quality and size of tubers from one variety to another at the Victoria-Haliburton site. Quality is obviously linked to yield, and the case of low yielding Pugh's Purple the misshapen form of the tubers is obvious in the photograph (Figure 4). Many factors both climatic and non-climatic influence tuber quality including presence of virus, soil conditions, and pests. In the Haliburton case for example parts of the field had a low population of wire worms whereas others seemed to not have them. In future studies a standard way of describing visible tuber quality is desirable.

**Figure 4. Pugh's Purple tubers harvested from a single plant in Victoria, BC. Note mishapen tubers.**


Very large differences in yield are apparent with notable single varieties far out-yielding other heritage ones and certainly the more widely available four varieties from West Coast Seed. Considering the relatively standard conditions within each site these differences are especially notable and perhaps point to the suitability of particular varieties to the weather conditions of 2012 and in general for the climate of the region. For example, Corne de Mouton performed exceptionally well at Caledon compared to a commercial standard such as Chieftain and widely available Banana. Similarly Mrs. Moehrle's yellow widely out-yielded all the West Coast varieties including the heritage variety Banana at Victoria. Within the limitation of the study there appear to be major differences in yield under identical field and climatic conditions. Furthermore some of the heritage varieties are much more productive than the more widely available varieties. Clearly much more work needs to be done including an investigation of some of the heritage varieties in breeding more productive regionally adapted types.

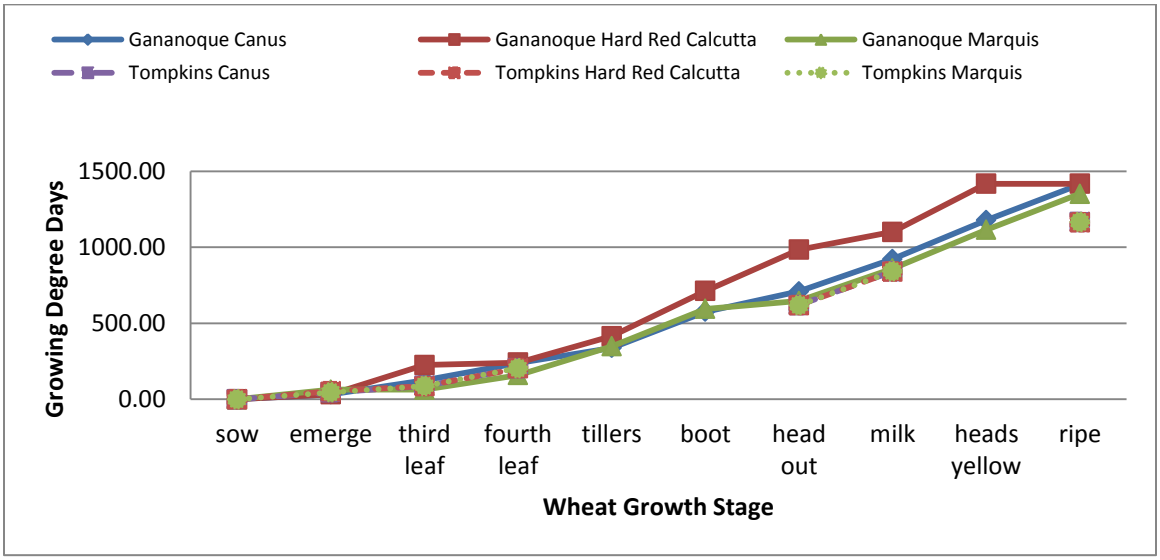
# Wheat

## Growth and Development

Five varieties of wheat were planted at each of two sites but at both sites the cultivars Thatcher and Stanley did not germinate. Accordingly the wheat trial was limited in its scope.

Wheat data reveal that the three wheat varieties behaved in more or less the same way at each trial sites (Appendix II Figures 26-28) with little difference in the timing of stages from variety to variety. Heading out for example took place at about the same time for each variety at each site (Figure 5). The Tompkins grower noted no differences between varieties, in terms of their growth and development (thus all appear as lines on top of each other on the graphs in Figure 5).

**Figure 5. Heritage wheat variety growth and development by GDD (growing degree days)**




Notably too the trajectories of growth are very similar at both sites despite significant differences in climatic conditions such as the intense heat and drought at Gananoque. After emergence, Tompkins Saskatchewan was about 10 days behind Gananoque for all three varieties. However with respect to Growing Degree Days (accumulated warmth) five of the six plantings progressed at the same rate. Hard Red Calcutta required about 200 more growing degree days in the second half of its growth cycle at Gananoque (Figure 5). At Tompkins, all three varieties ripened rapidly, which the grower attributed to the hot, dry growing conditions and all three varieties were ripe at 1165 GDDs in contrasting to the average of 1395 GDDs for Gananoque.)

The climatic moisture deficit at both sites (-244 mm Gananoque vs -267mm Tompkins) was similar perhaps contributing to the generally similar outcomes. Relative humidity was generally

lower at Tompkins including more frequent readings below 40 % and below 80% (Huff and Hebda 2013: Figure 11).

It should be noted that despite beginning with a standard protocol observations were not made quite the manner at the two sites so that data are not exactly comparable. Wheat is obviously a key food crop and trails need to be expanded well beyond this pilot effort. A wider range of varieties might demonstrate greater differences from climatic region to climatic region. IN any case it is clear that observation need to be made in a standard manner at all trial sites and perhaps for fewer, but obvious, stages.

## Disease and Insect observations

The development of disease and insect infestations in wheat is influenced by numerous factors, including the seed source, planting history at a site, varietal resistance, heat and humidity. Grower observations across sites over numerous years can help identifying different influences, as well as which varieties are likely to have resistance to pests which may be more common as the climate warms. In 2012, disease and insect observations were recorded anecdotally , and the two wheat growers noted very few disease problems with any variety of wheat.

### Gananoque

Gananoque, which experienced drought, heat stress and high relative humidity values during the growing season. The three wheat varieties planted all had some viral infections on the flag leaves. Hard Red Calcutta had “2% flag leaf curl (virus) on June 30; Canus had “5% rust” with 1 head with blight on July 10, and Marquis had “7% leaf curl” on July 3. At the end of the season, August 15, Marquis was reported as having spikelets already germinating on the head.

### Tompkins

Tompkins experienced serious drought through the growing season, although it had the lowest average relative humidity of all sites, very few days of heat stress, the most hours of sun and the highest Potential Evapotranspiration. The growers reported very few disease and insect problems with wheat. All three wheat varieties (Marquis, Canus and Hard Red Calcutta) matured rapidly due to warm weather in mid-July, when they began to brown off at the root base. The ground was “hard and dry” when plants were harvested on August 15.

## Yield

In 2012, no yield data were recorded by growers for the wheat varieties planted. In future years, a more rigorous protocol is recommended to capture yield information, even though it is less directly related to climate factors than progress through wheat development stages.

# Recommendations and Conclusions

## Review of recommendations in Preliminary Report

**Recommendation 1:** Prepare a comprehensive report on the 2012 crop-climate project.

- ✓ Thanks to the grant from the W. G. Weston Foundation in the fall of 2012 we prepared a comprehensive analysis of the project and its results in two parts (Huff and Hebda 2013) and this report. We included analyses of relative humidity and moisture deficits.
- ✓ Several suggestions in the preliminary report for field activity were implemented in a limited manner in 2013 such as making more frequent observations using revised field observation forms. Selected discussions were undertaken to improve growing and observation protocols. These will be included in future proposals and guidelines.
- ✓ A comprehensive instruction manual is under preparation and will be completed by end of October 2013.

**Recommendation 2:** Implement a second year of the crop-climate project to include new partners such as the USC Canada Seed initiative and University of Victoria and to represent more climatic zones and heritage varieties.

- ✓ Limited trials were implemented in British Columbia (potatoes) and Ontario (grains and potatoes) according to the funding available.
- ✓ Discussions were undertaken with several potential collaborators especially the Bauta Family Initiative on Seed Security for a more wide-ranging project in 2014. These discussions identified a strong interest in more information on wheat in particular and the need for a relatively simple but reliable protocol for field observations.
- ✓ As pointed out in the preliminary report and clear from the additional analyses in Part 1 and 2 of this report there is a need for good training of project participants in the standards of equipment deployment and crop observation.

## Recommendation for Continuing the Crop Climate Project

The data collected so far are highly promising but cover only a few heritage varieties in a limited range of weather conditions. Much more crop climate data are needed to reveal clearly the relationship between the growth and yield of specific varieties and climatic conditions. Varieties need to be observed during several growing seasons and across as wide a range of climates as practical to establish a solid data base for growers to consult in making crop choices and adapting their production methods. In gathering the varietal information, relatively simple protocols and standards need to be established and verified.

Several insights have been gained into what affects growth of crop varieties and what might contribute to the differences. These ideas need to be pursued to identify unambiguously those factors most important in crop production. By doing so, simple guidelines for varietal choices may be developed. Participants suggested the value of the use of crop-climate hypotheses that

might help narrow down which weather and plant observations are most important. They also identified the need to engage a few large scale growers (especially of potatoes) and include a few more commercial varieties to make the results of the study as widely useful as possible. Several such hypotheses have been proposed in this report and the key ones need to be identified in consultation with collaborators and experts.

As noted at the outset the need is urgent to develop, gather and compile crop climate data and make it available. A small scale project such as this one must expand and engage as many participants as practical. To achieve these ends, and to attract support, the concept of the project and the emerging information need to be widely known.

The following recommendations address the continuation of the project from four perspectives: Project approach ad structure, Crop-Climate Monitoring protocols, Data compilation and analysis, outreach.

## Project approach and structure

1. Conduct a least three years of field trails to obtain enough data for significant results from analyses
2. Conduct trials across a wide range of climates (at least 5 climatic regions) using a wide range of genetic material (different heritage and conventional varities) to identify most easily recognizable differences. Now that we have some information it would be desirable to have a few selected growers under more extreme climatic conditions such as shorter growing season than used in the pilot year.
3. Involve participants from the Bauta Family Initiative on Seed security as collaborators and growers. Since the less expensive HOBOs record temperature and relative humidity reliably it would be efficient to establish regional clusters of growers such as those envisaged in the USC seed initiative associated with a Davis weather station to collect precipitation and other data.
4. Verify in consultation with collaborators, the most useful and efficient plant and climate attributes to monitor.
5. Focus on the growing and observation of key wheat varieties.
6. Where possible identify and use regional climate networks.
7. Complete writing of instruction manual with good illustrations in time for next growing year.
8. Prepare and submit a proposal for addition funding to W.G. Weston Foundation for 2014 to complete analyses and continue project in 2014 crop year.

## Crop-Climate Monitoring Protocols

1. Review growth stages and eliminate those that are most ambiguous to identify.
2. Ensure the training complete well before planting time and start of crop year.
3. Include reliable measures of yield and vigour in observations of new crop years.

## Analysis

1. Compile, analyze and summarize 2013 field data to improve the interpretation of crop-climate relationships for key varieties and add to variety profiles
2. Use 2013 data, grower knowledge and information in the literature to identify and focus on key weather factors that limit development and yield.

## Outreach

1. Compile and post observations on internet so that they are widely available for growers to see, use and elicit feedback.
2. Create heritage variety descriptions in a standard format, including developing climatic profiles, and publish them on the Seeds of Diversity website.

The 2012 Crop-Climate pilot project demonstrates that within the limitations of the methods, growers can gather useful plant growth data while instruments continually collect climate information. We learned how to best deploy meteorological equipment , which equipment was most useful and for what kind of data. We further learned how to best aggregate and compile the data and some of the challenges in doing so. We discovered that during this year of regionally very different weather (even extreme) conditions potato varieties behaved very differently whereas the three wheat varieties did not. Different varieties responded differently at each site and the same varieties developed differently at different sites. We proposed reasons for these varied patterns of development linked to weather variables such as temperature and relative humidity.

To generate reliable data and be most useful and applicable the project needs to be run for several years including more participants and a broad range of varieties.

Considering this time of intensifying and accelerating climate change crop-climate studies such as ours are a vital adaptive tool. We hope that our project and its results point to a way to gather the information so urgently needed to support affordable and sustainable food production in the future.

# References

Campbell, A.B. Wheat. *In:* The Canadian Encyclopedia. Online: http://www.thecanadianencyclopedia.com/articles/wheat

Foley, J.A. and others. 2011. Solutions for a cultivated planet. Nature 478: 337-342

Francl, L.J. 1989. Are physiological days of potato calculated accurately? American Potato Journal Volume 66, pp. 391-395.

Hebda, R.J. 2012. Crop-Climate Project: Summary Report for 2012. Prepared for the W. Garfield Weston Foundation.

Huff, V. and R. J. Hebda. 2013. Crop-Climate Project 2012 Report: Part I. Climatic Growth Factors.

IBSNAT. 1993. Research Report Series 02. A Simulation Model for Potato Growth and Development: SUBSTOR – Potato Version 2.0. Dept. of Agronomy and Soil Science, College of Tropical Agriculture and Human Resources, Univ. of Hawaii, Honolulu, HI.

