Feasibility of Using Compost in Raspberry Production: A Preliminary Review and Economic Analysis of Materials and Processes Available in the Fraser Valley

Prepared for Agriculture and AgriFood Canada
By J.W. Paul, PhD PAg
February 2013
Feasibility of Using Compost in Raspberry Production: 
A Preliminary Review and Economic Analysis of Materials 
and Processes Available in the Fraser Valley

Report Prepared by 
J.W. Paul, PhD PAg
3911 Mt Lehman Rd 
Abbotsford, BC V4X 2N1 
transform@telus.net

For 
Agriculture and Agri-Food Canada 
850 Lincoln Rd Box 20280 
Fredericton, NB E3B 4Z7 
Att: Bernie Zebarth 

February 14, 2013
Feasibility of Using Compost in Raspberry Production: A Preliminary Review and Economic Analysis of Materials and Processes Available in the Fraser Valley

Summary

There are currently approximately 1012 ha of raspberries grown above the Abbotsford-Sumas Aquifer in south coastal British Columbia. The aquifer provides drinking water for residents both in Canada and the US. It is an unconfined aquifer which makes it susceptible to agricultural management on the soil surface, such as manure and fertilizer management for raspberry production.

Traditionally, poultry litter was used as a fertilizer and a soil conditioner for raspberries because poultry production was local and therefore convenient. During the 1980s and 1990s, nitrate contamination of the aquifer due to excess poultry litter application became a concern. Recent research suggested that the use of compost in raspberry production may decrease the potential nitrate pollution in the aquifer, provide the additional benefits associated with organic matter addition, and has the potential to significantly reduce populations of root lesion nematode (pers comm. Tom Forge, Agriculture and Agri-Food Canada).

This report investigated quality of compost for raspberry production, identified quantities of compost that may be required, potential feedstocks for producing the compost, options for composting feedstocks, and economics of compost production and compost use.

Fully mature composts have qualities most likely to reduce the risk of nitrate leaching, and more likely to provide disease suppressive benefits. Compost produced from poultry litter alone may remain high in nitrogen and may not be able to develop disease suppressive characteristics in a timely manner. The best compost for raspberries will likely be able to provide sufficient phosphorous and potassium for crop growth, but may not be able to provide enough nitrogen on a short term basis.

Based on specific compost characteristics, application of approximately 50 tonnes per ha of a mature high C/N ratio compost may provide beneficial affects without increasing the risk of nitrate leaching. Annual spring banding of a mature lower C/N ratio compost at rates as low as 7 tonnes per ha may provide nutrient and disease resistance benefits for the duration of the raspberry crop growth cycle. Assuming these application rates and that compost is applied on all land in raspberry production, the total quantity of compost required annually for the 1012 ha of raspberries over the Abbotsford aquifer is estimated at 11,900 tonnes (5,600 tonnes for replanting and 6,300 tonnes for annual application).

There are many potential feedstocks that can be used to produce compost for raspberries. A blend of food waste and yard waste may provide the quality of compost required. It is also likely be the least costly compost because the cost of producing the compost is offset by the tipping fee. Agricultural wastes such as horse manure, separated dairy cattle manure and spent mushroom compost may also be suitable sources for quality compost. The cost of providing agricultural waste based composts may be higher because there are traditionally lower or no tipping fees associated with these sources of organic matter.

A combination of turning and aeration is recommended to produce quality compost for raspberries. It is also recommended that the composting process meet current BC Regulations for composting (Organic Matter Recycling Regulation) as this regulation also ensures the quality of compost as required by the international Good Agricultural Practice guidelines.

The greatest potential direct economic advantage for using compost is longer plant life and potentially reduced requirements for fumigants and pesticides. The fertilizer value of compost is difficult to define.
The indirect economic advantage of using compost may be to decrease the nitrate loading of the aquifer. There is currently little economic incentive to produce high quality mature composts that may have disease suppressive effects. Additional research on the nutrient release from compost and the potential disease suppressive effects of compost is recommended.
Contents

Feasibility of Using Compost in Raspberry Production: A Preliminary Review and Economic Analysis of Materials and Processes Available in the Fraser Valley ................................................................. 1

Summary ........................................................................................................................................... 2

Table of Contents ................................................................................................................................. 4

List of Tables ........................................................................................................................................ 8

List of Figures ......................................................................................................................................... 9

Introduction .......................................................................................................................................... 11

Background on Raspberry Production over the Abbotsford Aquifer ...................................................... 14

Abbotsford produced almost 50% of the raspberries produced in Canada in 2011 ............................... 14

World Raspberry Production Has Increased in the Last 20 Years ......................................................... 14

Raspberry Production in Abbotsford has Declined More than 50% in the Last 20 Years ....................... 14

Most of Canada’s Raspberry Production Occurs Over the Abbotsford Aquifer .................................. 15

Raspberry Plantings Are Being Replaced with Blueberries in Abbotsford ........................................... 15

Berry prices and Cost of Production Influencing Change from Raspberry Production to Blueberry Production in Abbotsford ........................................................................................................... 15

Competition in a World Market ........................................................................................................... 16

Poultry Manure Was Historically Used as a Soil Amendment for Raspberry Production ..................... 16

Poultry Manure Use When Replanting Raspberries ........................................................................... 16

Recent Research Identifies Poultry Manure Application as Contributing to Nitrate Pollution in the Aquifer ........................................................................................................................................ 17

Defining Qualities of Compost for Raspberry Production ................................................................ 18

Definitions of Compost ....................................................................................................................... 18

Availability of Nitrogen and other Nutrients in Composts .................................................................. 19

pH and Electrical Conductivity in Compost ........................................................................................ 21

Compost Characteristics for Disease Suppression .............................................................................. 22

Compost for Control of Root Lesion Nematodes ................................................................................. 23

Conclusion ........................................................................................................................................... 24

Identifying Quantities of Compost Required for Raspberry Production .............................................. 25

Amount of Land Cropped to Raspberries ............................................................................................ 25

Compost Required for Replant ............................................................................................................ 25

Compost Required for Annual Spring Compost Application for Raspberry Production .................... 26

Fertilizer Value of Compost for Annual Application .......................................................................... 26
Compost in Conjunction with Fertilizer ................................................................. 27
Compost May Provide all of the Required Phosphorus and Potassium .................. 27
Calculating the Amount of Compost Required for Annual Applications for Raspberry Production... 28
Conclusions ............................................................................................................. 29
Investigating Potential Feedstocks for Producing Compost with Desired Characteristics .................. 30
Composting Theory .......................................................................................... 30
Temperature ........................................................................................................ 30
Air-Filled Porosity ............................................................................................ 31
Bulk Density ....................................................................................................... 31
Moisture Content .............................................................................................. 31
Mixing.................................................................................................................. 31
Available Organic Materials for Composting ..................................................... 31
Poultry manure .................................................................................................. 32
Horse manure .................................................................................................... 33
Separated dairy cattle manure .......................................................................... 33
Spent mushroom compost ................................................................................ 34
Poultry processing waste .................................................................................. 35
Greenhouse waste ............................................................................................. 35
Biosolids ............................................................................................................. 36
Commercial food waste ..................................................................................... 36
Yard waste from communities ........................................................................... 36
Yard waste and food waste from communities .................................................. 37
Conclusions ........................................................................................................ 37
Composting Options to Produce Compost with Desired Qualities .................... 39
Static pile composting (no forced aeration, no turning) ...................................... 39
Turned windrow composting (turning, no forced aeration) ................................ 40
Aerated static pile composting (forced aeration and no or minimal turning or mixing) .................. 41
Turned and aerated composting (both forced aeration and turning) .................... 43
Conclusions ........................................................................................................ 44
Regulations Affecting Production of Compost with Desired Qualities ............... 45
Local Government Bylaws ............................................................................... 45
Regional Government Bylaws ......................................................................... 45
Regulations Affecting Production of Compost with Desired Qualities .............................................. 66
Economic Analysis of Producing and Using Compost for Raspberry Production .......................... 66
Identifying Gaps .................................................................................................................................. 67
References ............................................................................................................................................ 68
List of Tables

Table 1. Compost required for replanting raspberries. ................................................................. 25
Table 2. Estimated total and available nitrogen from spring applied compost at various application rates. .................................................................................................................. 28
Table 3. Compost required for annual application for raspberry production. ........................................... 29
Table 4. Characteristics of various feedstocks for composting. .............................................................. 32
Table 5. Building costs for various composting technology types (equipment or storage areas not included). ................................................................................................................................. 53
Table 6. Input values and assumptions for a food waste and yard waste composting process that will produce 11,900 tonnes of finished compost per year ...................................................................................... 54
Table 7. Capital and operations cost per tonne of food waste and yard waste processed for a facility producing 11,900 tonnes of product .................................................................................................................................. 54
Table 8. Revenue and expenses for a food waste/yard waste composting facility producing 11,900 tonnes of compost per year (for comparative purposes only - not for business planning) .................................................................................. 55
Table 9. Input information and assumptions for a spent mushroom compost process that can produce 11,900 tonnes of finished product per year. ........................................................................................................... 56
Table 10. Revenue and expenses for a spent mushroom compost facility producing 11,900 tonnes of finished compost for raspberry production (for comparative purposes only, not for business planning). ................................................................. 57
Table 11. Production costs per tonne for a spent mushroom compost facility producing 11,900 tonnes of finished compost ........................................................................................................................................ 58
Table 12. Revenue and cost formula for a 10 year cycle of raspberry production (from BC Ministry of Agriculture 2007b), upgraded with 2012 information on fumigants, pesticides and fertilizers (most of the "other expenses" are similar to the 2007 model) .......................................................................................................................... 60
Table 13. Net revenue ($ per acre) with various scenarios including compost application and reduced fertilizer or pesticides. ......................................................................................................................... 61
List of Figures

