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Development of a Ripening Index for Commercial Wild Blueberry Fields

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Executive Summary

Commercial wild blueberry (*Vaccinium angustifolium* Ait.) fields exhibit considerable genetic diversity, due to the random development of naturally occurring clones. Most aspects of blueberry production are impacted by the variability, including flowering and fruit development. Further variations in fruit development and ripening are influenced by the location of fruit on stems and within flower clusters, as well as local field conditions, especially weather. Fruit within individual fields ripen somewhat unevenly, therefore, even though every berry follows a similar pattern of development from bloom to ripening.

Wild blueberry fields are harvested only once per production cycle, in spite of the uneven ripening, and are currently judged to be ready for harvest using a "best guess" estimate. The objective of this study was to determine if a more precise "ripening index" for wild blueberry fields could be developed using weather data, specifically growing degree days (a measure of temperature). We also assessed changes in the chemistry of the ripe fruit harvested during the two weeks prior to harvest, to determine if differences exist.

Temperature data loggers were set up in 10 commercial fields on May 1 of 2007 and 2008. Starting at approximately two weeks prior to the historical harvest dates, fruit samples (four samples per field) were obtained from each field on three separate dates up to harvest. Each sample was separated into green, partially ripe (red), ripe and over ripe fruit, to determine percents (by weight). Ripe fruit was analyzed for total solids, pH, total acidity, and total anthocyanins and phenolics. Temperature data were used to calculate growing degree days (GDD), which were, in turn, used to develop ripening models. We were forced to develop models from a previous study since the data from the three sample dates per field was not sufficient to allow development of models directly from this study. We also obtained weather data from three Environment Canada weather stations with which we developed ripening models over a three year period.

Ripe fruit from both years of the study were analyzed for pH and total solid content (SSC or Brix) using simple lab tests. There was very little variation in fruit pH or SSC content over the two years of the study, suggesting that the ripe fruit has similar properties throughout the season. The more complex tests for total acidity, and total anthocyanins and phenolics were completed only on the 2008 samples. There were no differences in levels of total acidity among all the fields, differences in levels of anthocyanins in two of the 10 fields sampled, and differences in phenolics in one field only.

R^2 values for the models we developed were consistently higher from Environment Canada weather data than from the on-site weather stations; thus, three-year models were developed for five fields using Environment Canada weather station data. The models indicate that most fields are ready to harvest after an accumulation of 1000 to 1100 growing degree days (base, 5° C),

calculated from May 1. The models also predict harvestable fields at 400 to 500 growing degree days from the first observation of ripe fruit in the fields. Once each field reaches the harvestable state, the harvest should occur somewhere within a two week period. After two weeks, an increase in over ripe fruit will reduce the % of ripe fruit in the harvest.

Based on the results of this study, we conclude that producers can predict the optimum harvest period for individual fields by using growing degree information provided by the nearest Environment Canada weather station. This will require some knowledge of the location of individual fields in relation to the established Environment Canada weather stations, as well as possible differences in climatic zones.

Title: Development of a Ripening Index for Commercial Wild Blueberry Fields

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Introduction and Background.

Commercial blueberry fields developed from abandoned farmlands which were gradually populated by blueberry clones, or from woodlands with blueberries within the under story component (Hall et al 1979; Eaton 1988). Seedlings developed from fruit transported by animals and birds become large clones of genetically similar stems that grow up from underground rhizomes. The crop is unique because of its distinctive genetic diversity (Heplar and Yarborough 1991; Kalt et al 2001) and the development of commercial fields from native stands of plants rather than from cultivars planted by producers (Kinsman 1993). The blueberry remains the dominant plant in commercial fields through regular pruning and application of selective herbicides, with maximum yields in the second growing season after pruning (Hall et al 1979; Kinsman 1993).

At the present time, commercial blueberry fields are routinely harvested when producers guess that a sufficient percentage of the fruit are ripe and are of good quality for the processor. The only methods available to estimate harvest readiness are estimates based on field observation and estimating the percentage of ripe berries. These methods are quite subjective and therefore somewhat unreliable.

It is well known that individual wild blueberry fruit follow a precise developmental and ripening process, from pollination through to full fruit ripeness in August. During pollination, pollen grains reach the placenta and fertilize the egg, thus stimulating the ovary wall of the berry to begin rapid growth and expansion.(Bell and Burchell 1955; Eck 1988). The result is a "set' berry, which is small, green and hard. The set berry then enters a phase of relative inactivity for a period of several weeks, during which it increases very little in size and remains green and hard (Ismail and Kender 1974). At the end of the inactive period the berry enters the second growth phase, marked by rapid cell expansion, and, over a period of two to four days, colour changes from green through pink and red, and finally to a blue, or ripe berry (Young 1952; Kalt et al 1995). The ripe (blue) berry is considerably larger than it was in the green phase, and is also somewhat softer. Chemical changes that occur during fruit ripening include decreases in acidity, and increases in sugars, total solids, phenolics and anthocyanins (Kalt et al. 1995, 2001). At the end of this process, the mature berry is ripe and ready for harvest. If the berry is not harvested immediately upon completion of ripening, it enters the senescence phase; ripe blueberries remaining on the stem can retain their desirable qualities for some time (several days to several weeks) before becoming soft or dropping off the plant (Kinsman 1993).

Although each individual berry follows the developmental and ripening process described above, berries within clusters, among individual stems, in separate clones and within different fields do not ripen uniformly; rather these processes vary considerably among populations of berries within stems, clones and fields. A number of factors, including pollination effectiveness (Barker et al 1963), cluster and stem location, genetic differences among clones, and variations in micro-climates contribute to the variation. In general, blossoms which receive more pollen produce larger fruit than do those receiving low numbers of pollen; larger berries also develop more rapidly and ripen earlier than do smaller berries (Ismail and Kender 1974). There also appear to be differences among fruit at different positions on the stem, with those at the top of clusters and stems maturing more rapidly than do those further down the stem. Similarly, blossoms within a bud develop at different rates; thus those that bloom first are often pollinated and begin development sooner than do those in the cluster that bloom later and develop more slowly (Ismail and Kender 1974).

Consequently, the fruit within fields will develop and ripen in a non-uniform manner. Since wild blueberry fields must be harvested once only for economic purposes, and because blueberries remain on the stem for some time after ripening (Kinsman 1993), producers wait until their fields have sufficient ripe fruit (usually estimated at greater than 80%) before harvesting. Even when fields appear to be fully ripe, however, there are always unripe berries present. Whenever harvest occurs, green, partially ripe and over ripe fruit are harvested among the ripe fruit and must be removed.