Symko, S. 1999. From a single seed – Tracing the Marquis wheat success story in Canada to its roots in the Ukraine. Agriculture and Agri-Food Canada. Online: http://www.agr.gc.ca/eng/science-and-innovation/science-publications-and-resources/resources/from-a-single-seed-tracing-the-marquis-wheat-success-story-in-canada-to-its-roots-in-the-ukraine-1of11/?id=1181224838769

# Appendix 1: Heritage Potato Results by Variety

## Banana

Flowers of Banana


Banana potatoes grown in 2012 for the Crop-Climate Project In Victoria, British Columbia

**Varietal Notes:**

| | |
|---|---|
| Maturity: | late |
| Skin colour: | light yellow |
| Flesh colour: | pale yellow |
| Tuber Shape: | banana |
| Origin and Breeding: | Grown in British Columbia for more than 90 years. Research suggests that the variety may have been introduced to early settlers and natives by Russian fur traders. The exact origin, parental lines or breeding techniques used to develop it are not known. |
| Year registered in Canada: | 1990 |
| Agricultural Features: | High tuber set (15 to 20 small tubers per plant) |
| Yield: | Low |
| Dormancy: | Medium |
| Storability: | Good |
| Utilization: | Very good for boiling, baking and frying; excellent salad potato. |
| Environmental Stress: | |
| Disease Response | |
| Moderately Resistant: | common scab |
| Moderately susceptible: | verticillium wilt |
| Susceptible: | late blight, leaf roll, PVX, PVY |
| Notes: | |
| Sources: | http://www.inspection.gc.ca/plants/potatoes/potato-varieties/banana/eng/1312587385647/1312587385648 |

## 2012 Results

### Seed Source

Certified organic seed potatoes were purchased from West Coast Seeds and distributed to participants.

### Growth Observations for Banana

Four growers (Table 7) grew banana potato in 2012. The planting dates in each location are listed, as are the dates on which half or more of the tubers planted reached the growth phase, as recorded by the grower. Figure 6 shows the comparative development at four locations based on days from planting, and Figure 7 shows the Growing Degree Days taken to reach each stage.

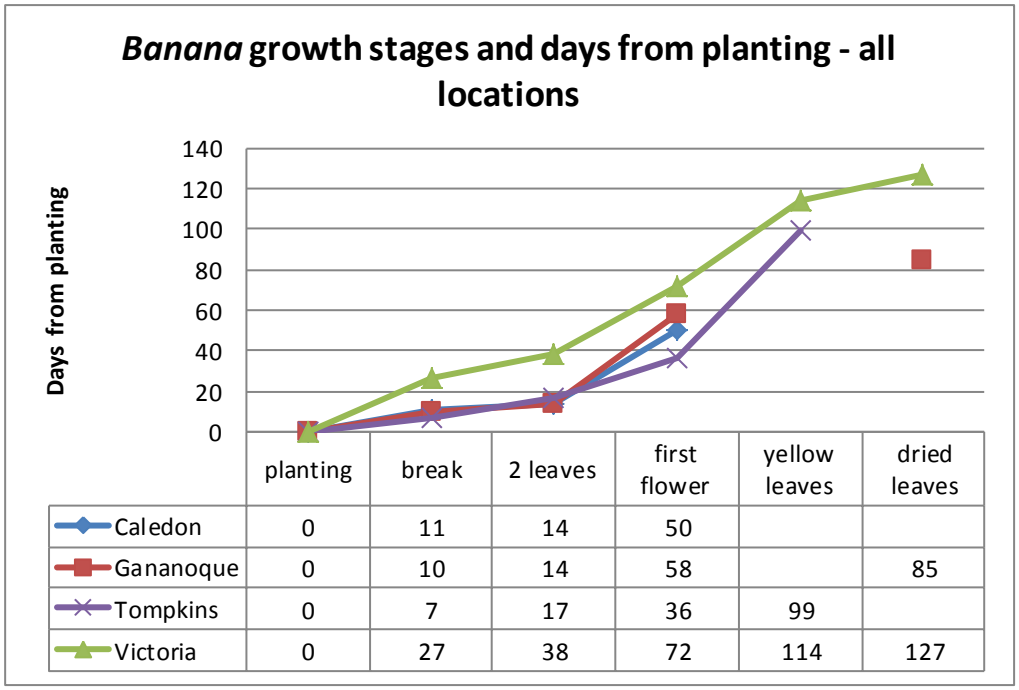
Banana grew the most slowly in Victoria, both in terms of the number of days and the accumulated heat taken to reach each stage – a pattern that is common for most potato varieties. In Gananoque, under conditions of high heat, humidity and moisture stress, potato plants reached the dried leaf stage very quickly.

On July 19 a test plant dug up at Victoria yielded 8 “large” tubers (6,6,7,8,11,5,6,6 cm long) 0n short 1-3 cm long stolons. There were only 2 tiny secondary tubers one of them on a 10 cm long stolon

**Table 7. Growth observations of Banana at four growing sites.**

| Location | Planting date | break | 2 leaves | first flower | yellow leaves | Dried leaves |
|---|---|---|---|---|---|---|
| **Caledon** | 15-May-12 | 25-May-12 | 28-May-12 | 03-Jul-12 | -- | |
| **Gananoque** | 11-May-12 | 20-May-12 | 24-May-12 | 07-Jul-12 | | 03-Aug-12 |
| **Victoria** | 22-Apr-12 | 18-May-12 | 29-May-12 | 02-Jul-12 | 13-Aug-12 | 26-Aug-12 |
| **Tompkins** | 09-May-12 | 15-May-12 | 25-May-12 | 13-Jun-12 | 15-Aug-12 | |

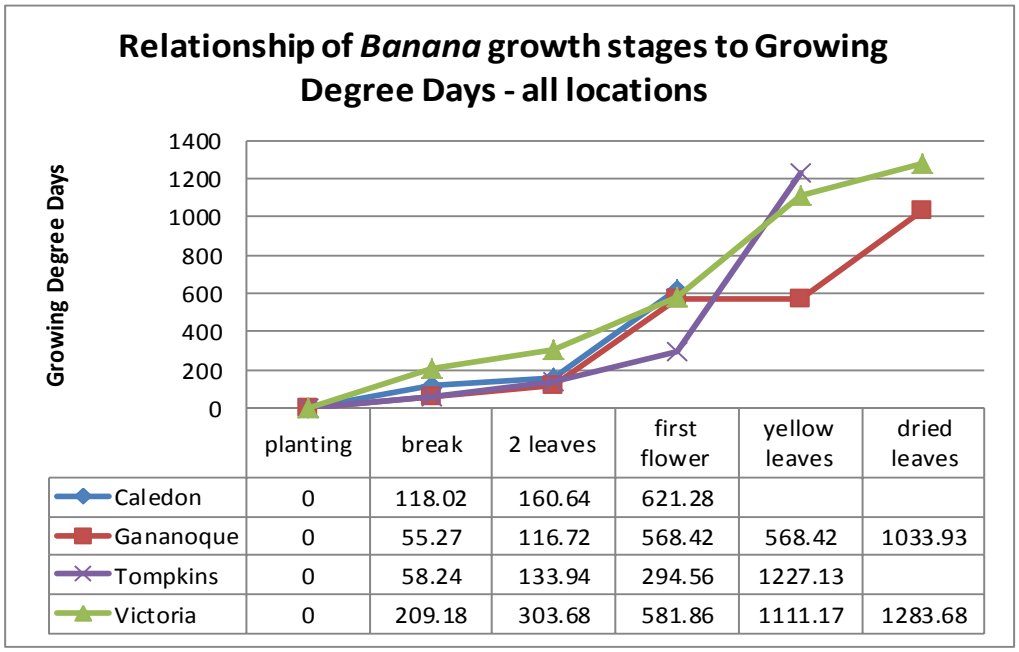
**Figure 6. Days from planting to median date of phenological growth phase at 4 locations for Banana potato.**




| | planting | break | 2 leaves | first flower | yellow leaves | dried leaves |
|---|---|---|---|---|---|---|
| Caledon | 0 | 11 | 14 | 50 | | |
| Gananoque | 0 | 10 | 14 | 58 | | 85 |
| Tompkins | 0 | 7 | 17 | 36 | 99 | |
| Victoria | 0 | 27 | 38 | 72 | 114 | 127 |

**Figure 7. Heat accumulation (Growing Degree Days) to median date of phenological growth phase at 4 locations for Banana potato.**

Heat accumulation is calculated as follows: From planting to emergence-Soil Growing Degree Days at 5 $^{o}$C, from emergence to 2 fully unfolded leaves- Air Growing Degree Days at 5 $^{o}$C at soil surface; remaining taken from the HOBO placed at 75 cm above ground.




| | planting | break | 2 leaves | first flower | yellow leaves | dried leaves |
|---|---|---|---|---|---|---|
| Caledon | 0 | 118.02 | 160.64 | 621.28 | | |
| Gananoque | 0 | 55.27 | 116.72 | 568.42 | 568.42 | 1033.93 |
| Tompkins | 0 | 58.24 | 133.94 | 294.56 | 1227.13 | |
| Victoria | 0 | 209.18 | 303.68 | 581.86 | 1111.17 | 1283.68 |

* Tompkins HOBOs were installed one week after the planting date. GDD for the 7 days to emergence is estimated from the Davis Weatherstation values GDD at 5 for this period.

**Yield**

Banana was the highest yielding of the varieties grown at Gananoque and Tompkins, where only four varieties (Banana, Chieftain, Russian Blue and Sieglinde) were grown. It had a below average yield at Victoria and Caledon, where there were 11 and 10 varieties grown respectively.

**Table 8. Banana potato yield (kg/plant) at four growing locations.**

| Victoria | Caledon (with watering) | Ironwood | Tompkins |
|---|---|---|---|
| 0.61 | 0.37 | 0.36 | Big yield<br>1-7 cm long |

**Discussion**

Banana potatoes had few reports of disease or insect problems, other than some minor browning of leaf edges and some chewing on the leaves. It appears to be quite adapted to a variety of growing conditions, and apparently able to out-produce other potatoes even under drought conditions.

## Chieftain


Chieftain potatoes grown in 2012 for the Crop-Climate Project In Victoria, British Columbia

### Varietal Notes

| | |
|---|---|
| Maturity: | mid-season |
| Skin colour: | Red |
| Flesh colour: | White |
| Tuber Shape: | oval to oblong |
| Origin and Breeding: | Bred by A.E. Kehr from (la1027-18 x La1354) and selected by the Department of Horticulture, Iowa State University, Ames, Iowa, in 1957. |
| Year registered in Canada: | 1973 |
| Agricultural Features: | High yielding variety, attractive appearance, widely adapted. Under-sizing can be a problem if soil moisture becomes limiting. Well suited for washing at maturity. Good storability. Medium specific gravity. |
| Yield: | High |
| Dormancy: | |
| Storability: | Good |
| Utilization: | Good for boiling, chipping at harvest, french fries |
| Environmental Stress: | |
| Disease Response | |
| Moderately Resistant: | late blight, common scab, rhizoctonia, silver scurf, stem-end browning, tuber net necrosis, verticillium wilt. |
| Moderately susceptible: | |
| Susceptible: | black leg, fusarium dry rot, leaf roll, phoma rot, PVX and PVY. |
| Notes: | |
| Sources: | http://www.inspection.gc.ca/plants/potatoes/potato-varieties/chieftain/eng/1312587385685/1312587385686 |

## 2012 Results

### Seed Source

Certified Organic seed potatoes were purchased from West Coast Seeds and distributed to participants.

### Growth Observations for Chieftain

Four growers (Table 9) grew Chieftain potato in 2012. The planting dates in each location are listed, as are the dates on which half or more of the tubers planted reached the growth phase, as recorded by the grower.

One plant was dug up on July 19th in Victoria. It had 7 "large" potatoes (i.e. 6,7,8,9 cm long) 0n 3-5 cm stolons. A second set of 8 tiny new pea sized tubers had been produced on 2-7 cm long stolons

**Table 9. Growth observations of Chieftain at four growing sites.**

| Location | Planting date | break | 2 leaves | first flower | yellow leaves | Dried leaves |
|---|---|---|---|---|---|---|
| **Caledon** | 15-May-12 | 28-May-12 | 31-May-12 | 18-Jun-12 | -- | |
| **Gananoque** | 11-May-12 | 24-May-12 | 30-May-12 | 20-Jun-12 | | 25-Jul-12 |
| **Victoria** | 22-Apr-12 | 18-May-12 | 05-Jun-12 | 23-Jun-12 | 04-Aug-12 | 26-Aug-12 |
| **Tompkins** | 09-May-12 | 25-May-12 | 28-May-12 | 17-Jun-12 | 01-Aug-12 | |