Figure 1. Raspberries and poultry farms have coexisted on the Abbotsford aquifer for many years........ 11
Figure 2. Raspberry production at the Abbotsford airport.......................................................... 14
Figure 3. Raspberry production in BC and Washington (production in thousand lb per year)........... 14
Figure 4. Many raspberry farms have converted completely to blueberry production..................... 15
Figure 5. Some farms are in transition to blueberries, or produce both raspberries and blueberries. .. 15
Figure 6. Changes in ammonium and nitrate during a one year composting process of duck and goose manure. It is interesting to note that in this case, some of the ammonium would have been lost to the atmosphere and the nitrate would been mineralized from the nitrogen fraction with time (Source: Transform Compost Products)............................................................................................................................................. 20
Figure 7. The composting process .................................................................................................. 30
Figure 8. Growth and activity of microorganism in response to temperature................................. 30
Figure 9. The composting process requires air filled porosity to provide oxygen for the composting microorganisms....................................................................................................................................... 31
Figure 10. If water can be squeezed from composting material, the moisture content is greater than 70% and is too wet for optimal composting .................................................................................. 31
Figure 11. Organic waste from a greenhouse growing peppers.......................................................... 35
Figure 12. Food waste and yard waste compost produced in the District of Mission ....................... 37
Figure 13. This static composting pile is likely to be wet, anaerobic and very slow to process into compost. ............................................................................................................................................... 39
Figure 14. Some static pile composting processes utilize a building, but are also subject to a slow process and anaerobic conditions........................................................................................................ 39
Figure 15. Static pile composting can be a simple and cost effective way to produce a high quality compost if designed properly and given enough time. ........................................................................... 40
Figure 16. Turned windrow composting was used successfully during the summer as the second stage of composting of poultry mortalities following Avian Flu................................................................. 40
Figure 17. Outdoor windrow composting is not recommended in south coastal BC......................... 40
Figure 18. Turned windrow composting inside a building is not a very efficient use of indoor space. .. 41
Figure 19. Aerated bunkers are an efficient and fast way of processing organic waste. This photograph is a compost facility on a goat farm. ........................................................................................................ 41
Figure 20. Forced aerated windrow at the District of Mission............................................................ 41
Figure 21. Covered and aerated windrow composting of animal manure........................................ 42
Figure 22. Enclosed static aerated composting in plastic bags (poultry mortalities 2004)................. 42
Figure 23. Aerated windrows inside a building with the aeration piping embedded in the concrete floor. Windrows are approximately 15 ft high and 23 ft wide................................................................. 42
Figure 24. Aerated and turned composting provides the highest quality compost in the shortest time period. Typically, these are flow-through systems where raw material comes in one end, and finished compost exits the other end.

Figure 25. Turned and aerated composting of hog manure.
Feasibility of Using Compost in Raspberry Production: A Preliminary Review and Economic Analysis of Materials and Processes Available in the Fraser Valley

Introduction

Much of the raspberry production in south coastal British Columbia occurs on the soil above the Abbotsford-Sumas Aquifer, a supply of groundwater that is 260 square kilometers, and is used as a water supply by more than 100,000 people in Abbotsford and northwest Washington State (Abbotsford-Sumas Aquifer International Task Force 2012). A shallow layer of soil overlies mostly sand and gravel, which leaves the aquifer very susceptible to agricultural management on the soil surface, such as raspberry production.

Poultry litter has been used successfully as a fertilizer and a soil conditioner for raspberries because poultry production was locally produced and convenient to use. In some cases, the poultry and raspberries were produced on the same farm. Increasing concerns regarding nitrate contamination of the aquifer triggered increased manure exports from the aquifer (Sutherland 2005). The Sustainable Poultry Farming Group estimated that poultry litter export from the Abbotsford aquifer increased from 6,200 cubic yards in 1993 to 26,800 cubic yards in 2003 (Sutherland 2005). Good Agricultural Practice guidelines (BC Ministry of Agriculture 2012), which requires that no raw manure is applied less than 120 days before harvest, may either reduce poultry manure applications or alter the time of manure application to a time that is less optimal from a plant nutrient uptake perspective.

Poultry manure is also applied when replanting the raspberries as the soil benefits from addition of organic matter. These applications of manure may also have a significant impact on potential nitrate pollution of the aquifer.

The use of compost in lieu of raw manure in raspberry production has potential to reduce groundwater nitrate contamination, provide the additional benefits associated with organic matter addition, and significantly reduce populations of root lesion nematode (pers. comm. Tom Forge, Agriculture and Agri-Food Canada).

This feasibility study will investigate the composting of locally produced organic waste to develop specific composts for raspberry production that reduce the risk of nitrate leaching to the aquifer, replace fumigants currently being used, provide nutrients for raspberry production, and provide beneficial microorganisms that may reduce pesticide requirements. The report will provide recommendations and identify gaps where more information or research is needed.

Figure 1. Raspberries and poultry farms have coexisted on the Abbotsford aquifer for many years.
may be required.

**Specific Deliverables**

1. **Define qualities of compost that are important for raspberry production.**

Compost is a word that describes organic material that has undergone some degree of decomposition. Important compost qualities that may have an effect on raspberry production include nutrient content, pH, electrical conductivity and maturity. These qualities vary in compost depending on the source(s) of the organic matter, the composting process, and the length of time that the organic material has been composted and cured.

Based on experience and from literature studies, mature composts have a greater likelihood of providing disease resistance to plants, as well as a consistent release of nutrients such as nitrogen. The effect of compost maturity on suppression of root lesion nematode populations is not well understood.

2. **Quantify the amount of compost required for raspberry production over the Abbotsford-Sumas Aquifer.**

The amount of compost required for raspberry production is dependent on the application rate, the number of applications required (only for renovation/replant, or annual applications for nutrients and other beneficial effects), the potential land area for raspberry production as well as the current land area used for raspberry production.

3. **Investigate potential feedstocks for producing compost with desired qualities.**

Based on the qualities of compost determined to be important, potential feedstocks for making composts having these qualities will be investigated. Potential feedstocks for composting include agricultural wastes such as poultry litter, spent mushroom compost, waste from greenhouse pepper and tomato production. Yard waste and food waste from residential and commercial collection are also potential feedstocks to produce quality composts.

4. **Composting options to produce compost with desired qualities.**

There are many different methods and technologies for composting, including turned windrows, aerated piles and aerated and turned composting processes. Some of the technologies will be evaluated in terms of their ability to produce the compost with the desired qualities for raspberry production in the south coastal British Columbia climate. Environmental effects associated with these technologies will also be evaluated, including loss of nitrogen to the atmosphere as ammonia or nitrous oxide.

5. **Regulations affecting production of compost with desired qualities.**

There are federal, provincial and municipal regulations affecting composting. In British Columbia, these regulations include the CFIA trade memorandum for composts, the BC Ministry of Environment’s Organic Matter Recycling Regulation, the Agricultural Waste Control Regulation, and local bylaws. These regulations will be reviewed in light of producing composts having desired qualities for raspberry production.

6. **Economic analysis of producing and using compost for raspberry production.**

Potential effectiveness of using compost for raspberry production requires economic analysis that includes the cost of producing composts with desired qualities, as well as a cost/benefit analysis for using composts in berry production. Some of the agricultural and non-agricultural wastes may have
tipping fees associated with them which may offset the cost of compost. An environmental cost/benefit analysis will be difficult to quantify but contributing factors will be addressed.

7. Recommendations and identifying gaps.

This deliverable will summarize what is currently understood to produce and use compost for raspberry production. It will also identify gaps in our knowledge and recommendations for additional investigation or research.
Background on Raspberry Production over the Abbotsford Aquifer

Abbotsford produced almost 50% of the raspberries produced in Canada in 2011

Farms in the City of Abbotsford produce most of the raspberries in British Columbia and almost 50% of the raspberries produced in Canada in 2011 (43% of the land used for raspberry production, Statistics Canada Agriculture 2011). This statistic gives credence to the name that was proudly displayed for years along Highway #1 – Abbotsford – Raspberry Capital of Canada.

In 2000, Canada was ranked as the 6th largest producer of raspberries behind Russia, Serbia, USA, Chile and Poland. In that year, BC produced 13,843 tonnes of raspberries, or 5.7% of the world raspberry production (Raspberry Development Council 2000). British Columbia production of raspberries is decreasing relative to world production (FAO Statistics).

World Raspberry Production Has Increased in the Last 20 Years

World raspberry production increased from 134,000 tonnes in 1961 to more than 500,000 tonnes in 2005. World raspberry production declined slightly since then to approximately 490,000 tonnes in 2009 (FAO Statistics). Raspberry production in Washington State has increased almost four-fold in the past 20 years, compared with a decrease in production in British Columbia (Figure 3 below, courtesy of Mark Sweeney, BC Ministry of Agriculture).