Light and temperature are two important environmental factors that influence plant development throughout the growing season. Temperature is such an important factor that for many agricultural crops the development to maturity is estimated through the mechanism of "degree days", which allows for a precise estimate of crop maturity (Fallon et al 2005; Zavalloni et al 2006). Degree days are calculated by adding the minimum and maximum daily temperatures, dividing by two and subtracting a minimum temperature specific to the crop. Degree day calculations have not been developed for many small fruit crops; rather development is estimated as days after the beginning of the growing season (Ballinger and Kushman 1970; Eck 1988). For example, highbush blueberries mature at 120 to 160 days after the beginning of the growing season, but this estimation does not account for the seasonal variability of the growing environment (Eck 1988). At present, no system that links wild blueberry fruit development to accumulated degree days is available.

In order to better estimate the optimum periods to harvest individual blueberry fields, a more precise method is required. This study is intended to build on the knowledge gained through Lara Gibson's M.Sc. project, which addressed the effects of weather conditions during the growing season on physical and chemical aspects of developing wild blueberry fruits. In her study she assessed physical parameters including colour (green, partially ripe (pink, red), ripe (blue), and over ripe (blue, but soft and/or shrivelled), fresh weight, size in mm, and firmness of ripe berries. Chemical parameters assessed included total soluble solids, total sugars, acidity, total phenolic content and content of specific anthocyanins. In each field, local weather conditions (air, soil temperature, sunlight energy and rainfall) were recorded by data logger stations. The study was designed to characterize blueberry fruit development patterns in fields located in different climatic zones, and to determine if weather patterns influence fruit development in a measurable way.

This study seeks to provide a method to more accurately predict optimum harvest times by developing a wild blueberry predictive harvest index model, using weather data and fruit quality measurements.

Materials and Methods.

Ten commercial fields, based on usual harvest times, were selected for the study. Five fields were those involved in the M.Sc. study of Lara Gibson, designed to characterize ripening in wild blueberry fields and to assess the relationships between weather conditions and ripening. The other five were selected to provide as much variation in "usual" ripening and harvest times as possible. Site characteristics of the fields are listed in Table 1. Soil characteristics were taken from Webb et al (1991) for the Debert field, from Webb (1990) for Mount Thom, and from Nowland and MacDougall (1973) for all other fields.

Weather stations were established to measure air (or canopy) temperature at the 10 fields, specifically daily maximum and minimum temperatures. Weather data were downloaded monthly from May 1 until just prior to harvest. Daily maximum and minimum temperatures from each field were used to determine growing degree days (GDD) and accumulated GDDs from May 1, using the formula: GDD = (Max °C + Min °C)/2- 5 °C). Negative values were recorded 0 GDD. These data were used to compare to the physical ripeness data (% weight of the four groups) and the chemical data, below.

Three sets of fruit samples were obtained from each field, starting at approximately two weeks prior to the historical harvest dates for the fields. Four transects were established in each field, and a fruit sample (approximately 700 g) was harvested with a hand rake along the line transect, and transported to the lab. A 500 g sub sample was cleaned of debris and separated into green, partially ripe, ripe (blue) and over ripe (blue, soft) groups. Each group was weighed. Some ripe fruit was saved for analysis of pH and total soluble solid content; the rest was frozen for later analysis.

Samples of the fresh ripe berries were extracted for acidity (pH) and total soluble solids (primarily sugars). Fresh berries were squeezed through a cheesecloth lined garlic press to obtain sufficient juice, approximately 50 ml. pH was determined using an Acumet model 10 meter (Denver Instruments Co., Co). Total soluble solids were measured using a digital refractometer (Spear Scientific Model 300016), using the method of (Kushman, 1963). Frozen fruit samples were thawed for four hours, squeezed as above, and titratable acidity was measured with a Metraholm 785 DMP Titrino.

Selected frozen samples were thawed and juiced as above, and used to assess selected phenolics and anthocyanins. Total phenolics were estimated using the Folin-Ciocalteu assay as described by Singleton et al (1999). Acidified methanol was used to extract the phenolics from dehydrated plant tissue. The mixture was subjected to sonication, at temperatures below 30°C. The crude extract was centrifuged at 3000 rpm and each by-product category extracted and analyzed by LC-MS/MS. Total anthocyanins were analyzed using liquid chromatography mass spectrometry analysis. The HPLC system consists of a Waters Alliance 2695 Separations Module that contains a quaternary pump, autosampler and used a Phenomenex Luna C18 column (150mm x 2.1mm, 5µm) with a Waters X-Terra MS C18 guard column, as per Vrhovsek et al (2004).

Data were analysed using Systat software (Wilkinson et al 1999) and Sigmastat® (Jandel 1995). Mean separation was by Tukey's test at $P \leq 0.05$. The blueberry ripening data were tested for correlations with accumulated seasonal growing degree days (Wikipedia, 2008) using SAS (SAS Institute, 1999).

Results and Discussion.

Fruit Ripening.

Fruit samples were obtained from each of the 10 fields on three dates, beginning at approximately two weeks prior to the historical harvest date for the field. Percent ripe berries (by weight) from the 10 fields are summarized in Table 2, with full details in Appendix 1. At the final sample dates, just prior to the historical harvest dates, the % ripe berries (by weight) ranged from a low of 62.9 % in Southampton (2007) to a high of 87 % in the Parrsboro (Airport) in 2008. These results confirm our earlier findings (Lara Gibson M.Sc. study) that harvested fruit always contains some fruit that are immature (green or red) or over ripe, thus resulting in % ripe fruit less than 100% (Table 2). In that study, the "peak" of % ripe berries was a gradual rise over a period of approximately two weeks, before a downward trend was observed as a result in the increase of over ripe berries. It appears, therefore, that the crop may be successfully harvested at any time during the two week period.

The accumulated growing degree days (GDD) for each field (from the on-site weather station) are listed for the final sample dates, which were just prior to the harvest dates of the fields (Table 2). In all cases except for Debert, the accumulated growing degree days from May 1 to the final sample harvest exceeded 1000 GDD, and were within the ranges predicted by our weather models (see below). The very low 2007 GDD value at Debert appears to have resulted from equipment malfunction.

During the present study, most of the samples appeared to be in the "harvestable" range, with the exception of several first harvest dates (Appendix 1). For example, Southampton and Diligent River 2007, and Athol, Fern Walker and Mount Thom 2008, demonstrated considerably lower % ripe berries at the first harvest date than at the later two dates. Similarly, the % green berries were consistently higher than at the later harvest dates (Appendix 1). The variations noted in the percentages of ripe blueberries are characteristic of the genetic diversity of wild blueberry fields (Hepler and Yarborough 1991).

Chemical Status of Ripe Fruit.