**Figure 8. Days from planting to median date of phenological growth phase at 4 locations for Chieftain potato.**

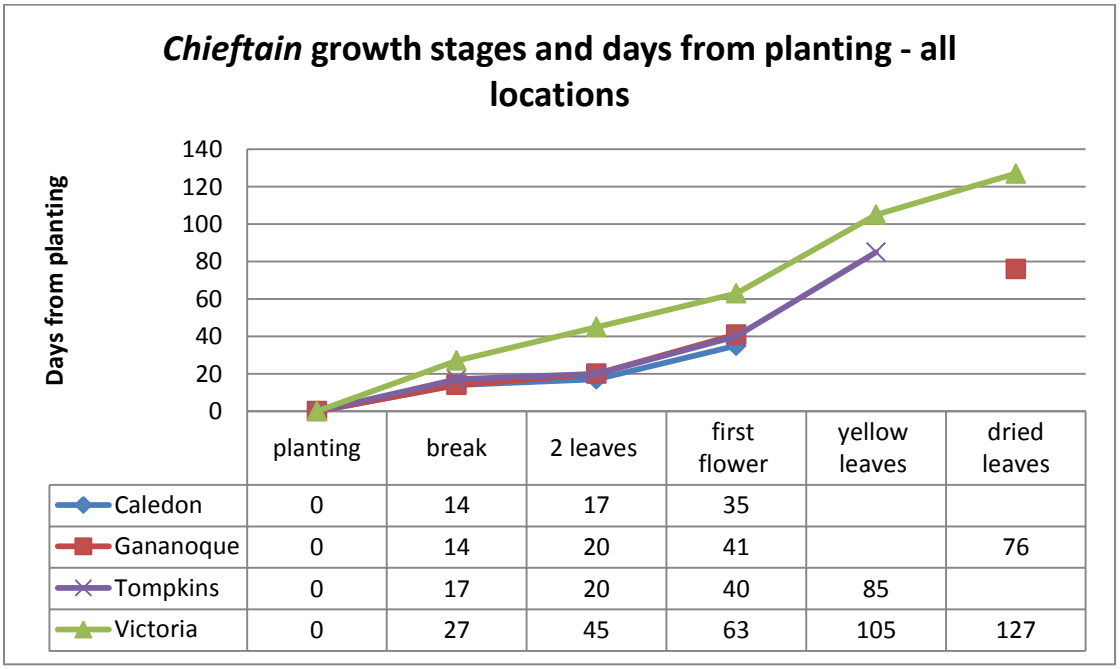
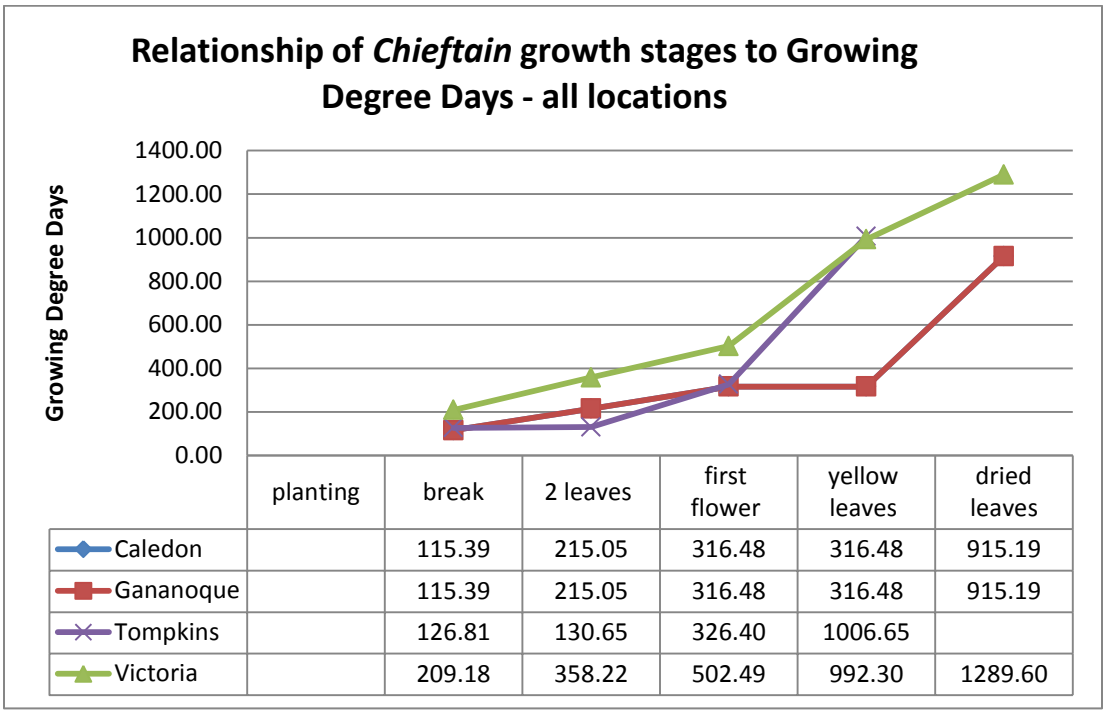


**Figure 9. Heat accumulation to median data of phenological growth phase at 4 locations for Chieftain potato.**

Heat accumulation is calculated as follows: From planting to emergence-Soil Growing Degree Days at 5 $^{o}$C, from emergence to 2 fully unfolded leaves- Air Growing Degree Days at 5 $^{o}$C at soil surface; remaining taken from the HOBO placed at 75 cm above ground.




| | planting | break | 2 leaves | first flower | yellow leaves | dried leaves |
|---|---|---|---|---|---|---|
| Caledon | | 115.39 | 215.05 | 316.48 | 316.48 | 915.19 |
| Gananoque | | 115.39 | 215.05 | 316.48 | 316.48 | 915.19 |
| Tompkins | | 126.81 | 130.65 | 326.40 | 1006.65 | |
| Victoria | | 209.18 | 358.22 | 502.49 | 992.30 | 1289.60 |

**Yield**

Chieftain yielded well at Victoria (.9 kg/plant), Caledon (.92 kg/plant), Gananoque (.73 kg/plant) and Tompkins ("moderate yield").

**Discussion**

Chieftain suffered from leaf curl in Gananoque, but not in the other locations. This may have been the result of the combination of heat stress, high humidity and drought.

## Russian Blue

Flowers of Russian Blue


Russian Blue potatoes grown in 2012 for the Crop-Climate Project In Victoria, British Columbia

### Varietal Notes

| | |
|---|---|
| Maturity: | Late |
| Skin colour: | dark purple |
| Flesh colour: | Blue |
| Tuber Shape: | round to oblong |
| Origin and Breeding: | Reported to be a heritage variety from Russia. |
| Year registered in Canada: | |
| Agricultural Features: | |
| Yield: | Heavy setting |
| Dormancy: | |
| Storability: | |
| Utilization: | Roasting, baking or grilling is recommended. |
| Environmental Stress: | Withstands dry conditions. |
| Disease Response | |
| Moderately Resistant: | late blight, hollow heart, second growth, shatter bruise, PVA, PVM, PVX, PVS. |
| Moderately susceptible: | |
| Susceptible: | PVLR, PVY, common scab, bacterial ring rot, and black leg. |
| Notes: | From West Coast Seeds:<br>Russian Blue is a late season HERITAGE variety. Dark purple skin on round to oblong tubers, plants are very heavy setting so give them more room in the row. It withstands dry conditions better than most. Their texture is much like a russet so they are good to bake or mash, cook as French fry or even make into chips; but they also can be steamed or boiled. Roasting or grilling the halves will actually darken the colour. |
| Sources: | http://www.westcoastseeds.com/tell-a-friend/vegetable-seeds/Potatoes/Russian-Blue-Organic |

## 2012 Results

### Seed Source

Certified Organic seed potatoes were purchased from West Coast Seeds and distributed to participants.

### Growth observations

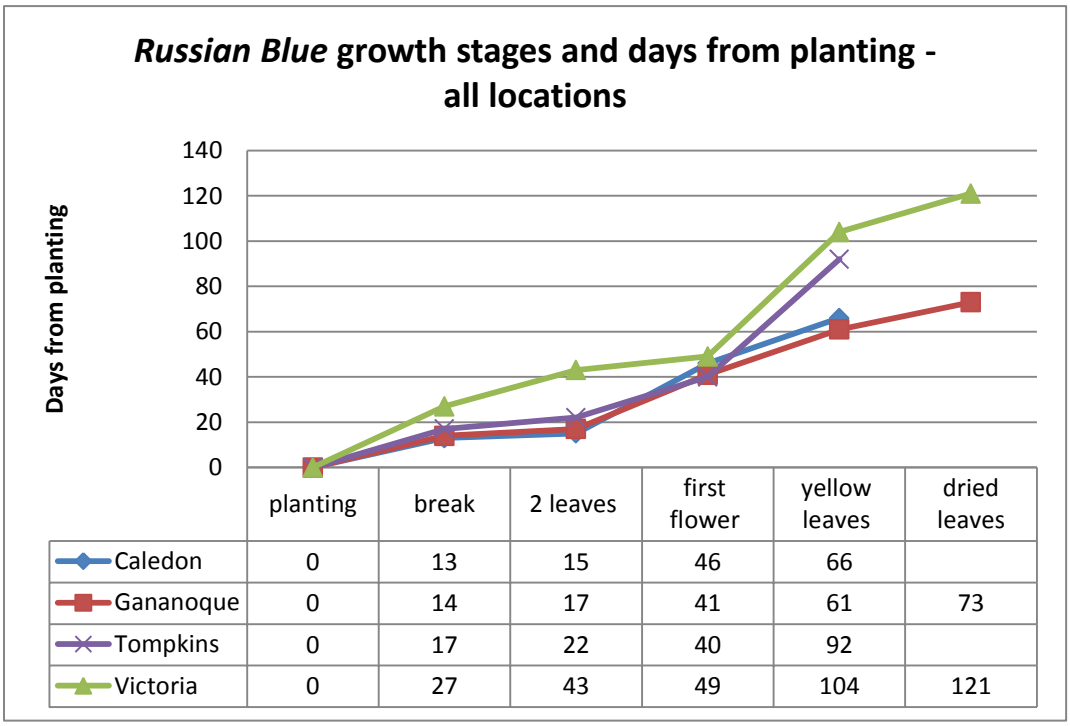
Four growers (Table 9) grew Russian Blue potato in 2012. The planting dates in each location are listed, as are the dates on which half or more of the tubers planted reached the growth phase, as recorded by the grower.

At Victoria upon full harvest on October 1st it was noted that tubers were produced deep in the soil 15 cm below the surface on long stolons. At this level the soil was relatively moist compared to the soil at the level of the tuber production of surface bearers. The tubers were more uniform in size and shape than fro other varities.

**Table 10. Days from planting to the date at which half of potato plants in plot were at each phase of development for Russian Blue potato.**

| Location | Planting date | break | 2 leaves | first flower | yellow leaves | Dried leaves |
|---|---|---|---|---|---|---|
| **Caledon** | 15-May-12 | 27-May-12 | 29-May-12 | 29-Jun-12 | 19-Jul-12 | |
| **Gananoque** | 11-May-12 | 24-May-12 | 27-May-12 | 20-Jun-12 | 10-Jul-12 | 22-Jul-12 |
| **Victoria** | 22-Apr-12 | 18-May-12 | 03-Jun-12 | 09-Jun-12 | 03-Aug-12 | 20-Aug-12 |
| **Tompkins** | 09-May-12 | 25-May-12 | 30-May-12 | 17-Jun-12 | 08-Aug-12 | |

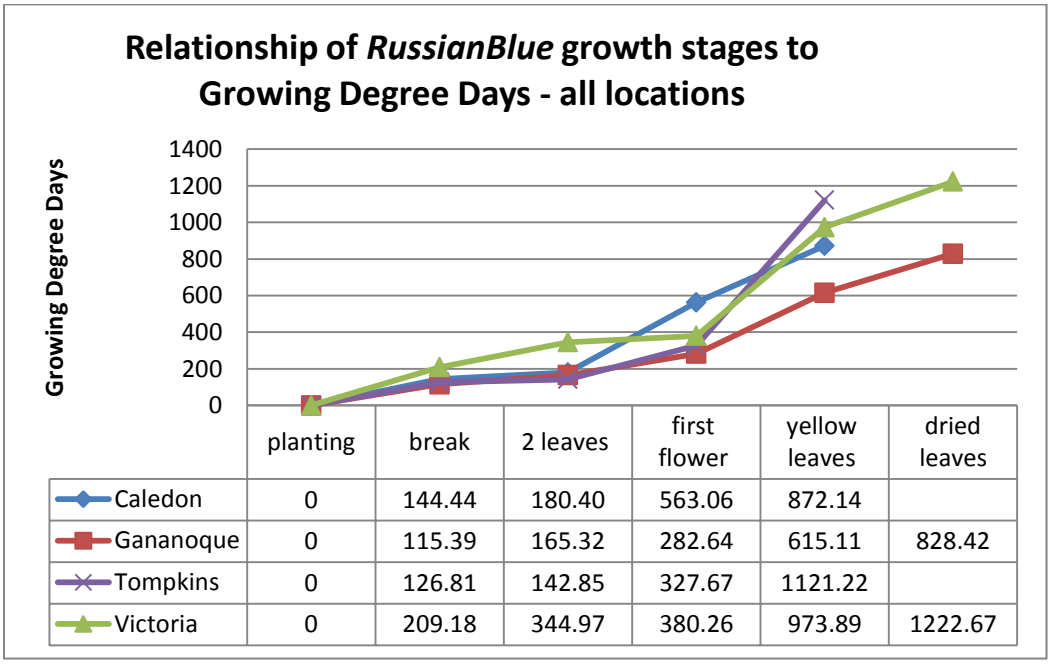
**Figure 10. Days from planting to median date of phenological growth phase at 4 locations for Russian Blue potato.**




| | planting | break | 2 leaves | first flower | yellow leaves | dried leaves |
|---|---|---|---|---|---|---|
| Caledon | 0 | 13 | 15 | 46 | 66 | |
| Gananoque | 0 | 14 | 17 | 41 | 61 | 73 |
| Tompkins | 0 | 17 | 22 | 40 | 92 | |
| Victoria | 0 | 27 | 43 | 49 | 104 | 121 |

**Figure 11. Heat accumulation to median data of phenological growth phase at 4 locations for Russian Blue potato.**

Heat accumulation is calculated as follows: From planting to emergence-Soil Growing Degree Days at 5 $^{o}$C, from emergence to 2 fully unfolded leaves- Air Growing Degree Days at 5 $^{o}$C at soil surface; remaining taken from the HOBO placed at 75 cm above ground.




| | planting | break | 2 leaves | first flower | yellow leaves | dried leaves |
|---|---|---|---|---|---|---|
| Caledon | 0 | 144.44 | 180.40 | 563.06 | 872.14 | |
| Gananoque | 0 | 115.39 | 165.32 | 282.64 | 615.11 | 828.42 |
| Tompkins | 0 | 126.81 | 142.85 | 327.67 | 1121.22 | |
| Victoria | 0 | 209.18 | 344.97 | 380.26 | 973.89 | 1222.67 |

**Yield**

Russian Blue had its highest yields at Victoria and Tompkins. It yielded in the mid-range at Caledon, and very poorly at Gananoque. At Victoria all tubers produced deep in the soil and were more uniform in size and shape than for other varieties.