Raspberry Production in Abbotsford has Declined More than 50% in the Last 20 Years

Raspberry production in Abbotsford decreased more than 50% from approximately 20,400 tonnes at its peak in approximately 1990 to less than 10,000 tonnes in 2011.

The decrease in raspberry production in Abbotsford was attributed to low raspberry prices and replacement of raspberries with blueberries (pers. comm. Mark Sweeney, BCMA). This decrease does not reflect the trends in world production or North American production.

Figure 2. Raspberry production at the Abbotsford airport

Figure 3. Raspberry production in BC and Washington (production in thousand lb per year).
Most of Canada’s Raspberry Production Occurs Over the Abbotsford Aquifer

According to the 2011 agricultural census, the land area in raspberry production in 2011 was 1312 hectares in Abbotsford. Of this 1312 hectares, approximately 1012 hectares of raspberry production occurs on the soil above the Abbotsford-Sumas Aquifer, a supply of groundwater with an area of 260 square kilometers, that is used as a water supply by more than 100,000 people in Abbotsford and northwest Washington State (Abbotsford-Sumas Aquifer International Task Force 2012). There is a shallow layer of soil underlain by mostly sand and gravel, which leaves the aquifer very susceptible to agricultural management on the soil surface, such manure and fertilizer management for raspberry production.

Raspberry Plantings Are Being Replaced with Blueberries in Abbotsford

Some of the land used for raspberry production in Abbotsford is being converted to blueberry production, with an increase in blueberry production from 1565 hectares 2006 to 2594 hectares in 2011 in Abbotsford (Statistics Canada Agriculture 2011). The area planted to raspberries decreased from 1636 ha in 2006 (Statistics Canada Agriculture 2006) to 1312 ha in 2011 (Statistics Canada Agriculture 2011).

The photograph on the right shows a large blueberry planting located over the Abbotsford Sumas Aquifer previously cropped to raspberries.

The transition to blueberry production is also evident on individual farms, where raspberries are being slowly replaced by blueberry plantings as shown in the photograph to the right.

Berry prices and Cost of Production Influencing Change from Raspberry Production to Blueberry Production in Abbotsford

World berry price is likely the most significant factor influencing the shift from raspberry production to blueberry production over the Abbotsford aquifer. The second factor is the cost of production resulting largely from increased disease pressure in raspberry production. According to the BC Ministry of Agriculture, ongoing concerns for raspberry production include root lesion nematode, followed by Phytophthora root rot, and a number of viruses.
Competition in a World Market

Competition in a world market requires that raspberry production in Abbotsford have a competitive edge. Historically, the soils and climate were well suited for raspberry production which in turn led to the development of a knowledge base, a processing infrastructure, and excellent support from provincial and federal agricultural staff through education, breeding programs and pest management programs.

There are a number of other ways that various geographical areas and raspberry growers have captured niche markets in the last number of years. These include development of flash frozen berries, organic berry production, and the development and adherence to Good Agricultural Practice (GAP), which is a series of formal programs designed to increase food safety.

There are very few organic raspberry farms over the Abbotsford Aquifer or in the Abbotsford area. In the US, a 2008 survey estimated that 7.7% of the US raspberry production was organic (AGMRC 2012). The challenges with pest control makes a transition to organic raspberry production more challenging, especially in our more humid climate in south coastal British Columbia.

Good Agricultural Practice is being adopted for fruit and vegetable production throughout North America. This is becoming a requirement for many processors and markets, and as such, it cannot be considered a niche market. Good Agricultural Practice requires that no raw manures be applied to the raspberry crop within 120 days of harvest (Global GAP 2012, Canada GAP 2012). This essentially means that no raw manures should be applied for raspberry production because fall and early spring application of manure is difficult and may result in a greater risk of groundwater pollution (BC Ministry of Agriculture 1997). Under Good Agricultural Practice guidelines, compost that meets specific compost quality specifications can be used as a fertilizer or soil conditioner. Good Agricultural Practice guidelines will be discussed further in the section on defining qualities of compost.

Poultry Manure Was Historically Used as a Soil Amendment for Raspberry Production

Establishment of the raspberry industry in Abbotsford coincided with an increase in poultry production. Many of the poultry farmers used the land on their farms for raspberry production and fertilized the raspberry plants with poultry manure. The shallow sandy soils benefited from the organic matter and nutrients provided by the manure. The manure was often top-dressed annually to established berry crops, and incorporated into the soil when replanting raspberry fields. The 1980 Berry Production Guide, published by the BC Ministry of Agriculture, recommended up to 22.5 tonnes of poultry manure per hectare (45 tonnes/ha if cow manure was used). The current Berry Production Guide recommends poultry manure application at rates of no more than 17 cubic yards per hectare (BC Ministry of Agriculture 2012a).

In the late 1980s and early 1990s, elevated nitrate concentrations were measured in the Abbotsford Aquifer and were reported to be primarily originating from poultry manure (Wassenaar 1995). Zebarth et al. (1994) reported that raspberry fields with a history of manure use accumulated more than two times more nitrate in the soil profile after harvest than fields without a history of manure application.

Poultry Manure Use When Replanting Raspberries

Raspberries are replanted every 8-10 years because plant vigor and berry yields begin declining after 4-7 years. This is thought to be due to soil borne pathogens such as root lesion nematodes and Phytophthora sp. (Forge at al. 2012). Phytophthora sp. are the primary cause of root rot in raspberry plants. Prior to 2011/2012, when new restrictions on fumigation were implemented, approximately 50%
of raspberry farms fumigated the soil prior to replanting to control nematodes and Phytophthora (pers. comm. Tom Forge, AAFC). Approximately 50% of the farms use poultry manure at replant (pers. comm. Mark Sweeney, BCMA). It is commonly understood that organic matter and nutrients in manure are good for the soil. Research demonstrating that incorporation of high rates of manure may reduce pathogens supports the conventional wisdom that replant incorporation of manure improves the quality of the soil for raspberries (pers. comm. Tom Forge, AAFC).

**Recent Research Identifies Poultry Manure Application as Contributing to Nitrate Pollution in the Aquifer**

Recent research indicates that application of high rates of poultry manure at the time of replanting to improve establishment and early growth led to high potential for nitrate leaching in the fall. Application of high rates of compost also improved early growth but decreased the risk of nitrate leaching in the fall (Forge 2012). Compost improved plant establishment and appeared to be inhibitory to the population of root lesion nematodes.

The results of this study suggest two potential and distinct benefits for using compost when replanting raspberries:

1. Reduced nitrate contribution to the aquifer
2. Decreased populations of root lesion nematodes

The second benefit may become more important if environmental and human health concerns regarding use of soil fumigants increase and alternatives to fumigants are promoted.
Defining Qualities of Compost for Raspberry Production

Compost is a term used to identify organic matter decomposed under aerobic conditions. Manure or other organic matter that is “aged” is sometimes referred to as compost. The term “compost” is also often used in conjunction with a self heating process to kill potential pathogens and weed seeds. The length and extent of the composting process varies, which may lead to very different characteristics than organic material that is “aged” or “composted” for a short period to kill potential pathogens.

Definitions of Compost

British Columbia’s Organic Matter Recycling Regulation (BC Ministry of Environment 2007) defines composting as follows:

"compost" means a product which is
(a) a stabilized earthy matter having the properties and structure of humus,
(b) beneficial to plant growth when used as a soil amendment,
(c) produced by composting, and
(d) only derived from organic matter;

"composting" means the controlled biological oxidation and decomposition of organic matter in accordance with the time and temperature requirements specified in Schedule 1 (minimum 55 C for 3 days throughout product for specified period).

British Columbia’s Agricultural Waste Control Regulation (BC Ministry of Environment 2008) mentions composting, but does not define compost as a product, or composting as a process.

British Columbia’s 2012 Berry Production Guide (BC Ministry of Agriculture 2012a) does not define “compost”, but alludes to food safety risks, and as such, recommends “only composted manure or manure aged at least 3 months should be used.”

British Columbia’s 2012 BC Good Agricultural Practices Guide (BC Ministry of Agriculture 2012b) does not define compost, but suggests that producers using composted manure meet the following guidelines:

- Become informed about proper treatment procedures (e.g. composting) that are designed to reduce or eliminate pathogens.
- When purchasing compost, ask for a certificate of analysis or documentation of treatment method to ensure the composting process is complete.
- When treating manure on-farm, record the treatment procedures (e.g. composting, anaerobic digestion), detailing the date treated and the method used.
- When treating manure on-farm, clean any equipment that is used to handle raw manure before handling finished compost so as not to re-introduce pathogens.

Organic Material Treatment Record (record template provided in the BC Good Agricultural Practices Guide), or your own record that includes:

- Date,
- Temperature,
- Turning frequency, and
- Initials.
The FDA Guidance for Industry: Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables (US Food and Drug Administration 1998) defines good agricultural practices for the use of animal manure or biosolids to include treatments to reduce pathogens and maximize time between application to production areas and harvest of the crops.