Ripe fruit from all the samples were assessed for pH and total soluble solid content (SSC, or Brix); these tests were simple and could be easily done in most labs. The pH of the fruit samples did not vary within fields for the three sample dates in 9 and 8 of the 10 fields in 2007 and 2008, respectively. In those fields where differences were observed, pH was consistently lower at the first sample date and then increased (Appendix 1). Similarly, total soluble solid content (SSC) was similar over the three sample dates for 9 of the 10 fields in 2007, and 6 of 10 in 2008. Where differences were observed, the SSC content of the fruit was highest at the latest date in three of the four fields.

Three fruit chemical parameters, % total acidity, total anthocyanins and total phenolics were assessed on the complete set of ripe fruit samples obtained during 2008. Within fields, there were no differences in the % total acidity among the 10 fields at the three sample dates (Appendix 2). Differences in total anthocyanins were observed in two of the 10 fields, with the highest value observed at the latest sample date. Differences in total phenolics over the three sample dates were observed only at the McCormick field (Appendix 2).

When the data were summarized to compare the mean values of % total acidity, total anthocyanins and total phenolics, some differences were observed among the 10 fields (Table 3). The differences observed in % total acidity were small, with only Kennel and Mt Thom demonstrating greater levels than that at the Airport field. Similarly, total anthocyanin levels were higher than those at Athol and Mt. Thom only in the Debert field. Finally, total phenolic contents of ripe fruit at Kennel and Diligent River were greater than that in the Athol and Mt. Thom fields, but not in the others.

The variations observed in this study appear to be lower than those observed by Kalt and McDonald (1996), using selected cultivars over a two year study. The mixing of fruit from a number of clones in the fields may have contributed to the averaging of the clonal variations observed by Kalt and McDonald (1996). At the same time, however, it is important to note that the chemical composition of ripe fruit appears to be, on average, quite consistent throughout the season. This suggests that the quality of ripe berries is determined more through genetic variation than by the time of harvest.

Weather Data and Fruit Ripening.

During 2007 and 2008, temperature data were obtained from all 10 fields, and used to calculate accumulated growing degree days (GDD), which were, in turn, compared to the % ripeness data. We discovered that we had insufficient data points with our three sample days to develop a working model. The models, therefore, were developed using the % ripeness data collected from 2005 to 2008 for Lara Gibson's

M.Sc. study. In addition, we obtained weather data from three Environment Canada weather stations which we used for comparisons with the on-site weather stations.

We were able to produce direct comparisons between Environment Canada weather stations and on-site stations only in 2006 and 2007 (Figure 1), as the weather stations were not put out in 2005 (the pilot study) until June 23. There were only small differences between the two stations at Athol (2006) and Southampton (2007) (Figure 1 b). The Nappan station is located approximately 10 km from the Athol field and 20 km from the Southampton field, but is located near sea level in the same climate zone (Kinsman 1993). At Diligent River, R^2 values and slopes were very similar in 2006, but R^2 values were quite different in 2007, with a considerably higher R^2 value for the Parrsboro weather station compared to the on-site station (Figure 1, c,d). Diligent River is located 10 km west of Parrsboro, within the Bay of Fundy coastal climate zone (Kinsman 1993). At the Farmington field (Figure 1, e,f), R^2 values and slopes were similar for both years, even though the Environment Canada station at Nappan, is located some 30 km from the Farmington field, and is closer to sea level. At Mt. Thom, R^2 values at the Debert Environment station were consistently higher than were those for the on-site station, although the slopes appeared to be similar (Figure 1, g, h). The Debert weather station is approximately 16 km from Mt Thom, and is at a lower elevation near Cobequid Bay. We were unable to obtain on-site weather data for the Debert site due to equipment malfunction.

The R^2 values for the Environment Canada weather stations were consistently higher than were those for the on-site weather stations (Figure 1), except for Southampton and Farmington in 2007, and we were able to obtain complete weather data from May 1 through the season from the Environment Canada stations. For that reason, we developed three year models for the five fields using the closest Environment Canada weather stations (Figure 2). The R^2 values ranged from a high of $R^2 = 0.769$ at Diligent River (Figure 2 b) to a low of $R^2 = 0.6423$ at Debert. There was considerable variation in the percentages of ripe berries at all the sites, as is expected in genetically diverse wild blueberry fields (Hepler and Yarborough 1991). At the same time, however, the slope patterns were similar in all the fields, rising slowly from no ripe berries at 400 to 600 growing degree day units (GDD) to a leveling off of the slopes at approximately 1000 to 1100 GDD (except 1300 at Mt Thom), followed by decreased percentages of ripe berries at approximately 300 GDD units after that (Figure 2), as the percentages of over ripe berries increased. We also observed that the number of growing degree days from the time that ripe fruit were first observed in the fields was 400-500 GDD (Figure 2).

It appears from the data obtained in these studies, that established weather stations will provide useful information related to accumulated growing degree day information that will allow producers to judge more precisely when their fields will be ready for harvest. This will be possible even with fields some distances from the weather stations, but may require some modifications based on distance from the station and the influences of microclimate in individual fields.

We estimate that there is an optimal harvest period of approximately two weeks for all fields, during which the amounts of the most desirable ripe fruit will be available. Prior to that optimum period, harvested berries will contain an excess of immature green berries, and after the optimum period, there will be rapidly increasing amounts of over ripe fruit. Our model predicts that the optimum period for harvest begins at 1000 to 1100 GDD from May 1 (or 400 to 500 GDD from the first ripe berries in individual fields), and persists for approximately another 200 GDDs, or approximately two weeks, before significant increases in over ripe berries occur.

Summary.

Wild blueberries are very diverse, due to large genetic variation among many clones. These variations, as well as differences in berry location on stems and within flower clusters, contribute in large measure to the uneven ripening observed in fields. As a result, the numbers of ripe berries in fields at harvest are always somewhat less than 100 %; the harvests are mixtures of ripe berries along with variations of green, partially ripe and over ripe berries. Our studies indicate that there is approximately a two week period during which any particular field may be harvested to give a maximum percentage of ripe berries. During this period as well, the chemical composition and quality of the ripe fruit (i.e., pH, total soluble solids, total acidity, total anthocyanins and total phenolics) remains relatively constant. The optimum harvest period for individual field harvest begins at approximately 1000 to 1100 accumulated growing degree days (GDD) accumulated from May 1. Producers may be able to use accumulated growing degree day data from local Environment Canada weather stations to assist them in predicting when their fields are ready for harvest.

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Table 1. Site characteristics of 10 blueberry fields.