**Table 11. Russian Blue yield (kg/plant) at four growing locations.**

| Victoria | Caledon | Gananoque | Tompkins |
|---|---|---|---|
| 0.82 | 0.58 | 0.07 | Moderate to large yield 1-10 cm long |

**Discussion**

Russian Blue experienced leaf curl at Gananoque, where the harvested tubers also had brown scab. In Tompkins, the plants bloomed continuously and appeared very healthy through the season. In Victoria, Russian Blue developed brown / black shrivelled leaves in early August. Is spite of this, it yielded well at all locations except Gananoque.

## Sieglinde


*Sieglinde* potatoes grown in 2012 for the Crop-Climate Project in Victoria, British Columbia

### Varietal Notes

| | |
|---|---|
| Maturity: | Early |
| Skin colour: | clear yellow |
| Flesh colour: | Pale yellow |
| Tuber Shape: | oval to round |
| Origin and Breeding: | Originated in Austria or Germany |
| Year registered in Canada: | |
| Agricultural Features: | |
| Yield: | |
| Dormancy: | medium to long |
| Storability: | good [West Coast Seeds]; Poor [Euro Potato] |
| Utilization: | |
| Environmental Stress: | Medium to high drought resistance. |
| Disease Response | |
| Moderately Resistant: | scab, mosaic virus, warts, blackleg, PVA |
| Moderately susceptible: | PVS, PVX |
| Susceptible: | late blight, powdery scab, leaf roll |
| Notes: | According to West Coast Seeds, Sieglinde is a popular European variety with very thin skin, shallow eyes and firm yellow flesh. |
| Sources: | http://www.europotato.org/display_description.php?variety_name=Sieglinde<br>http://www.westcoastseeds.com/productdetail/Vegetable-Seeds/Potatoes/Sieglinde-Organic/#sthash.LGSxYBb4.dpbs |

## 2012 Results

### Seed Source

Certified Organic seed potatoes were purchased from West Coast Seeds and distributed to participants.

### Growth observations for Sieglinde

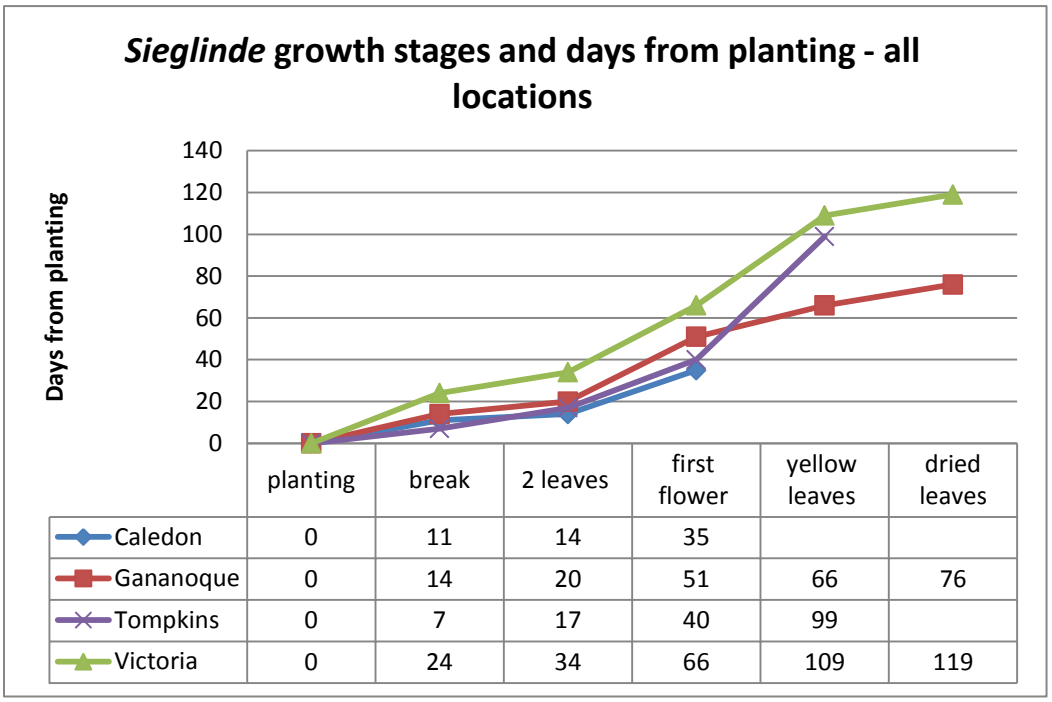
Four growers (Table 12) grew Sieglinde potato in 2012. The planting dates in each location are listed, as are the dates on which half or more of the tubers planted reached the growth phase, as recorded by the growers. In Gananoque and Victoria, Sieglinde required 76 days and 915 GDD to reach the dried leaf stage, in Victoria it took 119 days and 1177 GDD to reach the same level of maturity. Tompkins potato plants had the longest interval (59 days) and most accumulated heat (894 GDD) between first flower and yellowing leaves of all locations (Figures 12 and 13). This is the active growth phase, and is the critical period for tuber initiation and bulking and likely affects overall yield. Temperature stress during this phase, which was experienced in all locations, can depress yield.

A test plant was dug up At Victoria on June 26 (start of flowering) and had 5 tubers of edible size 2-6 cm long. The mother tuber had become detached but was still firm. Several stolons had grown outward from the mother tuber and had pea sized mini-tubers.

**Table 12. Growth observations of Sieglinde at four growing sites.**

| Location | Planting date | break | 2 leaves | first flower | yellow leaves | Dried leaves |
|---|---|---|---|---|---|---|
| **Caledon** | 15-May-12 | 25-May-12 | 28-May-12 | 18-Jun-12 | -- | |
| **Gananoque** | 11-May-12 | 24-May-12 | 30-May-12 | 30-Jun-12 | 25-Jun-12 | 25-Jul-12 |
| **Victoria** | 22-Apr-12 | 15-May-12 | 25-May-12 | 26-Jun-12 | 08-Aug-12 | 18-Aug-12 |
| **Tompkins** | 09-May-12 | 15-May-12 | 25-May-12 | 17-Jun-12 | 15-Aug-12 | |

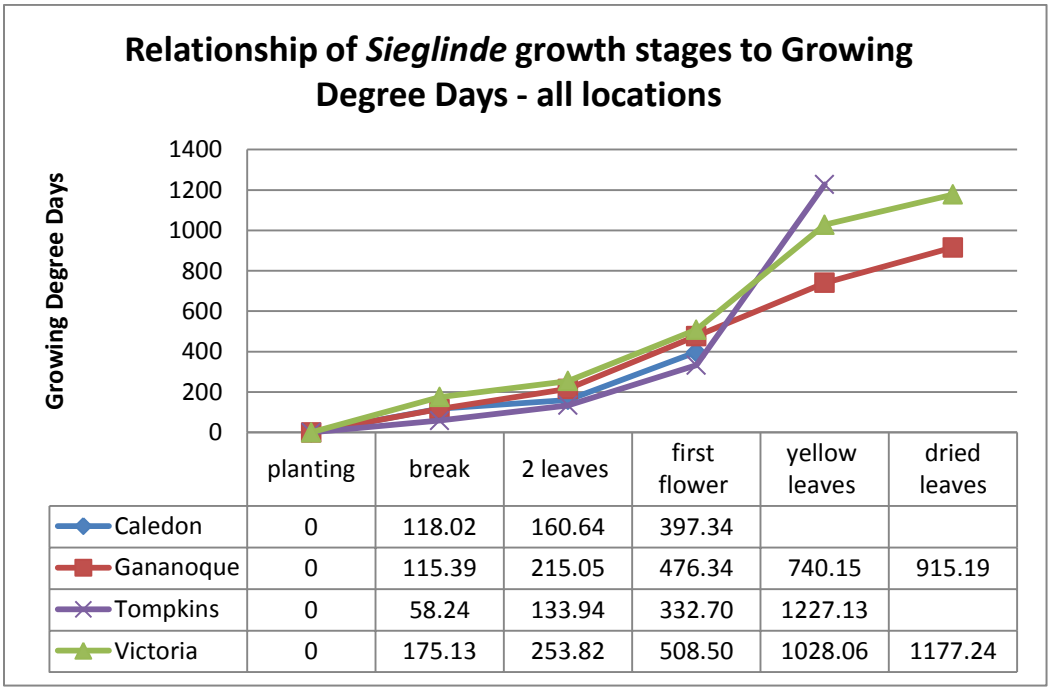
**Figure 12. Days from planting to median date of phenological growth phase at 4 locations for Sieglinde potato.**




| | planting | break | 2 leaves | first flower | yellow leaves | dried leaves |
|---|---|---|---|---|---|---|
| Caledon | 0 | 11 | 14 | 35 | | |
| Gananoque | 0 | 14 | 20 | 51 | 66 | 76 |
| Tompkins | 0 | 7 | 17 | 40 | 99 | |
| Victoria | 0 | 24 | 34 | 66 | 109 | 119 |

**Figure 13. Heat accumulation to median data of phenological growth phase at 4 locations for Sieglinde potato.**

Heat accumulation is calculated as follows: From planting to emergence-Soil Growing Degree Days at 5 $^{o}$C, from emergence to 2 fully unfolded leaves- Air Growing Degree Days at 5 $^{o}$C at soil surface; remaining taken from the HOBO placed at 75 cm above ground.




| | planting | break | 2 leaves | first flower | yellow leaves | dried leaves |
|---|---|---|---|---|---|---|
| Caledon | 0 | 118.02 | 160.64 | 397.34 | | |
| Gananoque | 0 | 115.39 | 215.05 | 476.34 | 740.15 | 915.19 |
| Tompkins | 0 | 58.24 | 133.94 | 332.70 | 1227.13 | |
| Victoria | 0 | 175.13 | 253.82 | 508.50 | 1028.06 | 1177.24 |

**Yield**

Sieglinde yielded moderately well at all locations. In Gananoque, where overall yields were low when compared with other locations, Sieglinde was second only to Banana in yield.

| Victoria | Caledon | Gananoque | Tompkins |
|---|---|---|---|
| 0.84 | 0.61 | 0.23 | Moderate yield<br>4-12.5 cm long |

**Discussion**

Leaf curl and browning along the edges was reported for Sieglinde everywhere except Victoria. Possible ground level ozone sensitivity was reported in Caledon. The moderate yield of healthy tubers at all locations, including its higher yield at Gananoque under conditions highly unfavourable to potatoes, suggests that Sieglinde may tolerate drought better than other varieties.

## Congo

| | |
|---|---|
|  |  |
| Flowers of Congo | Congo potatoes grown in 2012 for the Crop-Climate Project In Victoria, British Columbia |

### Varietal Notes

| | |
|---|---|
| Maturity: | Late |
| Skin colour: | Blue |
| Flesh colour: | Blue |
| Tuber Shape: | long to oval |
| Origin and Breeding: | Either from United Kingdom or United States. |
| Year registered in Canada: | |
| Agricultural Features: | |
| Yield: | |
| Dormancy: | |
| Storability: | |
| Utilization: | |
| Environmental Stress: | |
| Disease Response | |
| Moderately Resistant: | |
| Moderately susceptible: | |
| Susceptible: | |
| Notes: | Genetic fingerprinting has determined that the following potatoes are likely closely related:<br>British Columbia Blue; McIntosh Black; River John Blue; Sharon's Blue |
| Sources: | http://www.europotato.org/display_description.php?variety_name=Congo<br>http://potatoes.wsu.edu/varieties/blue-purp-vars.htm#C |

## 2012 Results

### Seed Source

Garrett Pittenger of Caledon provided organically grown tubers for Congo potatoes.

### Growth Observations

Congo potatoes were grown in both Victoria and Caledon (Table 13), though they were only grown to maturity in Victoria. There was considerable difference among sites in terms of the time and GDD taken between the phases that were monitored. In Caledon, emergence took 15 days and 158 GDD, whereas in Victoria, it took 30 days and 294 GDD to emerge (Figure 14 and Figure 15). From emergence to 2-leaf horizontal phase, it took 3 days and 35 GDD in Caledon, and 10 days and 89 GDD in Victoria. Days from planting to first flower was 55 and 54 for Caledon and Victoria, during which Caledon accumulated an additional 510 GDD while Victoria accumulated only 127 GDD. This may indicate that flowering in Congo is strongly more influenced by day-length than either growing time or accumulated heat. By the time of harvest at Caledon in mid-August, Congo leaves had yet to yellow or brown, and was likely not finished tuber development. In Victoria, the leaves were dried out by August 31, after 117 days and 1295 GDD.