The US Produce GAPS Harmonization Initiative defines the use of manure and compost as follows:

“If animal-based soil amendments or biosolids are used, records of composition, dates of treatment, methods utilized and application dates must be documented. Evidence of processing adequate to eliminate pathogens of human concern, such as letter of guarantee, certificate of analysis (COA) or any test results or verification data (e.g., time and temperature) demonstrating compliance with process or microbial standards, shall be documented. Such soil amendments must be produced and applied in accordance with applicable federal, state, or local regulations.”

(United Fresh Foundation Center for Food Safety and Quality 2012).

The US Produce GAPS Harmonization Initiative also addresses raw or incompletely treated manure:

“Operation discontinues use, or develops and implements policies to safely use animal-based soil amendments that may contain raw or incompletely treated manure. Produce grown without such controls are either diverted to thermal-processed products or destroyed.”

(United Fresh Foundation Center for Food Safety and Quality 2012)

In the absence of further specific definitions, “compost” and “composting” will be defined as per the Organic Matter Recycling Regulation (BC Ministry of Environment 2007), which includes a specific period of thermophilic activity to kill potential pathogenic organisms as required and understood in the internationally accepted Good Agricultural Practices Guidelines.

Availability of Nitrogen and other Nutrients in Composts

In general, nutrient release characteristics from compost are dependent on the source of the organic material to produce the compost, the amount of nutrients in the organic material that was composted, the age of the compost and the carbon to nitrogen ratio (C/N ratio) of the compost. For this discussion, nitrogen in the compost will be the primary consideration, as this is the nutrient causing the most concern with potential nitrate contamination of the Abbotsford Aquifer.

For example, poultry manure composted for three days to meet pathogen kill requirements as required by the Organic Material Review Institute regulations (OMRI 2012) may have significant available nitrogen remaining. In comparison, poultry manure composted for 6 months or more will have much less available nitrogen. The nitrogen in poultry litter composted for a longer period will be stored primarily in the organic fraction, and will not be as available to the plant, or for leaching. Yard waste compost typically has lower nitrogen concentrations, higher C/N ratio, and slower nitrogen release than poultry manure based composts (Bomke et al. 2004).

Rosen and Bierman (2005) estimated that 30% and 14% of the nitrogen in composted poultry manure and dairy manure, respectively, was available for a crop in the year of application. They did not specify or define compost, but the estimates reflect higher nitrogen contents in poultry manure compost than in dairy manure compost. The soluble ammonium fraction in poultry manure compost is typically higher than in dairy cattle manure compost.
The age of the compost is a primary factor in determining the ammonium to nitrate ratio in compost. Organic material high in nitrogen such as poultry manure that has been composted for only a short period of time will have a high ammonium concentration, which will decrease with time as the ammonium is converted to nitrate during the composting process (Figure 6).

![Changes in ammonium and nitrate during a one year composting process with animal manure](image)

*Figure 6. Changes in ammonium and nitrate during a one year composting process of duck and goose manure. It is interesting to note that in this case, some of the ammonium would have been lost to the atmosphere and the nitrate would have been mineralized from the nitrogen fraction with time (Source: Transform Compost Products).*

The C/N ratio will define the amount of ammonium and/or nitrate in the compost as well as the nitrogen release characteristics of the compost. In general, as the C/N ratio of the compost increases, the concentration of available nitrogen as either ammonium or nitrate decreases. It is also likely to observe a more rapid conversion of ammonium to nitrate. Bomke et al. (2004) observed that high ammonium concentrations remained in poultry manure based composts after 180 days of composting.

Compost having a C/N ratio of less than 15 may release significant amounts of soluble nitrogen available for plant growth. Poultry manure composts will typically have C/N ratios below 15. Compost with a C/N ratio above 25 will not provide much soluble nitrogen for plant growth, and will pose negligible risk for nitrate leaching (Bomke et al. 2004). Further decomposition of high C/N ratio composts in soil may actually require more nitrogen than the compost contains, which means that the soil microbes may remove plant available nitrogen from the soil around the compost if it is available. It must be
understood that significantly more nitrogen will be required to further decompose sawdust or woodwaste applied to soil. Separated dairy cow manure containing bedding, beef feedlot manure containing bedding, and yard waste compost with a high amount of wood trimmings may have C/N ratios above 25 and will likely release little nitrogen for crop growth and present a negligible risk of nitrate leaching.

**pH and Electrical Conductivity in Compost**

Raspberries require a pH between 5-6 (BC Ministry of Agriculture 2001), or 5.5 to 6.5 (Ontario Ministry of Agriculture 2012). Raspberries also grow well in higher pH soils (Ontario Ministry of Agriculture 2012). Raw poultry litter has a high pH of up to 9, depending on the age and type of litter (Keener et al. 2011). The pH of compost depends on a number of factors including nitrogen content, age of the compost and the amount and type of wood in the compost. High pH values in immature compost are usually transient and related to the ammonium concentration of the compost. For example, the compost identified in Figure 6 started with a pH of 8, and ended with a pH of less than 5. As can be seen from Figure 6, this was related to the ammonium concentration. Most animal waste composts will have a high pH at the beginning of the composting process, which may decrease as the compost ages, depending on the amount of wood in the compost. Haque and Vandepopulierre (1994) reported that the pH of three layer manure based composts increased from 8.9 to 9.0 following 57 days of aerated composting. During this period, ammonium concentrations decreased from 413 to 167 mg N kg\(^{-1}\). This supports the suggestion that animal manures having a high nitrogen concentration will require a longer composting period before the pH is reduced significantly.

Yard waste compost typically has a lower pH. Addition of food waste to yard waste increases the nitrogen content of the composting material, which then increases the pH during the composting process and is likely to maintain a higher pH for a longer time period.

Electrical conductivity (EC) is a measure of the soluble nutrients in compost or soil. Electrical conductivity typically ranges from less than 1 dS/M in some woodwaste based compost to greater than 12 dS/M in poultry litter based composts. Raw poultry litter has a high electrical conductivity because of the significant concentration of soluble nutrients.

Higher electrical conductivity in compost indicates a higher concentration of soluble nutrients, most of which are required for plant growth. The sodium concentration in manure or compost is typically less than 15% of the total electrical conductivity. It is not possible to grow plants directly in most composts, as the electrical conductivity in the compost will cause dehydration in the plant. This is also true for raw or partially composted poultry litter. Compost is generally incorporated into the soil, allowing for a dilution of the soluble nutrients in the compost.

Many plants are negatively affected in soil having an electrical conductivity higher than 3 dS/M, but it requires extremely high rates of compost over a long period of time to significantly increase the soil electrical conductivity with the high rainfall in south coastal BC.

Electrical conductivity in compost is most likely to be a concern for early raspberry growth with compost containing high electrical conductivity applied at substantial application rates (50-100 tonnes per ha) shortly before planting during a very dry period. The possibility of raspberry growth suppression due to high electrical conductivity needs to be considered in future research to determine optimum compost application rates when replanting raspberry fields.
Compost Characteristics for Disease Suppression

The use of compost may provide disease suppression for the raspberry plants. It is well understood that increasing soil organic matter with compost reduces the need for pesticides and chemicals. There are four mechanisms for this (Campbell 2006):

1. Competition for nutrients between microbes in the compost and potential pathogens in soil
2. Production of antibiotic compounds by microbes in compost
3. Predation of potential pathogens in soil by beneficial microbes in soil, and
4. Activation of disease-resistant genes in plants by compost-inhabiting microorganisms, known as induced systemic resistance (ISR) or systemic acquired resistance (SAR), which means that the plant has a greater resistance to potential pathogens

There are two excellent literature reviews that outline the plant disease suppressive effects of compost (Campbell 2006, Amlinger 2007). The general conclusion from these two literature reviews is that compost maturity is the most significant factor in determining whether the compost is disease suppressive. Other general observations from the two literature reviews are:

1. Specific disease suppressive effects of compost are more likely for soil-borne pathogens and not for pathogens that attack leaves or stems
2. Composts with high ammonium concentrations are not as disease suppressive as compost with low ammonium concentrations
3. Composts with high amounts of lignin demonstrate disease suppressive qualities for a longer period of time.
4. Compost can induce all four mechanisms of increased disease resistance (outlined above)

Campbell (2006) concluded that the level of suppression for diseases and pests ranged from 20 to 90% with soil-borne diseases. He further noted that disease suppression varied with compost type and application rate, as well as different batches of the same compost.

The source of the composted organic material is not as important as the maturity of the compost. Amlinger (2007) concluded that compost produced from poultry litter demonstrated the least disease suppressive effects. It is possible that this is due in part to the high ammonium concentrations found in most poultry manure composts. Both Amlinger (2007) and Campbell (2006) concluded that the source of the compost was less important than its maturity.

In a more recent literature review, Noble (2011) summarized that in 59 out of 79 container experiments, addition of 20% (v/v) or more compost in the growing medium provided disease suppression in plants. He reported that in field experiments, addition of compost resulted in greater disease suppressive effects in 45 out of 59 experiments.