Field	Location	Soil Type/drainage	Climate Region	
Athol (Sandpit)	N 45° 40.5'; W 64° 13.3'	Shulie Brown sandy loam well drained	Northern Highlands, sheltered, inlanc elevation, warmer	
Southampton (Eaton)	N 45° 35.9'; W 64° 14.8'	Rodney dark brown sandy loam well drained	Northern Highlands, sheltered, inlanc elevation, warmer	
Collingwood (Higgs)	N 45° 36.8'; W 63° 56.5'	Rodney dark brown sandy loam well drained	Cobequid Highlands, cold winters, w summers, sheltered	
Debert (NSWBI)	N 45° 26.6'; W 63° 26.9'	Woodville sandy loam well drained	Interface, Bay of Fundy and Cobequi Highlands, near sea level, medium wa	
Diligent River (822/823)	N 45° 24.2'; W 64° 27.4'	Hebert greyish brown over yellowish to reddish sandy loam excessively well drained	Bay of Fundy Coastal zone, mild win wet summers	
Farmington (Mosher)	N 45° 34.6'; W 63° 53.8'	Wyvern well drained, dark brown sandy loam, well drained	Cobequid Highlands, Cold winters , snow, warm summers, high elevation	
Milleville (F.Walker/Langille)	N 45° 60.3'; W 63° 82.7'	Hebert brown sandy loam excessively well drained	Cobequid Highlands, low elevation, s warm	
Mount Thom (Tower)	N 45° 30.4'; W 62° 57.7'	Kirkhill gravelly sandy to gravelly loam well drained	Cobequid Highlands, Cold winters , snow, cool summers, high elevation	
Parrsboro (Airport)	N 45° 25.2'; W 64° 19.3'	Hebert grayish brown sandy loam excessively well drained	Bay of Fundy Coastal zone, mild win wet summers	
Pigeon Hill (McCormick)	N 45° 32.9'; W 63° 52.0'	Wyvern dark brown sandy loam well drained	Cobequid Highlands, Cold winters , snow, warm summers, high elevation	
Westchester (Kennel)	N 45° 33.5'; W 63° 51.9'	Westbrook brownish sandy loam over gravelly sandy loam, well drained.	Cobequid Highlands, sheltered bowl, summer	

Table 2. Ripening and growing degree days (GDD) in 10 fields, 2007 and 2008. Fruit values are means of 4

Field	"usual " Harvest	Harvest date[z]		% Ripe[y]			
		2007	2008	2007	2008	2	
Airport	Aug 26	Aug 27	Aug 25	70.2	87.0	1	
Southampton/Athol	Aug 15	Aug 14	Aug 11	62.9	77.2	1	
Debert	Aug 20	Aug 20	Aug 18	nd	76.7	5	
Diligent River	Sept 5	Sept 3	Sept 1	87.2	87.4	1	
Langille/Fern Walker	Aug 15	Aug 14	Aug 11	71.1	77.9	1	
Higgs	Aug 15	Aug 14	Aug 11	69.2	77.9	1	
Kennel	Aug 15	Aug 15	Aug 11	61.9	80.6	1	
McCormick	Sept 5	Sept 3	Sept 1	76.8	65.2	1	
Mosher	Sept 1	Aug 27	Sept 1	70.6	77.1	1	
Mt. Thom	Aug 30	Aug 27	Aug 25	63.1	84.9	1	
Means				70.3	79.2	1	

Z date of last sample harvest
Y percent of total fresh weight (about 500g)
X SSC = percent total soluble solids, or Brix
W Accumulated growing degree days (GDD), from May 1 to harvest date

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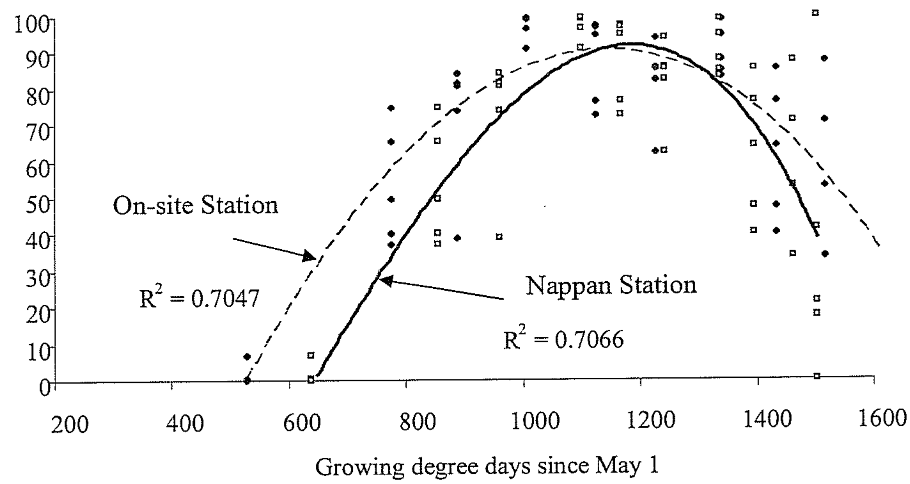
Table 3. Comparison of mean levels of titratible acidity, total anthocyanins and total phenolics in ripe fruit from ten wild blueberry fields, 2008.

Field	% Titratible Acidity[z]	Total Anthocyanins[y]	Total Phenolics[w]
Airport	0.419 b	184.4 ab	0.118 ab
Athol	0.521 ab	163.8 b	0.115 b
Debert	0.444 ab	204.9 a	0.120 ab
Diligent River	0.459 ab	200.6 ab	0.136 a
Fern Walker	0.434 ab	183.4 ab	0.122 ab
Higgs	0.517 ab	187.4 ab	0.123 ab
Kennel	0.532 a	200.3 ab	0.134 a
McCormick	0.486 ab	184.1 ab	0.124 ab
Mosher	0.421 ab	180.9 ab	0.122 ab
Mount Thom	0.543 a	165.8 b	0.111 b

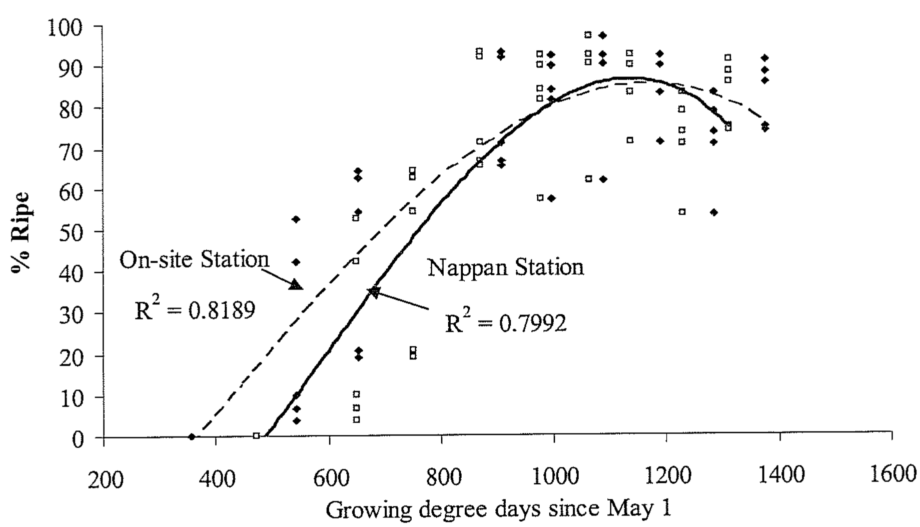
Z . % titratible acidity = % citric acid equivalent
y. mg g^{-1} dry wt.
w. uM gallic acid g^{-1} fresh wt.