**Table 13. Growth observations on Congo potato in Victoria and Caledon.**

| Location | Planting date | break | 2 leaves | first flower | yellow leaves | Dried leaves |
|---|---|---|---|---|---|---|
| **Caledon** | 15-May-12 | 28-May-12 | 31-May-12 | 8-Jul-12 | -- | -- |
| **Victoria** | 07-May-12 | 05-Jun-12 | 15-Jun12 | 29-Jun-12 | 8-Aug-12 | 31-Aug-12 |

**Figure 14. Days from planting to median date of phenological growth phase at 4 locations for Congo potato.**

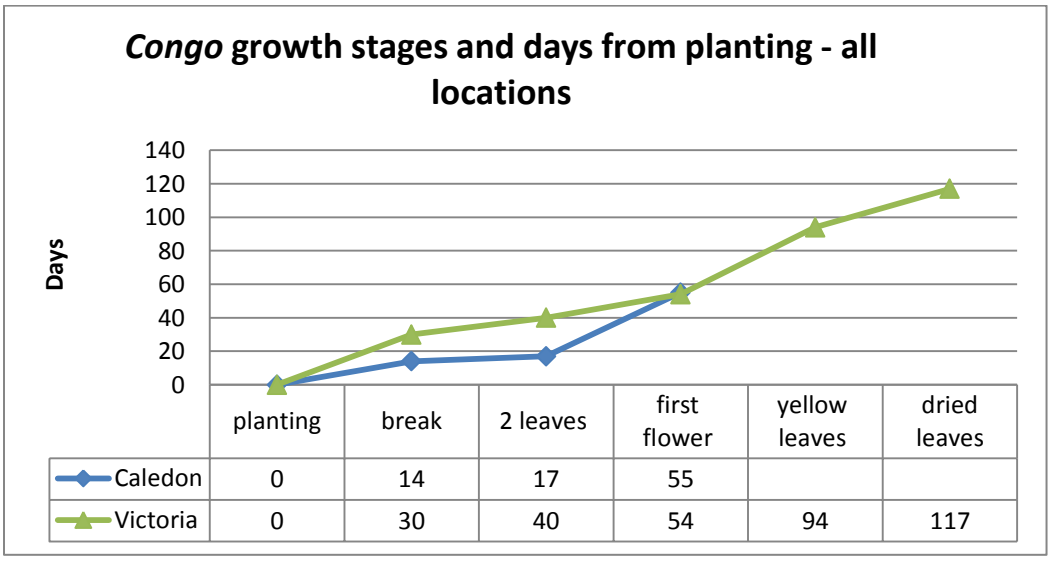
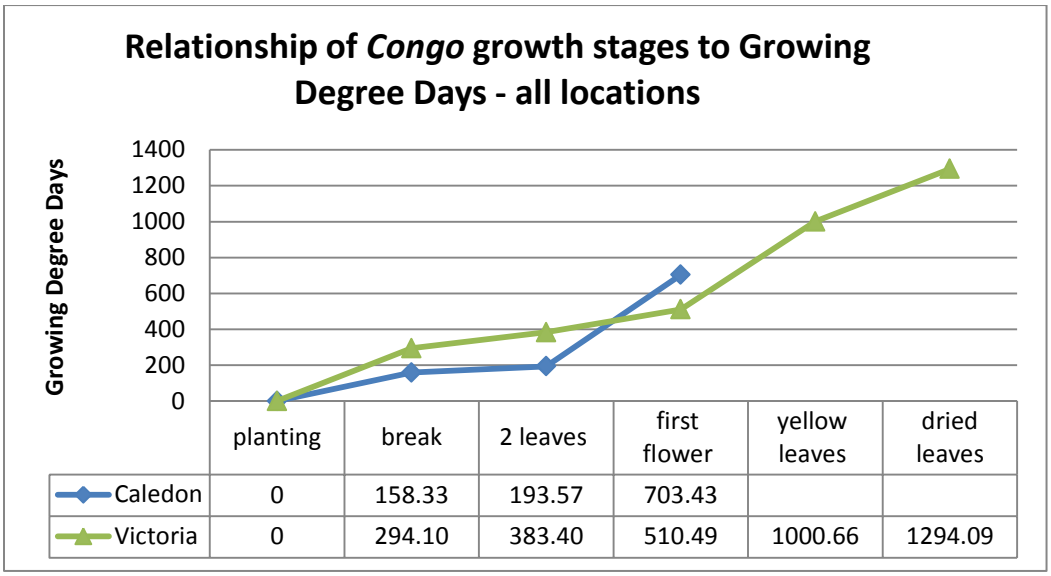


**Figure 15. Heat accumulation to median data of phenological growth phase at 4 locations for Congo potato.**

Heat accumulation is calculated as follows: From planting to emergence-Soil Growing Degree Days at 5 $^{o}$C, from emergence to 2 fully unfolded leaves- Air Growing Degree Days at 5 $^{o}$C at soil surface; remaining taken from the HOBO placed at 75 cm above ground.




## Yield

Congo had average to below average yields at the two growing sites, with .61 kg/plant in Victoria and .53 kg/plant in Caledon. It is likely that yields would have been higher in Caledon had the potatoes been left to grow through to maturity.

## Discussion

Congo is a late heritage variety that is valued for its rich purple colour and waxy flesh. Yield results indicate that it may be a reliable performer under a wide variety of conditions.

## Corne de Mouton


Corne de Mouton potatoes grown in 2012 for the Crop-Climate Project In Victoria, British Columbia

Flowers of Corne de Mouton

### Varietal Notes

| | |
|---|---|
| Maturity: | early to mid-season |
| Skin colour: | white to yellow |
| Flesh colour: | creamy yellow |
| Tuber Shape: | oval to very long. |
| Origin and Breeding: | France (possibly Denmark), as early as 1872. |
| Year registered in Canada: | |
| Agricultural Features: | Firm and waxy flesh. |
| Yield: | low to medium |
| Dormancy: | Medium |
| Storability: | Moderate |
| Utilization: | Excellent in salads, steamed, roasted, boiled. |
| Environmental Stress: | Medium frost resistance. |
| Disease Response | |
| Moderately Resistant: | Scab |
| Moderately susceptible: | PVX, potato leaf roll |
| Susceptible: | late blight, stem canker, wart, PVM, PVS, PVY |
| Notes: | Has many synonyms, including La Ratte and Asparges.<br>Popular Bluff Organics says this:<br>"This French potato is a culinary superstar of European haute cuisine. The taste is described as subtly sweet with a background bite of hazelnuts. It is excellent in salads or steamed and served hot or sautéed and holds its shape in stews. It also works great for roasting and boiling. Made famous as a puree by Chef Joel Robichon where he made use of this potato's exceptional ability to hold liquid. |
| Sources: | http://www.europotato.org/display_description.php?variety_name=Ratte<br>http://poplarblufforganics.com/La-Ratte.php |

## 2012 Results

### Seed Source

Seed potatoes for Corne de Mouton were provided by Garret Pittenger.

### Growth Observations for Corne de Mouton

Two growers (Table 12) grew Corne de Mouton potato in 2012. The planting dates in each location are listed, as are the dates on which half or more of the tubers planted reached the growth phase, as recorded by the grower.

**Table 14. Growth observation dates for Corne de Mouton.**

| Location | Planting date | break | 2 leaves | first flower | yellow leaves | Dried leaves |
|---|---|---|---|---|---|---|
| **Caledon** | 15-May-12 | 28-May-12 | 31-May-12 | 25-Jun-12 | -- | |
| **Victoria** | 07-May-12 | 30-May-12 | 15-Jun-12 | 03-Jul-12 | 27-Aug-12 | 07-Sep-12 |

**Figure 16. Days from planting to median date of phenological growth phase at 4 locations for Corne de Mouton.**

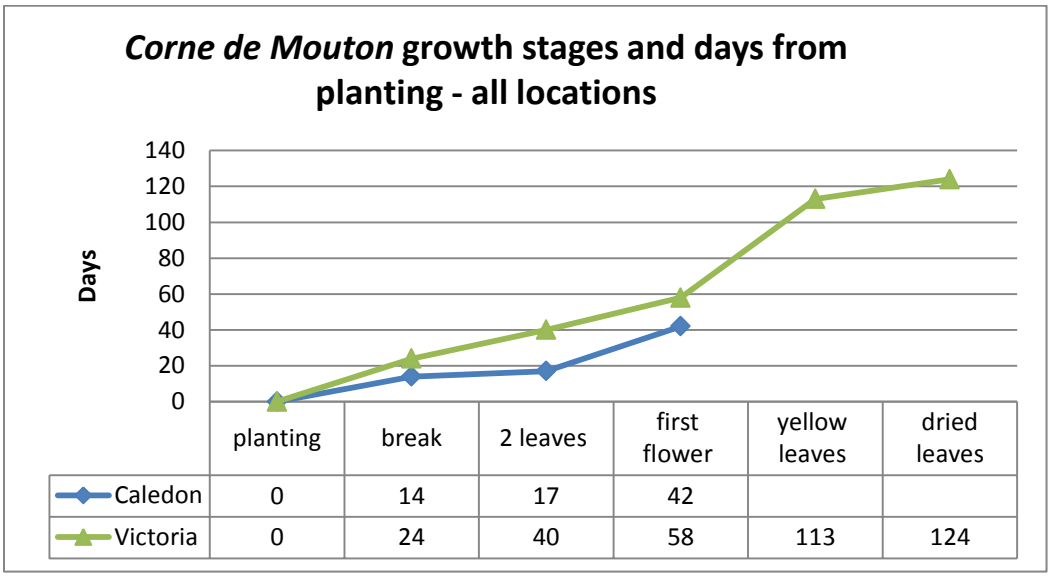
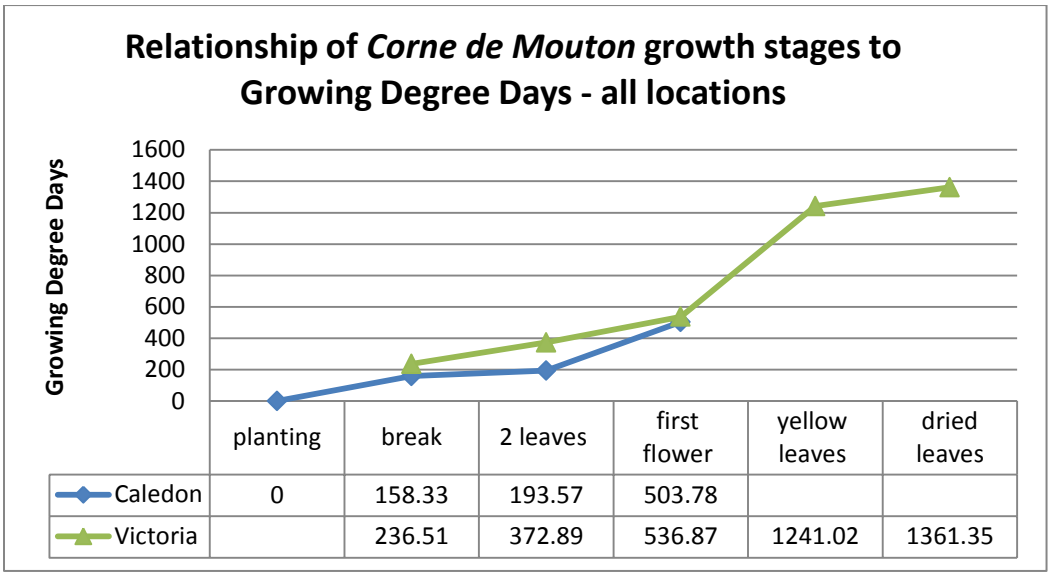


**Figure 17. Heat accumulation to median data of phenological growth phase at 4 locations for Corne de Mouton potato.**

Heat accumulation is calculated as follows: From planting to emergence-Soil Growing Degree Days at 5 $^{o}$C, from emergence to 2 fully unfolded leaves- Air Growing Degree Days at 5 $^{o}$C at soil surface; remaining taken from the HOBO placed at 75 cm above ground.




## Yield

Yield for Corne de Mouton at the two locations where it was grown were high. It was the highest yielder at Caledon (3.04 kg/plant), and second only to Mrs. Moehrle's Yellow at Victoria where it yielded 1.02 kg/plant. In Victoria the tuber size at harvest varied widely. Green mini-tubers were present on the stems above the soil surface.

This variety may be broadly adapted to drought, heat and humidity.

## Disease Observations

No pest or diseases were observed for this variety.

## Discussion

Corne de Mouton appears to be a very promising variety for a diversity of Canadian climates.

## Mrs. Moehrle's Yellow


*Mrs. Moehrle's Yellow* potatoes grown in 2012 for the Crop-Climate Project in Victoria, British Columbia

### Varietal Notes

| | |
|---|---|
| Maturity: | Mid-season |
| Skin colour: | Tan |
| Flesh colour: | Yellow |
| Tuber Shape: | Round |
| Origin and Breeding: | |
| Year registered in Canada: | |
| Agricultural Features: | |
| Yield: | |
| Dormancy: | |
| Storability: | |
| Utilization: | |
| Environmental Stress: | |
| Disease Response | |
| Moderately Resistant: | |
| Moderately susceptible: | |
| Susceptible: | |
| Notes: | G. Pittenger donated accession (CN105495) to Agriculture and Agri-Food Canada in 1999. |
| Sources: | http://pgrc3.agr.ca/cgi-bin/npgs/html/acchtml.pl?126655 |

## 2012 Results

### Seed Source

Garrett Pittenger of Caledon provided organically grown tubers for Mrs. Moehrle's potatoes.

### Growth Observations for Mrs. Moehrle's Yellow

Two growers (Table 15) grew Mrs. Moehrle's Yellow in 2012. The planting dates in each location are listed, as are the dates on which half or more of the tubers planted reached the growth phase, as recorded by the grower.