It is important to define mature compost, as maturity appears to be the most significant factor in defining compost that is more likely to suppress disease. Campbell (2006) defines the composting process in three phases, where the disease resistance qualities of the compost begin to develop in the third phase, after 27 to 365 days of composting. During this period, the temperature is normally below 50 °C, some of the lignin, cellulose and hemicellulose are degraded by thermophilic fungi, and there is intense competition for remaining food. It appears that the beneficial organisms do not function well at temperatures above 50 °C. This then suggests that if the compost is still > 50 °C, optimal disease suppressive effects of the compost are not as likely to develop.

With many composts, the peak of disease suppression potential is more likely to occur with compost that is greater than 6-12 months old, as many composts may maintain temperatures well above 60 °C.
even after 4-6 month of composting and curing. The size of the curing piles of compost is also a factor in the development of favorable conditions for the development of disease suppressive microorganisms because larger curing piles will retain heat for a longer time period.

The development of disease suppressive characteristics assumes that the compost remains at a moisture content conducive to microbial growth. The moisture content of the compost should be maintained at 40 to 50% moisture for the potential disease suppressive organisms to flourish (Campbell 2006). In south coastal British Columbia, composts that are being cured must be covered during the fall, winter and early spring to maintain moisture contents in compost from 40 to 50%.

There is local experience with producing disease suppressive composts. Kannangara et al. (2000) reported significant suppression of the soil borne fungal pathogen *Fusarium oxysporum* on cucumber. This suppressive effect was observed with compost produced from separated dairy solids. This compost was produced in an actively turned windrow process followed by curing for more than six months. The other two products, a worm casting and a product produced from aerobic digestion, did not demonstrate the same effects. The separated dairy manure compost happened to have lower ammonium concentrations and more bacteria and fungi than the other two products.

**Compost for Control of Root Lesion Nematodes**

In contrast to the considerable research on fungal diseases, the evidence of compost-induced suppression of pathogenic nematodes is not clear. Kimpinski et al. (2003) reported increased concentrations of all types of nematodes, including root lesion nematodes, during a 7 year study on potatoes in Prince Edward Island. Nahar et al. (2006) observed that spring incorporation of both raw and composted dairy cattle manure increased the numbers of non-plant parasitic nematodes but decreased plant parasitic nematode numbers in a soil in Ohio.

There has been research specifically with composts on raspberry production in south coastal BC. Forge and Kempler (2009) studied responses of nematode communities to surface application of compost at modest rates. They concluded that it was difficult to generalize about the growth-promoting or disease suppressing properties of composts because there was no consistent decrease in the numbers of plant parasitic nematodes following addition of compost. They observed that the numbers of plant parasitic nematodes in soil was inversely related with the number of omnivorous and predacious nematodes.

Forge (2012) reported substantially decreased densities of root lesion nematodes following addition of compost and poultry manure during replant of a raspberry crop. The suppression observed by Forge (2012) may have been related to the high application rates used (88 tonnes per ha of compost). In this study, neither the compost nor the manure was as effective as fumigation in reducing root lesion nematode density in the soil. The suppression of parasitic nematodes by raw poultry manure is well documented (Everts et al. 2006), and thought to be the result of biocidal ammonia. It was suggested that the controlling mechanism in compost-amended soil was perhaps enhanced biological control by natural enemies of nematodes rather than a biocidal effect. This research is particularly important because fumigation is expensive and environmental concerns have led to discussion on finding safer products to reduce root lesion nematodes. Similar conclusions on the effect of compost on root lesion nematodes were found by Forge et al. (2012 under review) with an application of compost dairy manure solids in raspberry production.

One explanation that suggests reduced incidence of disease may be observed without measuring less root lesion nematodes is as follows: “Nematodes usually form disease complexes with otherwise “minor” fungal plant pathogens, and the possibility exists for compost to improve root health without
necessarily reducing nematode populations by suppressing the fungal component of the root disease complexes” (pers. comm. Tom Forge, AAFC).

Conclusions

1. Organic material should be properly composted for the required times and temperatures to reduce potential pathogens as required under the Good Agricultural Practice guidelines.

2. Compost should be fully mature (6-18 months, depending on manure and on process) to have the greatest likelihood of exhibiting disease suppressive effects.

3. Compost produced from poultry manure only is not likely the best product for disease suppression, as it may result in too much nitrogen loss during composting, and may pose a risk of nitrate leaching if used as an amendment at high rates.

4. Modest annual applications of compost may supply the annual phosphorus and potassium requirements of the raspberries, but may not supply the annual nitrogen requirements, particularly during the period of rapid growth. This is true in particular if the C/N ratio of the compost is higher than 15. Compost should be applied in the spring for optimal nutrient benefit.

5. While compost applications may not meet crop nitrogen requirements in the year of application, cumulative applications and accumulation of mineralizable nitrogen may reduce fertilizer requirements. The potential for reduced fertilizer inputs may be monitored using an end of season nitrate test “report card” approach (BC Berry Production Guide 2012).
Identifying Quantities of Compost Required for Raspberry Production

Identifying the quantity of compost required for raspberry production is dependent on four factors:

1. The amount of land cropped to raspberries
2. Whether compost is only used at replant or also used annually
3. Economics – the price of compost and the price of fertilizer
4. How much compost can be applied

Amount of Land Cropped to Raspberries

The current land base over the Abbotsford aquifer planted to raspberries is estimated at 2500 acres (1012 ha) (pers. comm. Mark Sweeney, BCMA). Based on Census of Agriculture data, the land area in 1991 was 3376 acres (1367 ha) (Zebarth et al. 1998). Raspberry production peaked in approximately 1986 at 45 million lb., whereas it is currently 22 million lb. per year. Based on discussions with Mark Sweeney (BC Ministry of Agriculture), the average raspberry production per hectare has not significantly changed as increased yield potential from improved varieties is offset by increased disease pressure. This suggests that the land area for raspberry production may have been as high as 5000 acres (2024 ha) at the peak of raspberry production.

The present land area of 2500 acres (1012 ha) will be used to calculate potential compost requirements with the understanding that there is a potential for double this area over the Abbotsford Aquifer. Increased land area used for raspberry production requires higher economic returns for raspberries, either through higher world berry prices, or a niche market creating higher prices.

There are two potential uses for compost during raspberry production. The first use is for application of compost during replant or crop establishment. This occurs every 8-10 years as disease damages the raspberry plants. The second use is for annual spring application of compost as a nutrient source for the raspberry crop.

Compost Required for Replant

Based on a land area of 2500 acres (1012 ha), and raspberries being replanted every 8-10 years (pers. comm. Mark Sweeney, BCMA), the area requiring compost for raspberry replant is 278 acres (112 ha) (Table 1).

Table 1. Compost required for replanting raspberries.

<table>
<thead>
<tr>
<th>Current area in raspberry production</th>
<th>1012 hectare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area replanted annually (9 years)</td>
<td>112 hectare</td>
</tr>
<tr>
<td>Compost required @ 50 tonnes per ha</td>
<td>5,600 tonnes per year</td>
</tr>
<tr>
<td>Compost required @ 100 tonnes per ha</td>
<td>11,200 tonnes per year</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Potential area in raspberry production</th>
<th>2024 hectare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential area replanted annually</td>
<td>224 hectare</td>
</tr>
<tr>
<td>Compost required @ 50 tonnes per ha</td>
<td>11,200 tonnes per year</td>
</tr>
<tr>
<td>Compost required @ 100 tonnes per ha</td>
<td>22,400 tonnes per year</td>
</tr>
</tbody>
</table>

The optimal amount of compost that can be applied at replant has not been determined and would depend on compost quality. Assuming a compost with a C/N ratio of > 15, and depending on the nutrient content, application in the range of 20 tonnes per acre (50 tonnes per hectare) to 40 tonnes per
acre (100 tonnes per ha) may be appropriate. Recent research by Agriculture and Agri-Food Canada showed that rates of up to 88 tonnes per hectare of compost did not result in significantly higher nitrate concentrations in the soil profile after harvest than in the soil that was not amended with compost or manure (Forge et al. 2012).

Research is required to determine optimal application rates at which root health and establishment are maximized without excessive P inputs or nitrate production. Optimal application rates will also vary with the type of compost used. Up to 11,200 tonnes of compost per year is required for replant, assuming 2500 acres (1012 ha) cropped to raspberries, replanted every nine years (278 acres or 112 ha per year) with an application rate of 40 tonnes per acre (100 tonnes per hectare) (Table 1).

**Compost Required for Annual Spring Compost Application for Raspberry Production**

Annual spring compost application will supply nutrients and organic matter. The amount of compost required for annual spring application depends on the fertilizer value of the compost in the first and subsequent years after application, the actual nitrogen requirements of the raspberry crop, and whether the compost is used in conjunction with fertilizer or other sources of N.

The BC Ministry of Agriculture Berry Production Guide (2012a) recommends poultry manure applications of up to 17 cubic yards per hectare. The guide recommends either composted manure or manure that has been aged for more than 3 months. Good Agricultural Practices guidelines (BC Ministry of Agriculture 2012b) require any manure to be composted.

Compost must be applied during the spring after the period of major rainfall and leaching potential. The Environmental Guidelines for Poultry Producers (1997) recommended that poultry manure should only be applied to soils having established cover crops from September through March. Compost application in early April would be recommended for the greatest likelihood of nutrient uptake in the year of application.