Figure 1. Relationship of growing degree days from on-site data loggers and Environment Canada weather stations on % ripe blueberries in four blueberry fields

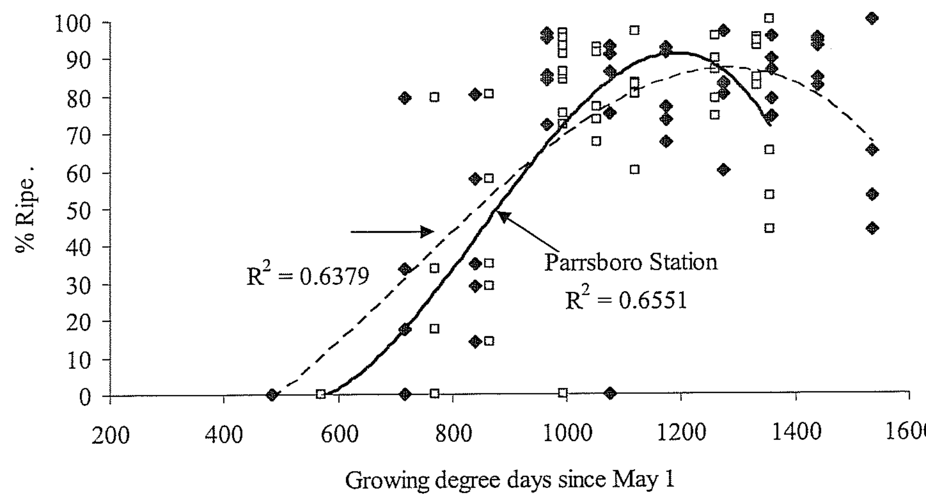
a) 2006 - Athol



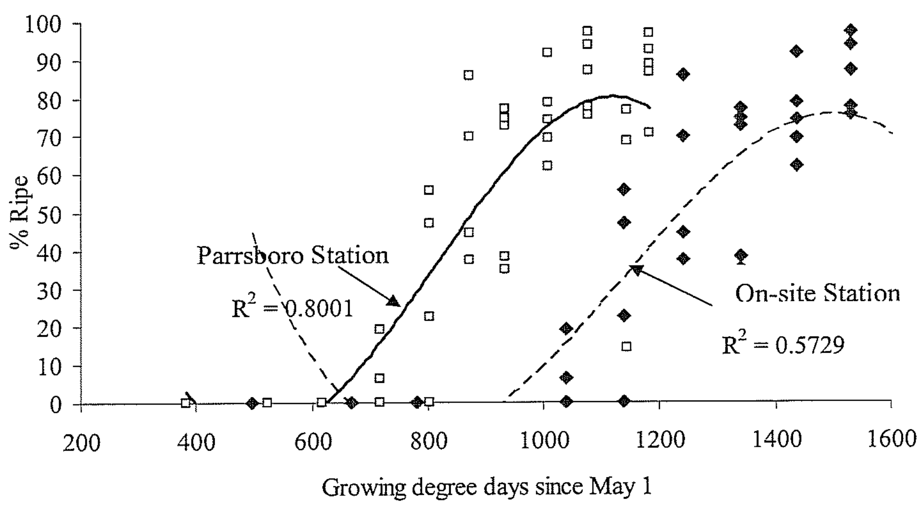
b) 2007 – Southampton



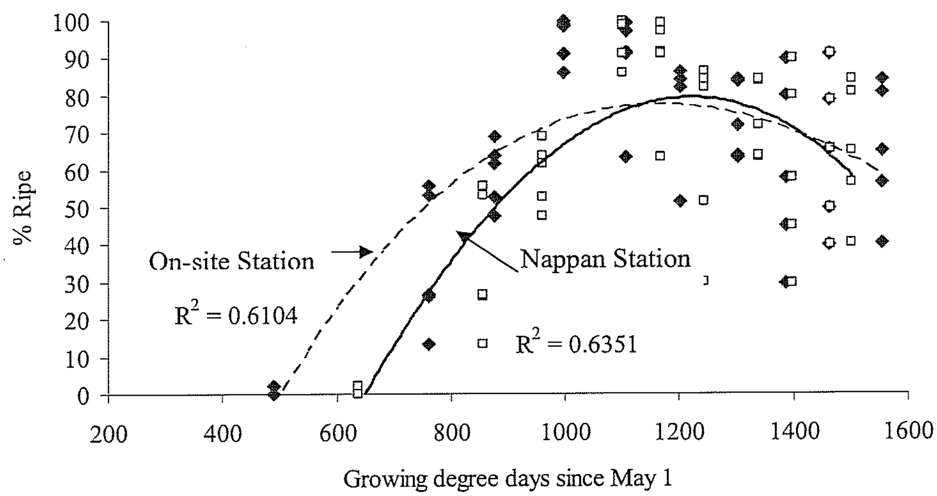
c) Diligent River 2006



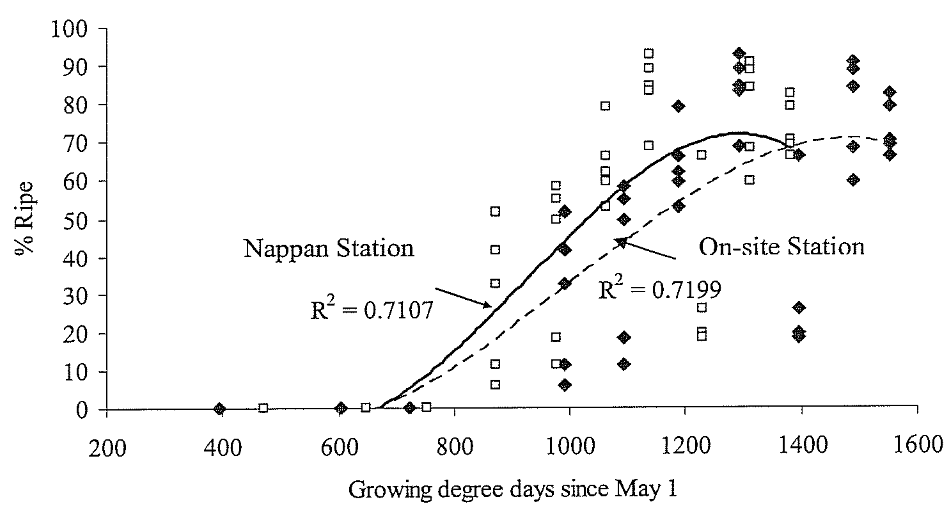