**Table 15. Growth observation dates of Mrs. Moehrle's Yellow Potato.**

| Location | Planting date | break | 2 leaves | first flower | yellow leaves | Dried leaves |
|---|---|---|---|---|---|---|
| **Caledon** | 15-May-12 | 28-May-12 | 31-May-12 | 03-Jul-12 | -- | |
| **Victoria** | 07-May-12 | 31-May-12 | 09-Jun-12 | 02-Jul-12 | 03-Aug-12 | 23-Aug-12 |

**Figure 18. Days from planting to median date of phenological growth phase at 4 locations for Mrs. Moehrle's Yellow.**

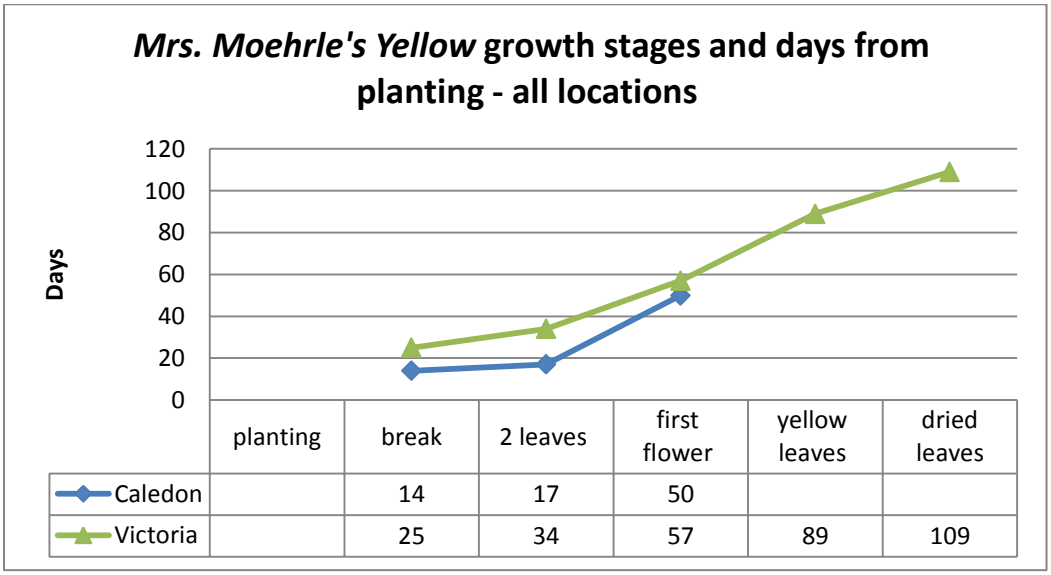
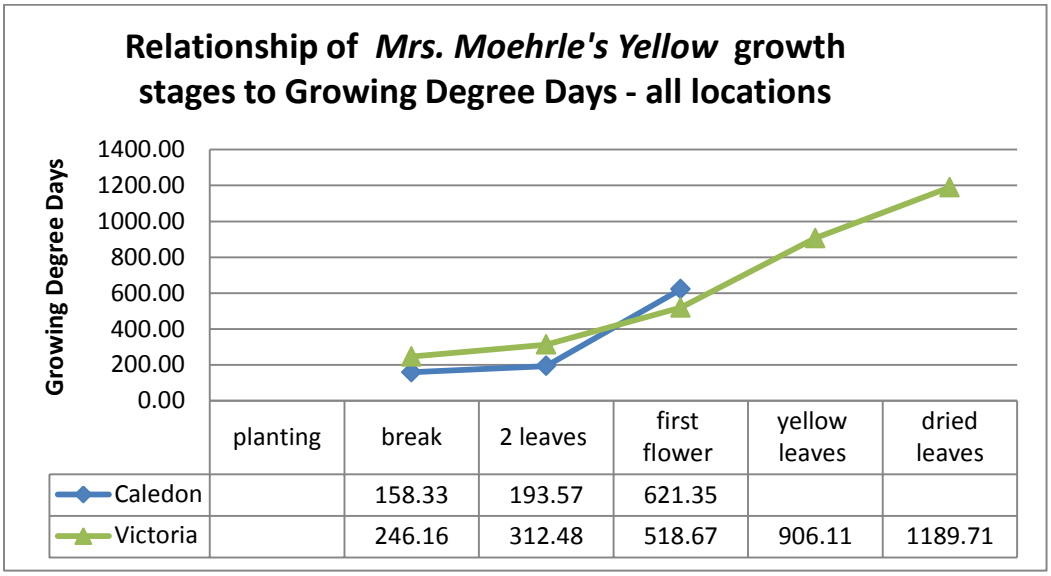


**Figure 19. Heat accumulation to median data of phenological growth phase at 4 locations for Mrs. Moehrle's Yellow potato.**

Heat accumulation is calculated as follows: From planting to emergence-Soil Growing Degree Days at 5 $^{o}$C, from emergence to 2 fully unfolded leaves- Air Growing Degree Days at 5 $^{o}$C at soil surface; remaining taken from the HOBO placed at 75 cm above ground.




| | planting | break | 2 leaves | first flower | yellow leaves | dried leaves |
|---|---|---|---|---|---|---|
| Caledon | | 158.33 | 193.57 | 621.35 | | |
| Victoria | | 246.16 | 312.48 | 518.67 | 906.11 | 1189.71 |

**Yield**

In Victoria, Mrs. Moehrle's Yellow produced the highest yield of all varieties planted there – 1.26 kg/plant. In Caledon, on the other hand, it was one of the lowest yielding potatoes (.47 kg/plant). The Victoria grower noted that the tubers at harvest were remarkably clean.

**Disease Observations**

Blight was observed on two late emerging plants on the lowest leaves, which were removed at Caledon. In Victoria two of seven planted tubers produced plants with weak growth and brown leaves and were removed and destroyed.

## Ozette


Ozette potatoes grown in 2012 for the Crop-Climate Project In Victoria, British Columbia

Ozette rarely flowers. Buds like these often abort before opening.

### Varietal Notes

| | |
|---|---|
| Maturity: | Late |
| Skin colour: | pale gold |
| Flesh colour: | creamy yellow |
| Tuber Shape: | Fingerling |
| Origin and Breeding: | According to Slow Food USA, Spanish explorers brought Ozette from Peru to the Makah Nation in Washington in the late 1700s. These tubers originate from material brought to Victoria from the Makah Reserve in the late 1980's and grown and shared locally by Richard Hebda. |
| Year registered in Canada: | |
| Agricultural Features: | |
| Yield: | |
| Dormancy: | |
| Storability: | |
| Utilization: | |
| Environmental Stress: | |
| Disease Response | |
| Moderately Resistant: | |
| Moderately susceptible: | |
| Susceptible: | |
| Notes: | Slow Food USA says this:<br>The potato has an earthy and nutty flavor that is similar to the taste sensed in cooked dry beans. The flesh is firm and the texture is very creamy. The Ozette is generally served steamed, fried, or roasted. |
| Sources: | http://www.slowfoodusa.org/index.php/programs/ark_product_detail/ozette_potato1 |

## 2012 Results

### Seed Source

Richard Hebda provided organically produced tubers to all growers for Ozette

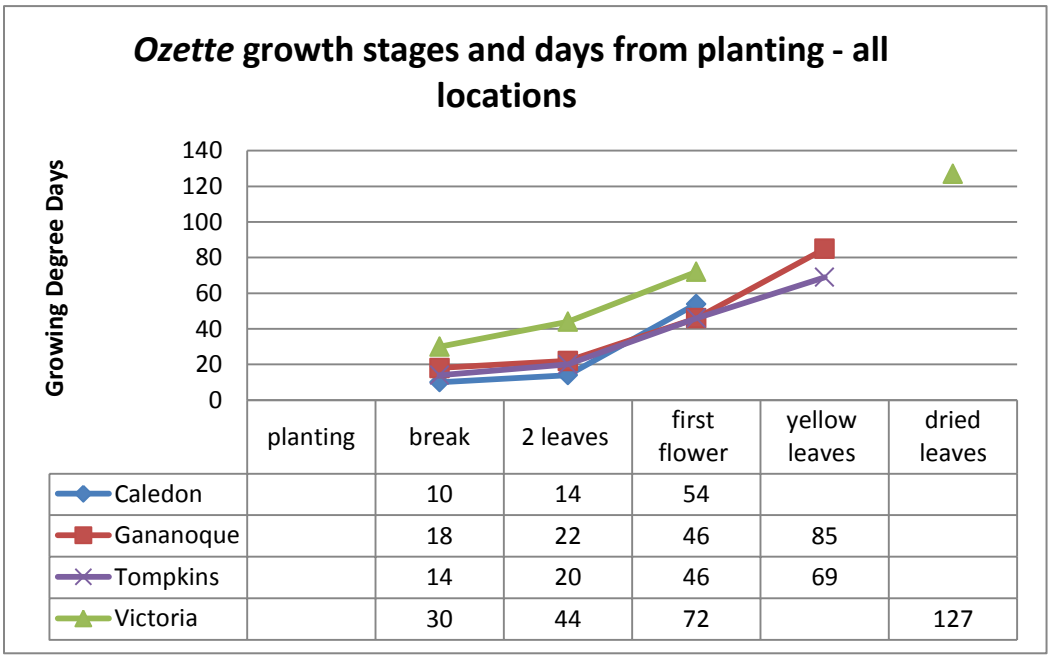
### Growth Observations for Ozette

Four growers (Table 16) grew Ozette in 2012. The planting dates in each location are listed, as are the dates on which half or more of the tubers planted reached each growth phase, as recorded by the grower. In Victoria, from planting on April 22 to leaf emergence took 30 days (Figure 20), during which the soil accumulated 240 GDD (Figure 21); by contrast, Ozette potatoes in Caledon emerged after only 10 days and 104 GDD. Caledon and Victoria growers did not report yellowing leaves during the observation period, while Gananoque and Tompkins growers did. Only in Victoria did the leaves actually dry out; this may be attributed to the other sites ending observations in mid-August.

**Table 16. Growth and development observations for Ozette.**

| Location | Planting date | break | 2 leaves | first flower | yellow leaves | Dried leaves |
|---|---|---|---|---|---|---|
| **Caledon** | 15-May-12 | 24-May-12 | 28-May-12 | 07-Jul-12 | -- | |
| **Gananoque** | 11-May-12 | 28-May-12 | 01-Jun-12 | 25-Jun-12 | 03-Aug-12 | |
| **Victoria** | 22-Apr-12 | 21-May-12 | 04-Jun-12 | 02-Jul-12 | -- | 26-Aug-12 |
| **Tompkins** | 11-May-12 | 24-May-12 | 30-May-12 | 25-Jun-12 | 18-Jul-12 | |

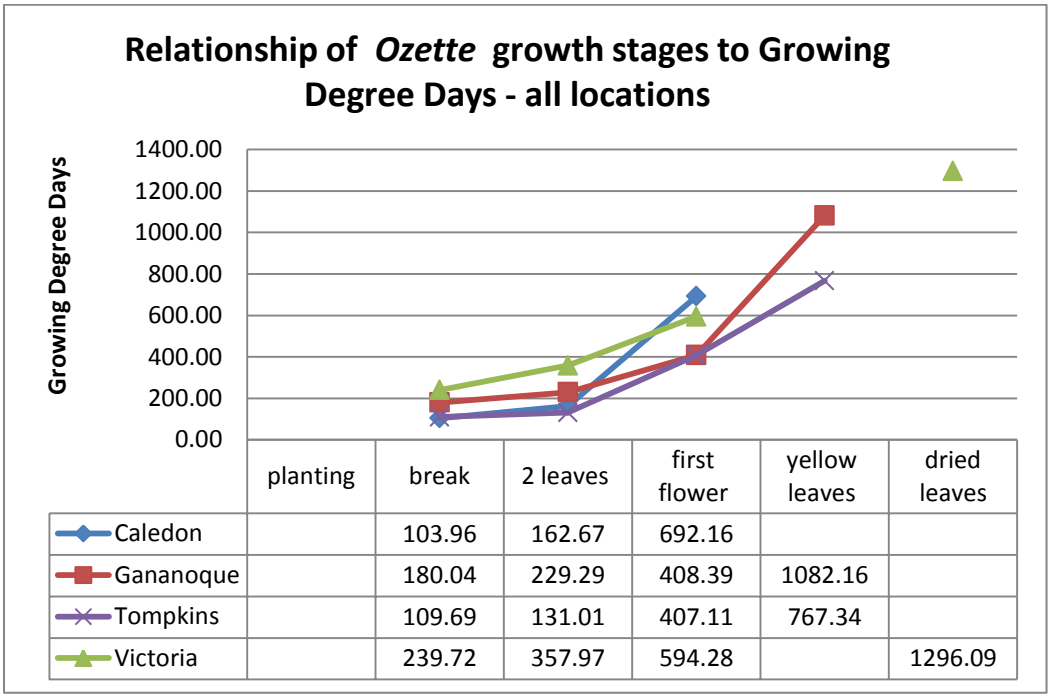
**Figure 20. Days from planting to median date of phenological growth phase at 4 locations for Ozette potato.**




| | planting | break | 2 leaves | first flower | yellow leaves | dried leaves |
|---|---|---|---|---|---|---|
| Caledon | | 10 | 14 | 54 | | |
| Gananoque | | 18 | 22 | 46 | 85 | |
| Tompkins | | 14 | 20 | 46 | 69 | |
| Victoria | | 30 | 44 | 72 | | 127 |

**Figure 21. Heat accumulation to median data of phenological growth phase at 4 locations for Ozette potato.**

Heat accumulation is calculated as follows: From planting to emergence-Soil Growing Degree Days at 5 $^{o}$C, from emergence to 2 fully unfolded leaves- Air Growing Degree Days at 5 $^{o}$C at soil surface; remaining taken from the HOBO placed at 75 cm above ground.




| | planting | break | 2 leaves | first flower | yellow leaves | dried leaves |
|---|---|---|---|---|---|---|
| Caledon | | 103.96 | 162.67 | 692.16 | | |
| Gananoque | | 180.04 | 229.29 | 408.39 | 1082.16 | |
| Tompkins | | 109.69 | 131.01 | 407.11 | 767.34 | |
| Victoria | | 239.72 | 357.97 | 594.28 | | 1296.09 |

**Grower Observations**

Ozette (also locally known as Nootka in Victoria) grows year long and rarely dries until hit by a heavy frost. With regular watering tubers plants grow to at least 1.5 metres long and start behaving like vines. Tubers appear to be set continually resulting in many tens of tubers of mixed size per plant.

**Yield**

Only the Victoria grower reported yield for Ozette, where it was one of the highest yielding potatoes at .9 kg per plant. The quality of the tubers was excellent.

**Pest Observations**

Ozette had small holes in the leaves at Gananoque in its early growth stages. Later on, potato beetles were found on several plants. Leaf edge browning was reported by both Gananoque and Victoria later in the season. No further details are provided as to whether it was part of the natural drying process or some type of disease.