**Fertilizer Value of Compost for Annual Application**

The fertilizer value of compost can be difficult to define. Compost provides nitrogen, phosphorus, potassium, and many of the micronutrients required for crop production. In terms of nitrogen, the availability of nitrogen is typically lower from compost than from raw manure. Nitrogen availability depends on many factors, but primarily C/N ratio and compost maturity (Gale et al. 2006).

The 2012 Berry Production Guide (BC Ministry of Agriculture 2012a) bases its manure guidelines on raw poultry manure, and does not include any suggestions for composts. The nitrogen credits in this guide are 4.5 kg N/yd³ if the manure is incorporated, and 3.0 kg N/yd³ if the manure is not incorporated. This assumes 50% nitrogen availability for incorporated manure and 33% for unincorporated manure. The 50% nitrogen availability for incorporated manure is based in part on research that measured 50% recovery of manure nitrogen 30 days after incorporation of manure (Dean et al. 2000). Bomke et al. (2004) measured 39 and 38% nitrogen availability for turkey and broiler litter, respectively, in the year of application. Gale et al. (2006) measured 40% plant available nitrogen from broiler litter manure during the growing season when it was incorporated within 2 hours of application in Washington State.

Nitrogen availability from compost ranges from 5 to 25%, which is generally lower than from uncomposted manures. Nitrogen availability in the year of application is dependent on the nitrogen concentration in the compost, how long the material was composted, and the C/N ratio of the compost. If the composting process is very short, the “compost” has almost the same characteristics as raw manure. Gale et al. (2006) observed that “composted” poultry manure had similar decomposition.
characteristics as fresh poultry manure and concluded the “composting” process used for the poultry manure composts used in their experiments was not very effective. Bomke et al. (2004) measured 10 to 26% nitrogen availability with a compost made with 60% poultry litter and 40% yard waste. Gale et al. (2006) further observed that composts with a C/N ratio of 9 to 27 averaged a release of 7% plant available nitrogen for a corn crop in the year of application.

Compost may supply additional nitrogen in subsequent years following application. Sanchez (2009) suggested that the nitrogen value of compost is more likely to be 20% the first year, and 10% for the second year. Gale et al. (2006) suggested that first year nitrogen availability may be as low as 7%, which suggests that nitrogen availability in subsequent years may be significantly lower than the 10% suggested by Sanchez (2009).

For the purpose of calculating nitrogen fertilizer value of compost, 20% of the nitrogen is assumed available in the year of application. First year nitrogen availability of compost is highly variable, depending on the type and age of the compost. Additional nitrogen will be available in subsequent years following compost application. There are other important long term benefits of compost application.

“The literature as well as the expert discussions during the symposium confirmed that compost cannot be assessed exclusively on account of the short-term fertilisation effect. Compost provides nutrients in different bonding and mobility forms. It changes the soil conservation and formation processes and the exchange dynamics for nutrients as well as the water household and material transformation. This stands in close connection with the properties of the humified organic matter i.e. the colloidal structure of humic matter.” (Amlinger et al. 2007).

**Compost in Conjunction with Fertilizer**

Compost will likely be used in conjunction with mineral fertilizer. Although the amount of nitrogen removed in the berry crop is 15-20 kg N per hectare (Dean et al. 2000), the nitrogen recommendations for raspberries are up to 100 kg N per hectare depending on yield expectancy (BC Ministry of Agriculture 2012a). Actual fertilizer nitrogen application for some growers ranges from 85 to 95 kg N per hectare (pers comm. Mark Sweeney, BCMA).

**Compost May Provide all of the Required Phosphorus and Potassium**

Compost provides phosphorus, potassium and other elements. Actual estimates of phosphorous and potassium availability varies with compost and soil type. Rosen and Bierman (2005) estimated that 70 to 80% of the phosphorus (P) and 80 to 90% of the potassium (K) was available from manure and compost in the year of application. In his review of the literature, Amlinger (2007) reported one study suggesting that 35% of the phosphorus was plant extractable, 20% was organic and more than 75% of the potassium in compost was soluble and plant available. Amlinger (2007) also correctly pointed out that mineral fertilizers do not have 100% efficiency. They reported that in the year of application, phosphorus efficiency rages from 15 to 20%, and potassium efficiency from 50 to 60%. In their literature review, many studies showed an increase in soil P and K concentration with repeated compost applications.

In some areas of North America and Europe, organic matter and fertilizer application to soil is controlled on the basis of phosphorus. This means that if phosphorus addition to soil will be limited based on soil phosphorus concentrations, it may reduce the amount of compost that can be applied.

The BC 2012 Berry Production Guide (Ministry of Agriculture 2012a) recommends fertilizer phosphorus and potassium applications based on the P and K concentrations in the soil. Recommended phosphorus
rates are 70 to 90 kg P\(_2\)O\(_5\) per hectare if the soil phosphorus concentration is low, and zero fertilizer if the concentration is rated as high or very high. Potassium fertilizer recommendations are 90 to 115 kg K\(_2\)O per hectare if the soil potassium concentrations are low, and zero fertilizer if the soil concentration is rated as very high. Potassium is more likely to be lost through leaching than phosphorus is. Phosphorus and potassium concentrations on many raspberry fields over the Abbotsford aquifer are already very high (Kowalenko et al. 2007).

With compost applied at a rate of 7 tonnes per hectare annually, a moisture content of 60%, and compost P\(_2\)O\(_5\) and K\(_2\)O concentrations of 1.5%, compost will provide an estimated 42 kg of P\(_2\)O\(_5\) and K\(_2\)O per hectare annually. It is unlikely that fertilizer phosphorus and potassium will be required with continued annual compost applications, but this may also depend on soil phosphorus and potassium concentrations. Soil phosphorus concentrations may impact the amount of compost that can be applied in the future. Discussions on this topic have been ongoing for more than 20 years. Concerns about high phosphorous in soil are mostly in relation to the risk of sediment transport into surface waterways. Most of the raspberry land over the Abbotsford aquifer is relatively flat and not considered high risk for phosphorous loss. The amount of phosphorus and potassium supplied by the compost is another reason for limiting annual compost applications to 7 tonnes per hectare.

**Calculating the Amount of Compost Required for Annual Applications for Raspberry Production**

An annual spring compost application rate of 7 tonnes per hectare is suggested for the following three reasons:

1. Current recommendations for poultry litter are in a similar range of application (BC Ministry of Agriculture 2012a).
2. This rate of compost matches more closely with nitrogen cycling in the raspberry crop.
3. This conservative rate of compost limits the potential for excess phosphorus and potassium accumulation.

The annual addition of compost should be based on the long term nitrogen cycling requirements of the raspberry crop, where the annual removal of nitrogen is 15 to 20 kg N per hectare per year. This would be equivalent to 3.5 to 7.0 tonnes of compost per hectare (7.5 to 15 yd\(^3\) per hectare). Both of these application rates are lower than the maximum poultry manure application rate suggested in the 2012 Berries Production Guidelines (BC Ministry of Agriculture 2012a). For comparison, a higher rate of application corresponding to 80 kg N per hectare is included, where 16 kg N per hectare is assumed available in the year of application. Part of the rationale for the lower rates of compost application is to avoid excess accumulation of phosphorus and potassium in the soil.

**Table 2. Estimated total and available nitrogen (N) from spring applied compost at various application rates.**

<table>
<thead>
<tr>
<th>Annual Total N from Compost</th>
<th>20</th>
<th>40</th>
<th>80</th>
<th>kg N/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent N in compost</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>%</td>
</tr>
<tr>
<td>Moisture Content of Compost</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>%</td>
</tr>
<tr>
<td>Compost Application</td>
<td>3.3</td>
<td>6.7</td>
<td>13.3</td>
<td>tonnes compost/ha</td>
</tr>
<tr>
<td>Bulk Density of Compost</td>
<td>600</td>
<td>600</td>
<td>600</td>
<td>kg/cubic meter</td>
</tr>
<tr>
<td>Compost Application</td>
<td>5.6</td>
<td>11.1</td>
<td>22.2</td>
<td>cubic meters/ha</td>
</tr>
<tr>
<td>Compost Application</td>
<td>7.4</td>
<td>14.8</td>
<td>29.6</td>
<td>cubic yards/ha</td>
</tr>
<tr>
<td>Available N from Compost</td>
<td>4</td>
<td>8</td>
<td>16</td>
<td>kg N/ha</td>
</tr>
</tbody>
</table>
Depending on the compost application rate, and the present and potential area in raspberry production over the Abbotsford Aquifer, the total annual compost requirement ranges from 3000 to 30,000 tonnes per year (Table 3). The estimate of 6,300 tonnes per year of compost is a reasonable estimate for annual compost requirements, which assumes an annual compost application of 7 tonnes per hectare.

Table 3. Compost required for annual application in raspberry production.