d) Diligent River 2007



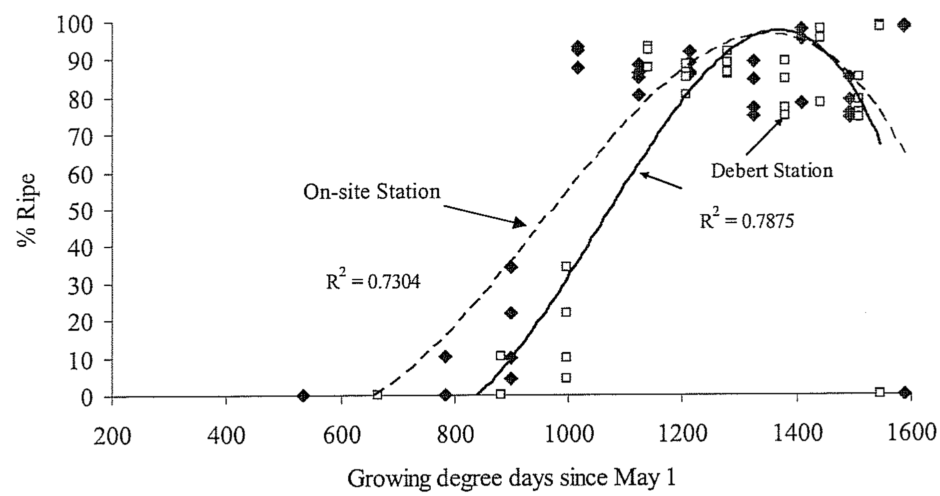
e) Farmington 2006



f) Farmington 2007



g) Mt. Thom 2006



h) Mt Thom 2007

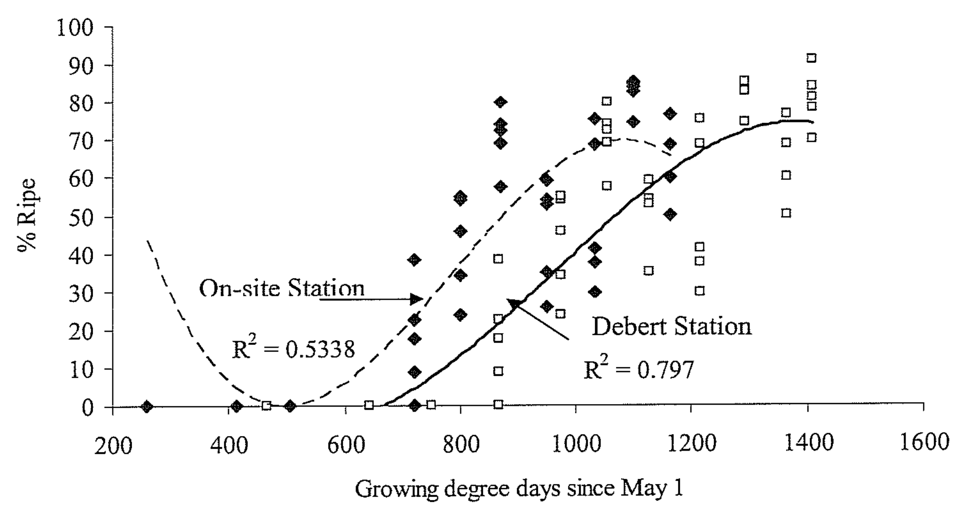
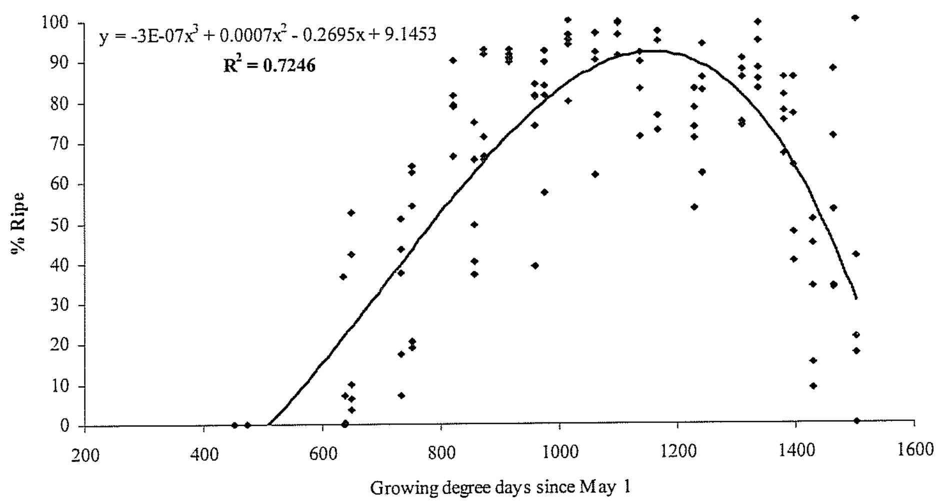
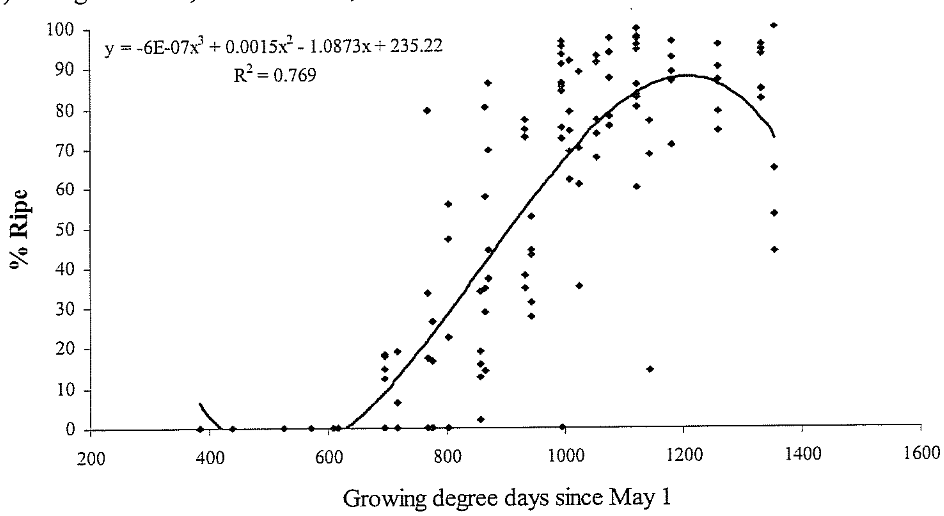


Figure 2. Relationship between growing degree days and % ripe berries over three years. Comparisons are with Environment Canada weather stations.