**Discussion**

To determine the suitability of this unique variety in different regions, Ozette needs further testing in a variety of climates, including yield measurements.

## Pugh's Purple


*Pugh's Purple* potatoes grown in 2012 for the Crop-Climate Project in Victoria, British Columbia

### Varietal Notes

| | |
|---|---|
| Maturity: | |
| Skin colour: | light purple |
| Flesh colour: | Purple |
| Tuber Shape: | long oval |
| Origin and Breeding: | Nova Scotia, Canada; named after Elizabeth Pugh. |
| Year registered in Canada: | |
| Agricultural Features: | |
| Yield: | |
| Dormancy: | |
| Storability: | |
| Environmental Stress: | |
| Disease Response | |
| Moderately Resistant: | |
| Moderately susceptible: | |
| Susceptible: | |
| Notes: | Garrett Pittenger is the source of the seed potatoes used in the CCP, and has been maintaining this variety for many years:<br>"This is one of three maritime Canadian 'blues' in my collection. The other two are Angelina Mahoney's Blue and Pugh's Purple. They are all 'Blue Nose' types: long oval shape, light purple skin with a much darker blue 'nose' on the tuber. Flesh is white with blue streaks around the eyes when peeled. I am told that the Nova Scotians were called 'Blue Noses' because of this potato that was a big part of their diet. " (Potato Gene Resources Newsletter, 2001). |
| Sources: | http://publications.gc.ca/collections/Collection/A47-8-8-2001E.pdf<br>http://potatoes.wsu.edu/varieties/blue-purp-vars.htm |

## 2012 Results

### Seed Source

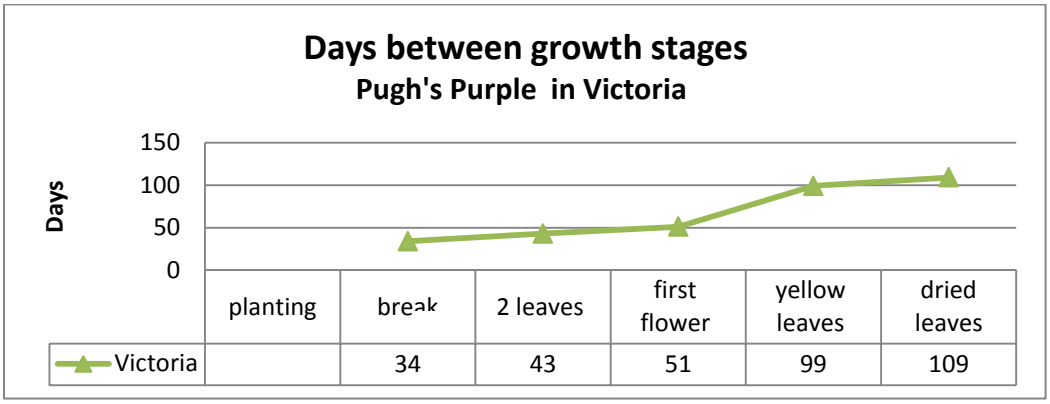
Garrett Pittenger grew the seed potato for this project.

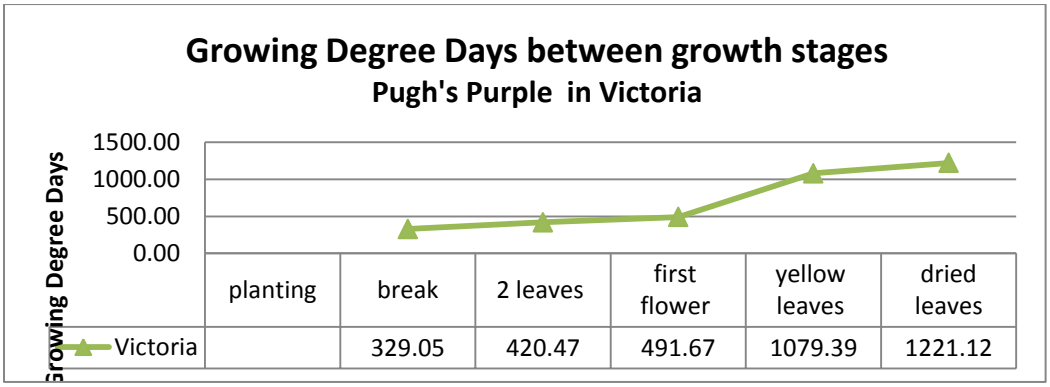
### Growth Observations for *Pugh's Purple*

Pugh's Purple was grown for observation only at Victoria in 2012, though yield was measured both at Victoria and Caledon (see Figures 22).

| Location | Planting date | break | 2 leaves | first flower | yellow leaves | Dried leaves |
|---|---|---|---|---|---|---|
| **Victoria** | 07-May-12 | 09-Jun-12 | 18-Jun-12 | 26-Jun-12 | 13-Aug-12 | 23-Aug-12 |

**Figure 22. Days and GDD between Growth Stages for Pugh's Purple Potato in Victoria.**




### Yield

Pugh's Purple yielded poorly in both Victoria and Caledon, with .25 and .53 kg/plant respectively.

**Disease Observations**

Plants in Victoria showed brown edges on the leaves early in growth and only 5 of 7 survived to harvest stage.

## Siberian


Siberian potatoes grown in 2012 for the Crop-Climate Project In Victoria, British Columbia

Siberian flower and buds.

### Varietal Notes

| | |
|---|---|
| Maturity: | Very late |
| Skin colour: | white |
| Flesh colour: | Red |
| Tuber Shape: | Round to oval |
| Origin and Breeding: | |
| Year registered in Canada: | |
| Agricultural Features: | |
| Yield: | |
| Dormancy: | |
| Storability: | |
| Utilization: | |
| Environmental Stress: | |
| Disease Response | |
| Moderately Resistant: | |
| Moderately susceptible: | |
| Susceptible: | |
| Notes: | Garret Pittenger donated this cultivar to the Plant Gene Resources of Canada facility in 1998. Accession number: CN 105529 |
| Sources: | http://pgrc3.agr.ca/cgi-bin/npgs/html/acchtml.pl?126691<br>http://potatoes.wsu.edu/varieties/blue-purp-vars.htm |

## 2012 Results

### Seed Source

Garrett Pittenger of Caledon provided organically grown tubers for Siberian potatoes.

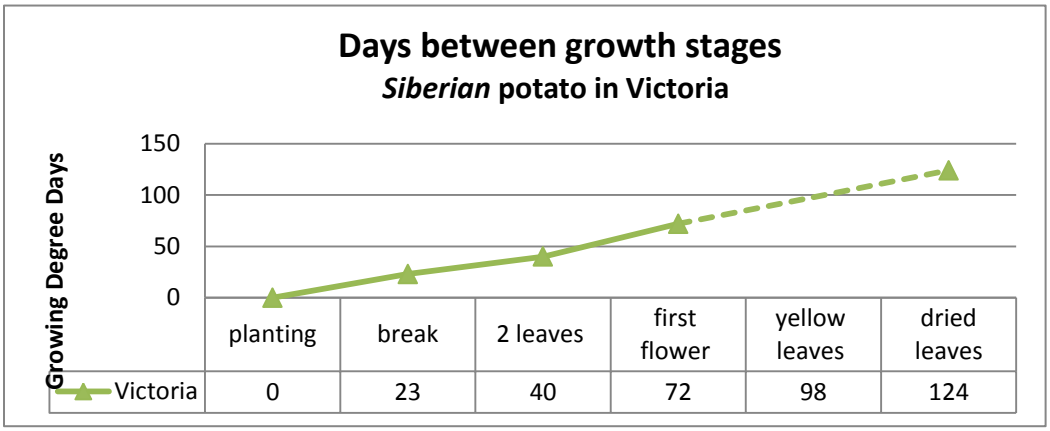
### Growth Observations for Siberian

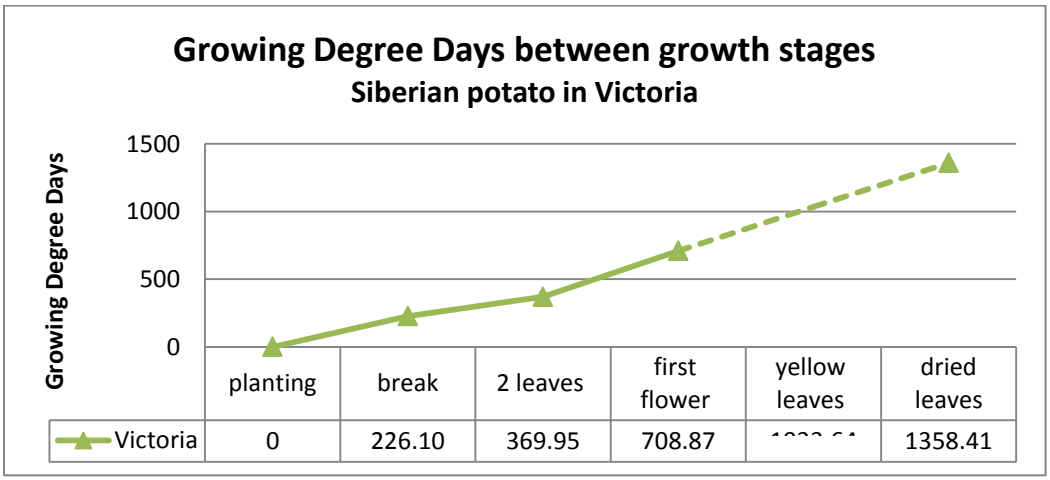
Siberian potatoes were grown in Victoria and Caledon in 2012. Growth observations for Caledon are incomplete but by July 19th the plants were 1.15 m long and trailing on the ground. By this time they had begun to flower.

**Table 17. Observation date for growth phases in Victoria.**

| Location | Planting date | break | 2 leaves | first flower | yellow leaves | Dried leaves |
|---|---|---|---|---|---|---|
| **Victoria** | 07-May-12 | 29-May-12 | 15-Jun-12 | 17-Jul-12 | | 07-Sep-12 |

**Figure 23. Days and GDD between Growth Stages for Siberian Potato in Victoria.**



**Yield**

Siberian yielded well at Caledon (1.25 kg/plant), and relatively poorly in Victoria (.51 kg/plant). The tubers in Victoria were varied in size, with many small tubers and a few large ones.

**Disease Observations**

Some leaf curl was observed in Victoria on July 17, but it was noted that the plants were otherwise very healthy looking.

**Discussion**

Growers at both locations noted that flowers were late to form. In Victoria, they required the most GDD to reach the dried leaf stage, confirming that they are a late potato. Siberian may be better adapted than others to the stressful climatic conditions prevalent in 2012 in Caledon, where it yielded well in spite of heat stress.

## Slovenian Crescent


Slovenian Crescent potatoes grown in 2012 for the Crop-Climate Project in Victoria, British Columbia

### Varietal Notes

| | |
|---|---|
| Maturity: | Early |
| Skin colour: | Pale yellow to white |
| Flesh colour: | Pale yellow brown to pale brown |
| Tuber Shape: | Crescent-shaped fingerling |
| Origin and Breeding: | |
| Year registered in Canada: | |
| Agricultural Features: | |
| Yield: | |
| Dormancy: | |
| Storability: | |
| Utilization: | |
| Environmental Stress: | |
| Disease Response | |
| Moderately Resistant: | |
| Moderately susceptible: | |
| Susceptible: | |
| Notes: | Mad Dog Farm grows seed potato near Nelson, BC: They describe Slovenian Crescent as<br>"A very nice crescent shaped fingerling that through nine years of selection is now our earliest potato. In 2010 we harvested our first plants in July from a mid-April planting. Very prolific."<br>http://www.maddogfarm.ca/ |
| Sources: | publications.gc.ca/collections/Collection/A47-8-13-2006E.pdf |

## 2012 Results

### Seed Source

Garrett Pittenger of Caledon provided the seeds for Slovenian Crescent.

### Growth Observations for Slovenian Crescent

Two growers (Table 18) grew Slovenian Crescent in 2012. The planting dates in each location are listed, as are the dates on which half or more of the tubers planted reached the growth phase, as recorded by the grower. Tubers were harvested before the yellow leaf stage at Caledon.