<table>
<thead>
<tr>
<th><strong>Current area in raspberry production</strong></th>
<th>1012 hectare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area in annual production less replant</td>
<td>900 hectare</td>
</tr>
<tr>
<td>Compost required @ 3.5 tonnes per ha</td>
<td>3,150 tonnes per year</td>
</tr>
<tr>
<td>Compost required @ 7 tonnes per ha</td>
<td>6,300 tonnes per year</td>
</tr>
<tr>
<td>Compost required @ 15 tonnes per ha</td>
<td>13,500 tonnes per year</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Potential area in raspberry production</strong></th>
<th>2024 hectare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential area replanted annually</td>
<td>1800 hectare</td>
</tr>
<tr>
<td>Compost required @ 3.5 tonnes per ha</td>
<td>7,084 tonnes per year</td>
</tr>
<tr>
<td>Compost required @ 7 tonnes per ha</td>
<td>14,168 tonnes per year</td>
</tr>
<tr>
<td>Compost required @ 15 tonnes per ha</td>
<td>30,360 tonnes per year</td>
</tr>
</tbody>
</table>

Conclusions

6. Raspberry production may benefit from a larger application of compost (50 to 100 tonnes per ha) during replant (every 8-10 years) as well as from annual spring application (7 tonnes per ha) to supply some or all of the annual nutrient requirements.

7. The amount of compost applied depends on soil phosphorus and potassium concentrations, as compost will supply both of these nutrients as well as many micronutrients.

8. Compost must be added in the spring to provide optimal nutrient benefit for the raspberries and reduce the risk of nutrient loss through leaching.

9. The amount of compost required annually for 1012 ha of raspberry production over the Abbotsford aquifer is estimated to be 5,600 tonnes for replant (50 tonnes per ha) and 6,300 tonnes for annual spring applications (7 tonnes per ha) for a total compost requirement of 11,900 tonnes per year.
Investigating Potential Feedstocks for Producing Composts with Desired Characteristics

Understanding the potential for composting various feedstocks to produce quality compost for raspberries, requires knowledge of composting basics. Some compost feedstocks have excellent characteristics for composting without addition of other organic materials. Most feedstocks require blending of materials to provide optimal moisture content, optimal bulk density and porosity, and C/N ratio.

The type of organic wastes that are available are also important, including quantities, characteristics, and potential tipping fees.

Composting Theory

Composting is a natural biological process, where aerobic microorganisms (primarily bacteria and fungi) decompose organic waste to produce a stable organic product that enhances the quality of the soil by providing organic matter, nutrients and beneficial microorganisms.

Human-controlled composting optimizes conditions needed for the natural decomposition process. By creating ideal conditions, a much faster and efficient decomposition of organic waste and stabilization of the final product can be achieved.

In order to enhance the composting process, the following criteria are important:

**Temperature**

The optimal temperature for composting is between 55 and 65 degrees C. This temperature is created by the microorganisms themselves and is important for killing potentially pathogenic organisms and weed seeds. At temperatures below 55 C, the process is slower and may not result in potential pathogen and weed seed kill. At temperatures higher than 65 C, some of the beneficial microorganisms may be killed which also slows the process. The temperature can be controlled by adjusting moisture, enhancing aeration and by mixing.
**Air-Filled Porosity**

Air-filled porosity refers to the volume of air inside a volume of compost. The organic waste must allow the passage of air through the material because composting is an aerobic process, where microorganisms require oxygen to decompose the organic material. The recommended air-filled porosity is between 35 and 45% of the volume of the material. Air-filled porosity is usually not measured directly, but inferred from measuring bulk density and moisture content.

**Bulk Density**

The bulk density is the total weight of the composting material (dry matter plus water) per volume, usually expressed in kilograms per cubic meter. The composting material should have a bulk density between 600 and 700 kg per cubic meter. Material having a bulk density lower than this is likely too dry, or the particles are too large to compost properly. Material having a higher bulk density is likely too wet, or has particles that are too small to allow oxygen to enter the material.

**Moisture Content**

The moisture content of the composting material must be between 45 and 65% (measured as the weight of water divided by the total weight of material). The bacteria and fungi important for composting live in a water layer around the organic particles. If the moisture content is below 45%, there is not enough water around the particles for the microorganisms to live, and if the moisture content is greater than 65%, the pores between the particles fill with water, and the microorganisms do not obtain enough oxygen. The rule of thumb is that if water can be squeezed out of the material, the moisture content is likely greater than 70% and is too wet.

**Mixing**

Mixing the composting material is very important to ensure that all of the material reaches temperatures required for potential pathogen and weed seed kill. Mixing also breaks preferential air pathways that develop, preventing oxygen from reaching all of the composting material. Development of preferential air pathways slows the composting process by creating anaerobic microsites in the compost.

**Available Organic Materials for Composting**

Composts can be produced from many different types of organic matter. With the close proximity of urban areas and the intensive agriculture in the Fraser Valley, there is a large variety of organic matter available that can be used to produce compost. There are a few organic materials that can easily be composted on their own. Other organic material may need to be blended with wood waste or other...
Some organic materials were purposely not included in this study. Liquid dairy cattle manure has a high moisture content, and is typically utilized on the dairy farms. Composting this manure would require too much wood waste or other bulking agent to be a practical solution for this industry. The same is true for digestate from a liquid anaerobic digester. Separated dairy solids are included as this product is sometimes in excess on large dairy farms. Slaughter waste has intentionally not been included because of prohibited material reporting requirements as discussed in the section on regulation. The most readily available organic materials that may be composted in south coastal British Columbia will be discussed as per Table 4.

Table 4. Characteristics of various feedstocks for composting.

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Tipping fee</th>
<th>Odor Potential</th>
<th>Physical Contaminants</th>
<th>Chemical Contaminants</th>
<th>Needs wood waste for bulking</th>
<th>Type of product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal manures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>poultry</td>
<td>No</td>
<td>yes</td>
<td>No</td>
<td>no</td>
<td>yes/no</td>
<td>organic fertilizer</td>
</tr>
<tr>
<td>Horse</td>
<td>No</td>
<td>minimal</td>
<td>Some</td>
<td>no</td>
<td>No</td>
<td>soil amendment</td>
</tr>
<tr>
<td>dairy (solids)</td>
<td>No</td>
<td>minimal</td>
<td>No</td>
<td>no</td>
<td>No</td>
<td>soil amendment</td>
</tr>
<tr>
<td>Spent mushroom compost</td>
<td>No</td>
<td>minimal</td>
<td>No</td>
<td>maybe</td>
<td>No</td>
<td>soil amendment</td>
</tr>
<tr>
<td>Poultry processing waste</td>
<td>Small</td>
<td>high</td>
<td>No</td>
<td>no</td>
<td>yes</td>
<td>soil amendment</td>
</tr>
<tr>
<td>Greenhouse waste</td>
<td>Small</td>
<td>some</td>
<td>Yes</td>
<td>no</td>
<td>No</td>
<td>soil amendment</td>
</tr>
<tr>
<td>Biosolids (sewage sludge)</td>
<td>Good</td>
<td>yes</td>
<td>No</td>
<td>yes</td>
<td>yes</td>
<td>limited use</td>
</tr>
<tr>
<td>Commercial food waste</td>
<td>Good</td>
<td>yes</td>
<td>Some</td>
<td>minimal</td>
<td>yes</td>
<td>soil amendment</td>
</tr>
<tr>
<td>Yard waste from communities</td>
<td>Good</td>
<td>minimal</td>
<td>Some</td>
<td>no</td>
<td>No</td>
<td>soil amendment</td>
</tr>
<tr>
<td>Yard waste/food waste blend</td>
<td>Good</td>
<td>yes</td>
<td>More</td>
<td>minimal</td>
<td>No</td>
<td>soil amendment</td>
</tr>
</tbody>
</table>

**Poultry manure**

A 2003 study (Timminga & Associates 2003) predicted production of 320,000 tonnes of poultry manure annually in British Columbia by 2010. This report identified four separate sectors in the poultry industry:

1. Broiler chicken - 51% of production – drier manure, contains sawdust bedding
2. Turkey – 23% of production – drier manure, contains sawdust bedding
3. Commercial Egg – 16% of production – higher moisture content, contains no bedding
4. Hatching Egg – 10% of production – higher moisture content, may or may have bedding

Much of the poultry industry is located in or near Abbotsford, and the manure has traditionally been applied to local raspberry fields. Some of this manure is being exported to other areas (Bomke et al. 2004).

Much of the broiler and turkey manure is either used in mushroom compost production, or is used for forage and vegetable production in the Fraser Valley and elsewhere. A significant amount of broiler
manure is now undergoing a short composting process to meet OMRI certification requirements and exported to Eastern Washington.

The commercial egg and hatching egg manure typically has higher moisture content than broiler or turkey litter and is not as cost effective to transport long distances. Most of this manure is utilized locally.

Poultry manure should not be composted as a sole ingredient source for raspberry production for the following reasons:

1. Composted poultry litter remains high in pH and nutrient concentration
2. Composting poultry litter results in significant ammonia losses unless blended with adequate amounts of bulking agent to encourage immobilization of the ammonia
3. Composting poultry litter has a high risk of odor emission during composting
4. Poultry litter has a higher and better use as an organic fertilizer or ingredient in mushroom compost production.

If poultry manure were included as an ingredient in the composting process, no more than 25% of the composting material should consist of poultry litter. The reason for this is dilute the nitrogen content of the poultry litter which reduces the ammonium concentration and high pH in the compost. Bomke et al. (2004) reported successfully composting 60% poultry litter with 40% composted yard waste. Although this process worked well, the ammonium concentrations in the compost remained very high after 180 days of composting.