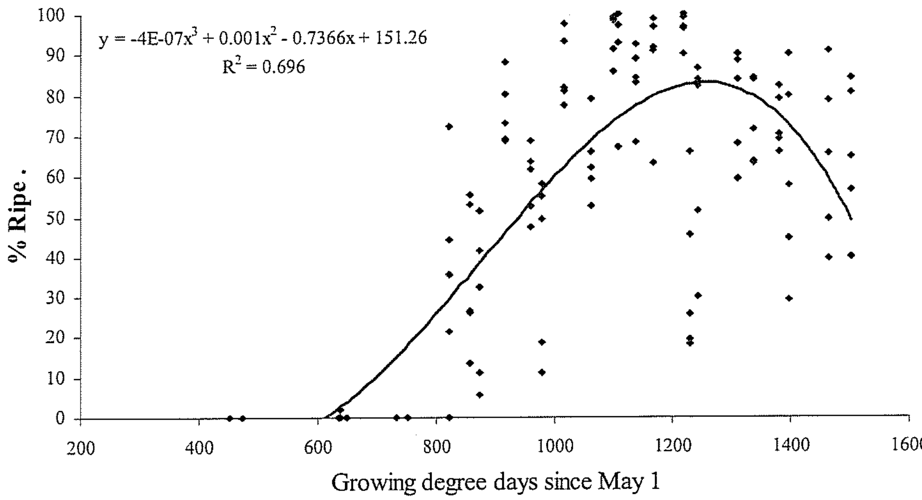
a) Athol/Southampton, 2005 to 2007, Nappan weather station.



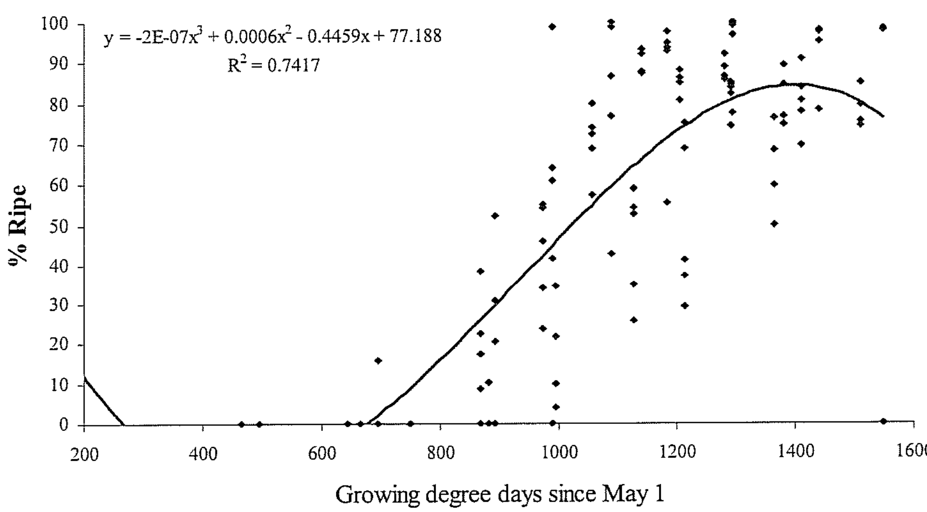
b) Diligent River, 2005 to 2007, Parrsboro weather station



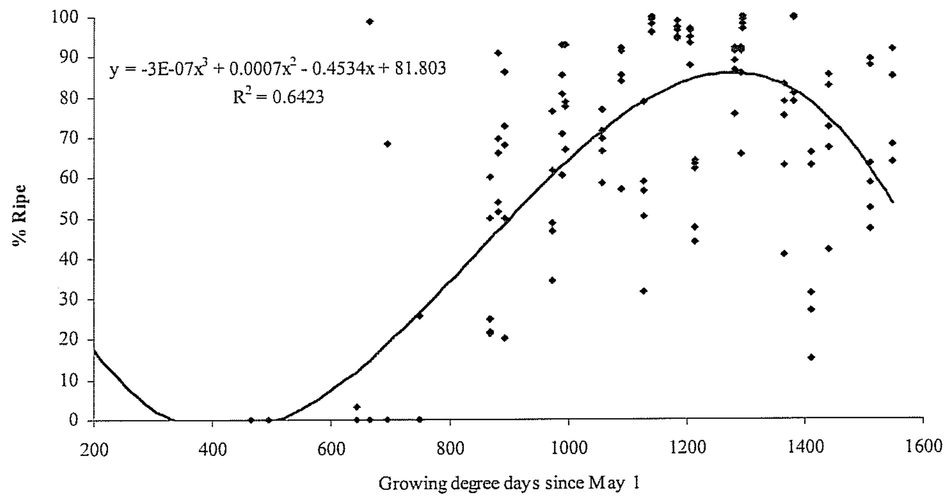
c) Farmington 2005 to 2007, Nappan weather station



d) Mt. Thom 2005 to 2007, Debert weather station.



e) Debert 2005 to 2007, Debert weather station



Appendix 1: Sample dates, fruit data, and fresh fruit chemical data in 10 fields

a) 2007

Field	Date	% Green	% Part. Ripe	% Ripe	% Over Ripe	pH	SSC[z]
Airport	Aug 11	3.1	3.5[y]	87.3	5.9	3.29 a[w]	11.98 b
	Aug 18	0.7	1.2	85.7	11.8	3.34 a	12.23 ab
	Aug 25	0.4	1.5	87.0	9.8	3.31 a	9.78 a
Athol	July 31	25.2	22.0	49.2	4.6	3.29 b	11.45 a
	Aug 4	14.4	10.9	67.8	6.1	3.25 b	10.78 a
	Aug 11	5.5	9.4	77.2	7.1	3.45 a	10.10 a
Debert	Aug 6	9.7	6.7	75.0	7.7	3.27 a	9.70 a
	Aug 13	3.0	1.9	87.3	7.6	3.27 a	9.78 a
	Aug 18	1.1	0.8	76.7	20.5	3.28 a	9.53 a
Diligent River	Aug 18	2.8	4.2	81.5	10.6	3.30 a	11.05 a
	Aug 25	2.0	3.3	86.9	7.5	3.27 a	9.75 a
	Sept 1	0.6	0.9	87.4	10.4	3.26 a	10.10 a
Fern Walker	July 30	23.8	11.5	57.6	6.6	3.40 a	9.65 a
	Aug 4	11.9	9.8	68.4	8.3	3.38 a	9.43 a
	Aug 11	4.6	5.6	77.9	10.8	3.48 a	9.03 a
Higgs	July 30	16.6	8.7	68.1	5.1	3.32 b	9.45 a
	Aug 4	8.1	5.6	76.8	8.4	3.45 a	9.23 a
	Aug 11	1.8	3.9	77.9	15.1	3.40 ab	9.43 a
Kennel	July 30	22.5	7.5	65.6	3.4	3.30 a	9.38 a
	Aug 4	13.5	8.2	69.6	7.6	3.34 a	9.28 a
	Aug 11	3.4	7.1	80.6	7.5	3.26 a	9.10 a
McCormick	Aug 18	3.4	5.7	82.2	8.1	3.24 a	8.55 b
	Aug 25	0.9	4.0	84.7	8.2	3.29 a	8.60 b
	Sept 1	0.5	3.0	65.2	30.1	3.31 a	10.30 a
Mosher	Aug 18	3.1	0.0	79.7	12.6	3.27 a	8.80 b
	Aug 25	0.8	0.0	82.9	12.2	3.29 a	9.13 ab
	Sept 1	0.5	0.0	77.1	18.9	3.24 a	9.58 a
Mt Thom	Aug 13	7.8	11.4	69.6	10.5	3.14 a	8.58 b
	Aug 18	4.5	5.5	80.6	8.7	3.11 a	8.75 b
	Aug 25	0.8	1.4	84.9	11.7	3.27 a	9.38 a