**Table 18. Observation dates for growth phases of Slovenian Crescent in Caledon and Victoria.**

| Location | Planting date | break | 2 leaves | first flower | yellow leaves | Dried leaves |
|---|---|---|---|---|---|---|
| **Caledon** | 15-May-12 | 01-Jun-12 | 05-Jun-12 | 03-Jul-12 | -- | |
| **Victoria** | 07-May-12 | 06-Jun-12 | 23-Jun-12 | 13-Jul-12 | 30-Jul-12 | 18-Aug-12 |

**Figure 24. Days from planting to median date of growth phase for Slovenian Crescent.**

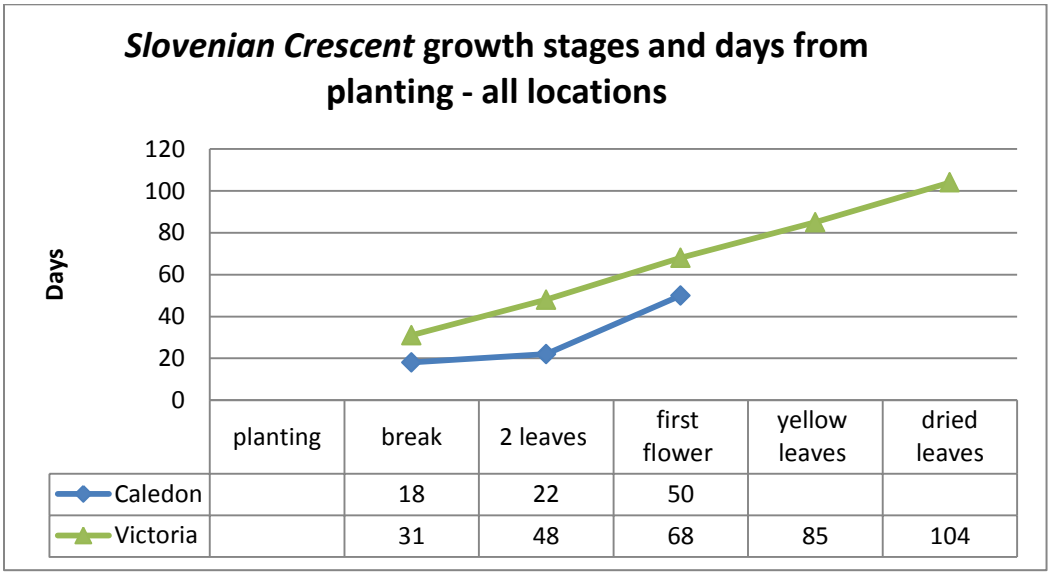
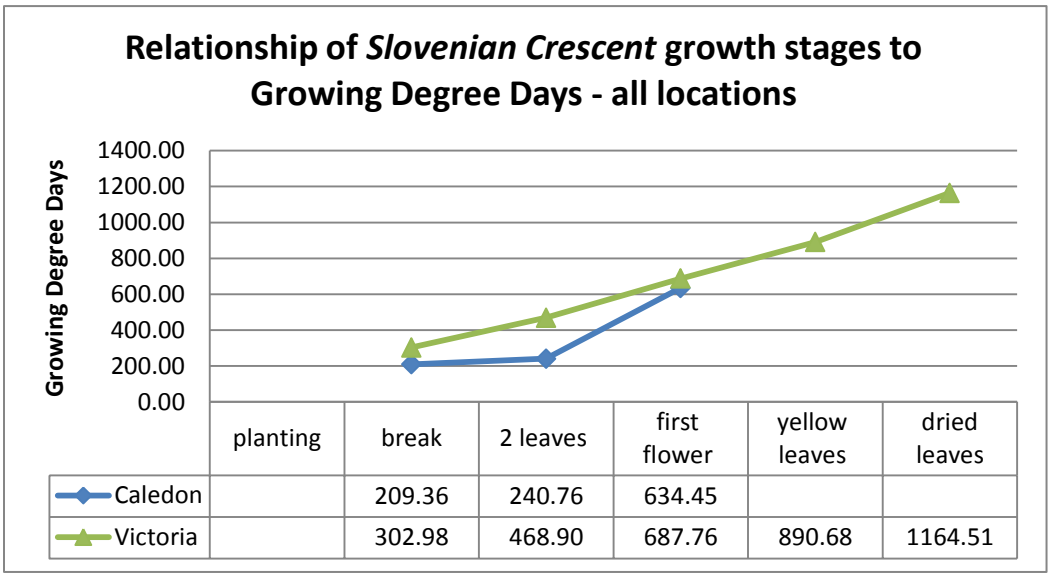


**Figure 25. Relationship of Slovenian Crescent growth stages to Growing Degree Days - Caledon and Victoria.**




| | planting | break | 2 leaves | first flower | yellow leaves | dried leaves |
|---|---|---|---|---|---|---|
| Caledon | | 209.36 | 240.76 | 634.45 | | |
| Victoria | | 302.98 | 468.90 | 687.76 | 890.68 | 1164.51 |

**Yield**

Slovenian Crescent was one of the two lowest yielding varieties grown at Victoria where many small tubers were produced. Its performance in Caledon, where it was also grown, is unknown.

**Disease Observations**

Leaf curl virus was noted on plants in Caledon on July 3. Flower buds which had begun to show on July 3rd had all aborted by July 19th.

# Appendix 2: Heritage Wheat Results by Variety

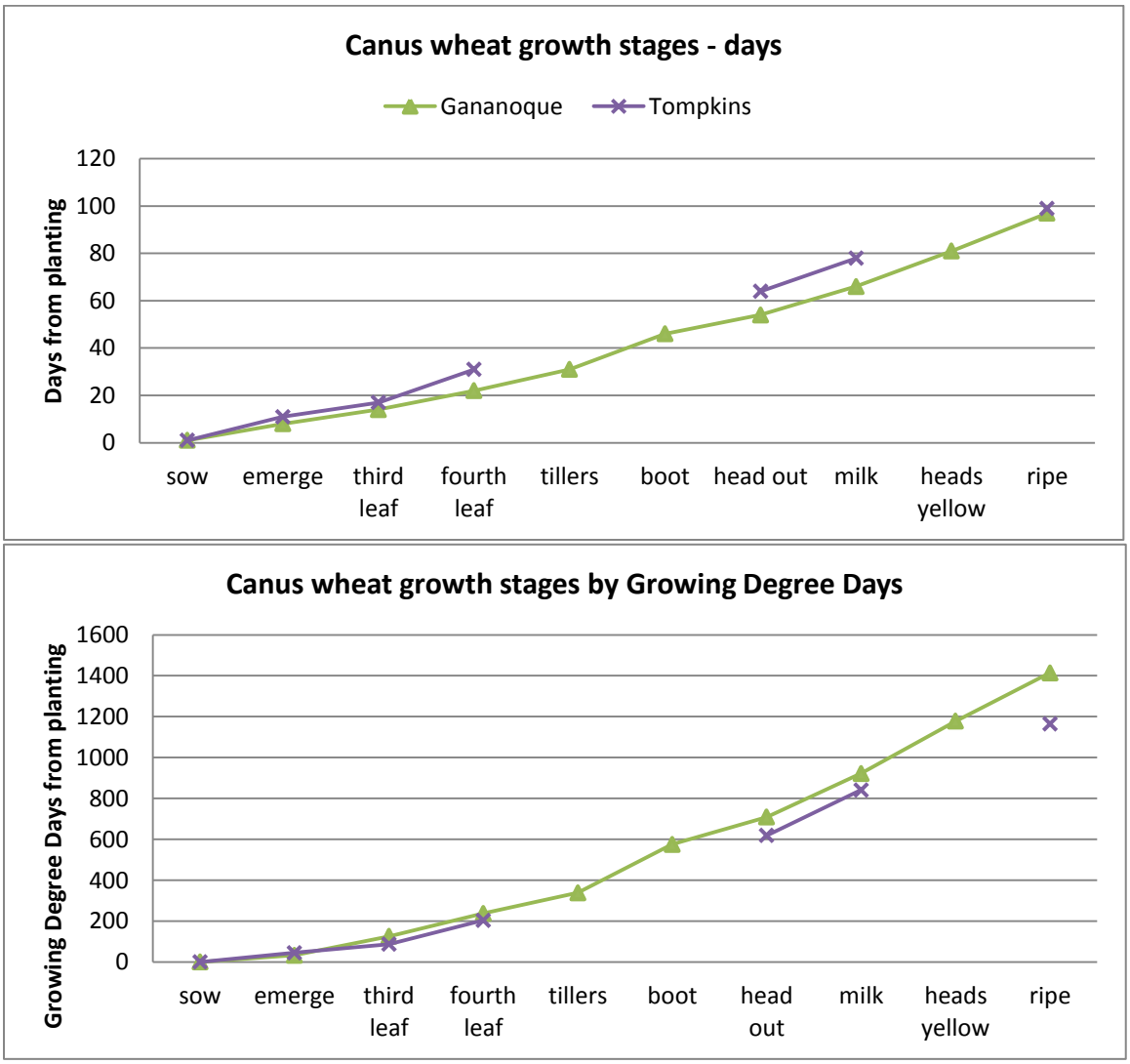
## Canus

Canus was developed at the University of Alberta in 1935. It is a cross between Marquis and Kanred, a Kansas bred variety of Turkish origin. It is resistant to root rot and smut.

### 2012 Results

Canus grew and developed at similar rates at both Gananoque and Tompkins (Figure 26), both of which experienced high temperatures, drought and climatic moisture deficits. Wheat ripened in 99 days in Tompkins and 97 days in Gananoque. Gananoque was warmer and accumulated 250 more Growing Degree Days during this period (1414 GDD for Gananoque and 1165 for Tompkins).

**Figure 26. Canus wheat growth stages by days and Growing Degree Days from planting.**



The Gananoque grower reported rust, blight on the heads and weed pressure. Tompkins grower reported that the extreme heat and moisture pushed the plants to mature earlier than normal. No yield results are available for these crops.

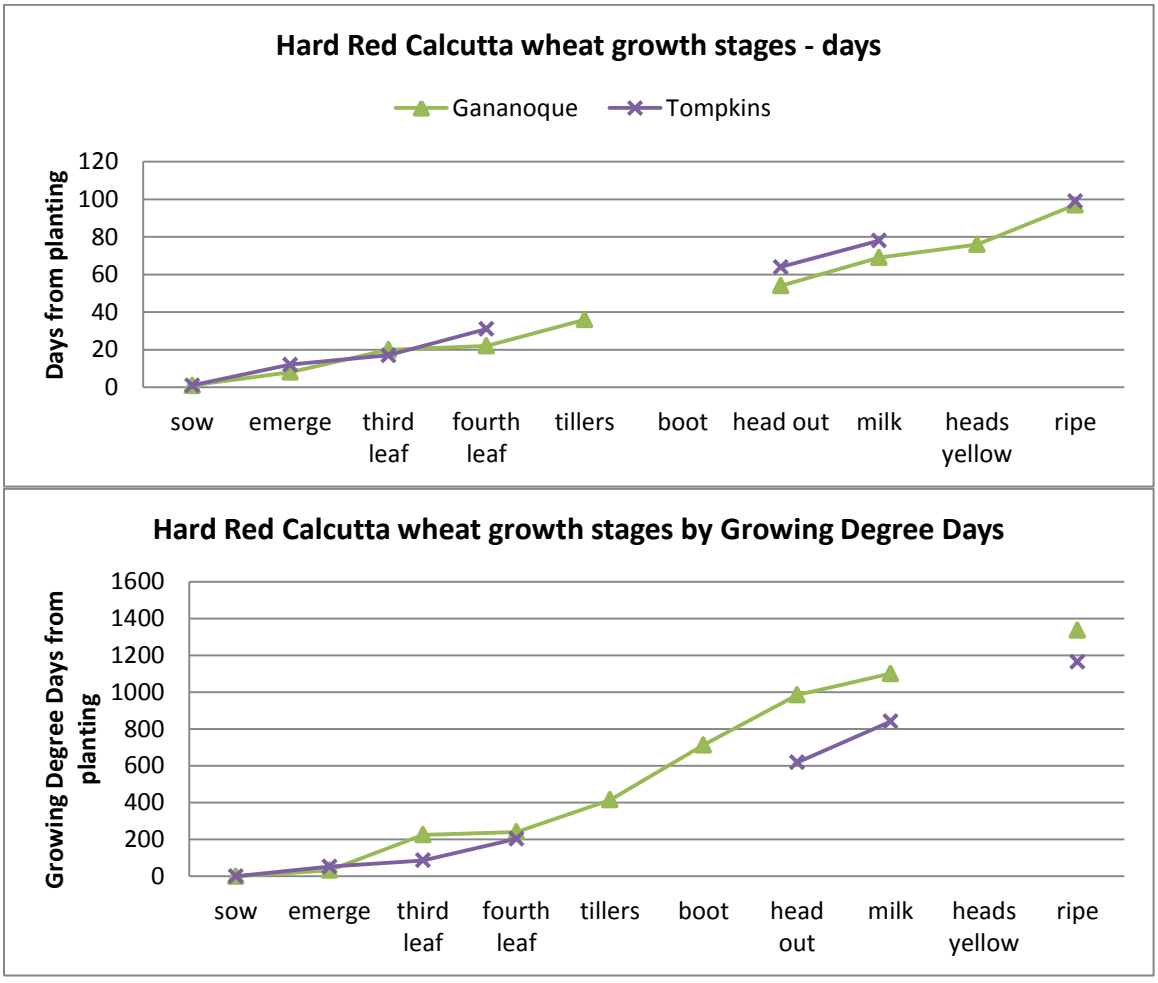
## Hard Red Calcutta

Hard Red Calcutta is an early spring wheat from India, grown in Canada since at least 1890 (Rempel n.d.).

### 2012 Results

Hard Red Calcutta grew and developed at similar rates at both Gananoque and Tompkins (Figure 27), taking 97 days in Tompkins and 99 days in Gananoque. The Tompkins grower observed that heat and drought were pushing the plants to mature rapidly after the milk stage. In Tompkins, development from milk stage to ripe took 21 days, during which 324 GDD accumulated. In contrast, the 28 days it took for Hard Red Calcutta to ripen in Gananoque accumulated only 236 GDD.

**Figure 27. Hard Red Calcutta wheat growth stages by days and Growing Degree Days from planting.**



Hard Red Calcutta was relatively disease-free in the 2012 plantings. Gananoque grower noted 2% flag leaf curl virus by late June, and the Tompkins grower noted that the plants were browning off at the root base (likely due to heat and drought stress) by July 22, at which point they were 1.175 m (46")tall.

## Marquis

### Varietal Notes

Marquis is one of the wheats bred by Agriculture Canada and developed in Agassiz, BC, released in 1910. It is a cross between Red Fife and Hard Red Calcutta, with shorter stems and earlier ripening. The early ripening makes it ideally adapted climates in the northern Prairie provinces (Symko 1999).

### 2012 Results

Marquis progressed through growth stages at about the same rate in Tompkins and Gananoque (Figure 28). Although reported to ripen faster than the other varieties tested here, it took the same number of days from planting to maturity in both Tompkins and Gananoque. In Tompkins, growth was slower up until the milk stage, at which point it fills and ripens more rapidly. Marquis had the same browning at the root base and rapid maturity reported by the Tompkins grower.

**Figure 28. Marquis wheat growth stages by days and Growing Degree Days from planting.**