z Percent total soluble solids
y Values are means of 4 samples of ripe fruit
w values in columns for each field followed by the same letter do not differ significantly at P = 0.05

b) 2008

Field	Date	% Green	% Partially Ripe	% Ripe	% Over Ripe	pH	SSC[z]
Airport	Aug 14	6.00[y]	8.86	74.66	12.19	3.36 a[w]	11.28a
	Aug 22	1.82	6.94	69.58	12.93	3.35 a	11.68 a
	Aug 27	0.32	5.01	70.18	20.46	3.33 a	11.33 a
Southampton	July 31	15.03	8.80	41.01	23.70	3.29 a	10.65 a
	Aug 8	5.94	11.21	68.08	14.08	3.24 a	11.37 a
	Aug 14	5.55	10.27	62.89	23.54	3.35 a	11.88 a
Debert	Aug 6	20.05	12.65	57.99	9.15	2.95 a	11.13 a
	Aug 13	7.97	14.69	64.46	11.49	3.19 a	11.40 a
						3.05 a	11.23 a
Diligent River	Aug 22	8.97	13.80	66.65	9.65	2.75 a	11.15 ab
	Aug 27	3.73	10.15	73.19	12.26	3.16 a	10.80b
	Sept 3	0.72	5.16	87.15	24.78	2.72 a	11.43 a
Langille	Aug 6	8.06	9.52	70.72	12.36	2.84 b	12.30 a
	Aug 10	3.52	8.28	68.70	18.00	3.31 a	11.80 a
	Aug 14	2.39	9.58	71.10	15.56	3.32 a	12.88 a
Higgs	Aug 8	3.34	5.54	78.13	12.39	2.82 b	11.95 a
	Aug 10	1.33	8.58	66.65	21.36	3.23 a	11.43 a
	Aug 14	0.78	9.43	69.22	16.67	3.29 a	11.58 a
Kennel	Aug 6	6.80	12.93	69.56	9.73	2.89 b	11.03 a
	Aug 10	3.09	10.52	69.23	16.16	3.25 a	10.60 a
	Aug 15	2.42	12.97	61.90	21.50	3.36 a	10.73 a
McCormick	Aug 22	4.40	9.56	70.78	12.34	2.89 a	10.98 a
	Aug 27	1.36	9.59	75.41	13.41	2.89 a	10.68 a
	Sept 3	1.02	4.22	76.79	22.07	3.03 a	10.58 a
Mosher	Aug 14	6.87	13.30	61.57	16.46	3.22 a	10.85 a
	Aug 21	2.20	9.03	65.13	22.17	3.25 a	11.58 a
	Aug 27	0.88	10.08	70.62	17.22	3.22 a	10.90 a
Mount Thom	Aug 16	9.53	13.53	64.52	10.89	3.13 a	12.78 a
	Aug 20	7.66	10.48	65.19	10.53	3.15 a	11.40 a
	Aug 27	1.25	4.30	63.07	7.83	3.09 a	11.15 a

z Percent total soluble solids
y Values are means of 4 samples of ripe fruit
w values in columns for each field followed by the same letter do not differ significantly at P = 0.05

Appendix 2: Percent titratible acidity, total anthocyanins and total phenolics in ten wild blueberry fields, 2008.

Field	Date	% Total Acidity[z]	Total Anthocyanins[y]	Total Phenolics[w]
Airport	Aug 11	**0.434 a**	**189.1a**	**0.119 a**
	Aug 18	**0.399 a**	**189.4 a**	**0.115 a**
	Aug 25	**0.425a**	**174.8 a**	**0.120 a**
Athol	July 31	**0.532 a**	**163.9 a**	**0.118 a**
	Aug 4	**0.585 a**	**169.1 a**	**0.112 a**
	Aug 11	**0.448 a**	**158.4 a**	**0.114 a**
Debert	Aug 6	**0.476 a**	**206.9 a**	**0.123 a**
	Aug 13	**0.395 a**	**217.6 a**	**0.120a**
	Aug 18	**0.460a**	**190.2 a**	**0.116 a**
Diligent River	Aug 18	**0.395a**	**172.1 b**	**0.128 a**
	Aug 25	**0.448 a**	**209.4 ab**	**0.136 a**
	Sept 1	**0.535 a**	**220.2 a**	**0.144 a**
Fern Walk	July 30	**0.472 a**	**171.4 a**	**0.124 a**
	Aug 4	**0.396 a**	**186.9 a**	**0.117 a**
	Aug 11	**0.434 a**	**191.9 a**	**0.125 a**
Higgs	July 30	**0.521 a**	**180.8 a**	**0.113 a**
	Aug 4	**0.482 a**	**167.9 a**	**0.130 a**
	Aug 11	**0.549 a**	**213.6 a**	**0.125 a**
Kennel	July 30	**0.451 a**	**183.9 b**	**0.132 a**
	Aug 4	**0.552 a**	**187.8 ab**	**0.142 a**
	Aug 11	**0.593 a**	**229.2 a**	**0.127 a**
Mc Cormick	Aug 18	**0.514 a**	**199.9 a**	**0.137 a**
	Aug 25	**0.504 a**	**195.1 a**	**0.130 ab**
	Sept 1	**0.440 a**	**157.4 a**	**0.106 b**
Mosher	Aug 18	**0.386 a**	**186.0 a**	**0.130 a**
	Aug 25	**0.451 a**	**189.9 a**	**0.113 a**
	Sept 1	**0.427 a**	**166.72 a**	**0.124 a**
Mt Thom	Aug 13	**0.511 a**	**151.6 a**	**0.108 a**
	Aug 18	**0.561 a**	**164.1 a**	**0.117 a**
	Aug 25	**0.555 a**	**181.6 a**	**0.107 a**

z. % titratible acidity = % citric acid equivalent

y. mg L^{-1} juice

w. uM gallic acid g^{-1} fresh wt.