**Horse manure**

There are an estimated 24,600 horses in the Lower Mainland of BC (BC Horse Council 2009). Assuming manure and bedding production of 56.6 L per horse per day (BC Ministry of Agriculture 2007b), the Lower Mainland produces 508,000 cubic meters of manure per year. At an average bulk density of 400 kg per cubic meter, the equivalent of 203,000 tonnes of manure is produced annually.

Horse manure consists primarily of shavings bedding with manure and urine. Many horse farms have bins on their farm and export manure to off-farm locations. There are costs associated with horse manure disposal. Moisture content varies with the season as most of the horse manure is stored outdoors.

There are two challenges with horse manure:

1. The moisture content of the manure depends on the time of year because many farms store the manure in outdoor piles or bins. Because of this, the manure will be wet during the rainy season and dry during the summer. This makes planning and management of a compost facility more challenging.
2. Horse manure composts benefits from being co-composted with other organic material that has a lower C/N ratio as horse manure typically contains a high percentage of bedding.

There is an opportunity to produce some excellent compost by blending horse manure with other products such as poultry processing waste. For this to be successful, the horse manure must be kept under cover so that it does not adsorb additional moisture during the rainy season.

**Separated dairy cattle manure**

There are a few large dairy farms that separate solids from the liquid manure. Most of the solids are currently being reutilized for animal bedding, or being applied to the fields. There is little being
composted for use off the farm. The C/N ratio of separated dairy solids is variable, depending on the amount of bedding that is used on the farm. An increased amount of bedding increases the C/N ratio. The moisture content is usually slightly higher than optimal, but with good management, separated dairy solids have been successfully composted to produce high quality composts.

**Spent mushroom compost**

The mushroom industry is large and is concentrated in the Lower Mainland of British Columbia. According to the BC Ministry of Agriculture, there were an estimated 52.5 million pounds of mushrooms produced in 2002 (BC Ministry of Agriculture 2012c).

The amount of spent mushroom compost was not included in the above study, but the estimated production is approximately 223,214 cubic meters per year, or approximately 150,000 tonnes. This is calculated based on the 2002 mushroom production quantity and a yield of 16 kg per sq meter (15 cm depth of compost) (Queensland Gov't. 2012, supported by Pennsylvania State 2012).

Spent mushroom compost consists of composted chicken manure, wheat straw and gypsum (calcium sulphate). Because of the gypsum addition to the compost, spent mushroom compost contains high concentrations of calcium and sulphate, both of which are beneficial as a soil amendment. It is commonly used as a soil amendment and an ingredient in soil mixes. Ames and Curtis (2006) provided a report on potential markets for mushroom compost in British Columbia and concluded that using spent mushroom compost for a soil amendment provided the best market opportunity. Suess and Curtis (2006) also included other reports showing that addition of spent mushroom compost to soil increased decomposition of pesticide residues.

Spent mushroom compost can be further composted without addition of bulking agents or other organic material. The moisture content of spent mushroom compost is 65-68%, which allows for efficient composting using an aerated composting process. Further composting of spent mushroom compost reduces the volume of the product by up to 50% within a few weeks using an aerated composting process.

Most of the spent mushroom compost is currently further processed and stored in static piles, either inside a building or outdoors. One concern with spent mushroom compost in large piles is the potential accumulation of hydrogen sulphide gas, which can be dangerous to humans and animals.

Spent mushroom compost may produce excellent compost for raspberries. It has a high buffering capacity and a pH near neutral. It contains a variety of macro and micronutrients. If it is well composted, the NPK content may be approximately 1.2 %N, 1.6% P₂O₅, and 2.3 K₂O%. The gypsum contributes to a total calcium content of 8%, and a sulphur content of 1.4%. Spent mushroom compost may have a relatively high concentration of soluble nutrients (high electrical conductivity). This is not a concern when topdressing spent mushroom compost for raspberry production in the field, as typically the electrical conductivity is lower in spent mushroom compost than in fresh or partially composted poultry litter which is commonly used in raspberry production.

Because most of the wheat straw for mushroom compost production comes from the US, a cautionary note is the potential presence of persistent herbicides such as aminopyralid that was registered for use in the US. It is understood that these chemicals are not broken down in the composting process, so there needs to be reassurance that they are either not present in the wheat straw, or have no negative effect for raspberry production.
Another opportunity with spent mushroom compost is heat recovery during the composting process. This can be done if the composting process is an indoor aerated process.

**Poultry processing waste**

The poultry industry is centralized in the Abbotsford area. Three poultry processing wastes are the hatchery waste (mostly eggshells), spent laying hens, and the chicken processing sludge. These materials have high moisture content and high odor potential, and require extensive use of bulking agents or other organic material to compost properly.

The hatchery waste is an excellent source of calcium with 32% calcium content in the raw hatchery waste. Nitrogen content is just over 2%. There is very little phosphorus or potassium. It is difficult to obtain accurate information on the amount of hatchery waste produced, but the amounts are estimated to be approximately 1000 tonnes per year.

Spent laying hens contain approximately 2% nitrogen and 5% fat (Montgomery 2005). Feathers and bones break down readily during composting. According to Census Canada 2011 statistics, the layer bird inventory in Abbotsford is 1.5 million birds (2.1 million birds in the Lower Mainland of BC), and because layers produce eggs for one year, all of these birds become cull chickens and need to be recycled. The average weight of these birds is 1.69 kg (Montgomery 2005) which means that there is approximately 2500 tonnes of spent laying hens annually (3400 tonnes in the Lower Mainland of BC).

The chicken processing sludge has a moisture content of 85 to 88%, and contains significant odor. This material contains a significant amount of fat, more than 5% nitrogen, 1% phosphorus, and negligible potassium. The high fat content contributes to the high odor potential. As with hatchery waste, it is difficult to obtain reliable information on how much of this material is currently being disposed of.

Although the poultry processing waste quantities are not as large as other agricultural materials, they require environmentally sustainable management and recycling. This material may produce excellent compost for raspberry production when blended with horse manure.

**Greenhouse waste**

According to the 2011 Agriculture statistics, the Lower Mainland of BC has 263 hectares of greenhouse vegetable production. Commercial pepper and tomato production requires annual removal of the plants and the growing media. Cucumber production cycles more often but may use the same growing media for several cycles. Much of the industry is now using coconut fiber or yellow cedar sawdust as the growing media. The amount of waste produced from a greenhouse was not well documented on the greenhouse vegetable industry websites. If equal volumes of plant and growing media waste is assumed, and a 10 acre greenhouse produces approximately 675 cubic meters of growing media, the waste plant tonnage is estimated at 22,000 tonnes per year from 263 ha of greenhouse vegetable production (bulk density of 500 kg per cubic meter).

![Figure 11 Organic waste from a greenhouse growing peppers](image)
The challenge with the greenhouse waste is that it contains plastic twine used to support the plants. Some greenhouses are separating the twine from the vegetable matter. Excellent compost can be produced when composting the plants together with the growing media.

Greenhouse waste as a viable option for producing quality compost for raspberry production will not be considered at this time because of the contamination of the plant material with plastic, and the challenges the vegetable industry has with removing this plastic.

**Biosolids**

Biosolids is the solid portion produced at the end of the municipal wastewater treatment process. It contains up to 4% nitrogen, depending on the type of wastewater process, and has a moisture content of 88%. It has a bulk density equal to that of water. Biosolids need to be composted together with equal tonnages of wood waste or other bulking agent having a moisture content of 50% or less.

Biosolids compost is a beneficial product when it is composted properly. Biosolids compost will not be considered as compost for raspberries, primarily because of optics associated with biosolids reuse for edible fruits and vegetables. There is some controversy regarding biosolids reuse with edible food crops throughout North America. The Canadian Councils of Ministers of the Environment (CCME 2009) produced a report entitled “Emerging Substances of Concern in Biosolids: Concentrations and Effects of Treatment Processes”, which discusses some of the compounds that may remain in biosolids.

**Commercial food waste**

The quantities of commercial food waste produced in British Columbia are not well documented. Much of this waste is transported by commercial waste haulers to landfills or other sites. EBA (2012) estimated that 147,000 tonnes of organic waste was recycled from businesses in 2010, of which 63% was food waste. EBA (2012) also estimated that 38% of the organic waste is currently recycled in Metro Vancouver, which suggests that there could be well over 250,000 tonnes of commercial organics in Metro Vancouver. Communities in the Fraser Valley Regional District would also potentially contribute significant amounts.

Composting commercial food waste requires addition of bulking agent such as wood waste or horse manure. There are some food processors that may have a clean source of food waste, but there may be significant amounts of non-compostable material in this product that needs to be separated and disposed of. The potential benefit is the significant tipping fee that may be associated with receiving this product. It also must be understood that this product may be highly variable in quality and quantity throughout the year.

Excellent compost for raspberry production can be produced from commercial food waste, however a high level of control is required to manage the variability of the material, address the separation of non-compostable material, and produce a clean mature product.

**Yard waste from communities**

There is a significant amount of yard waste produced in the lower Fraser Valley that is currently being composted at various composting sites. As most of the communities are moving towards combined food waste and yard waste collection, yard waste alone will not be considered as a source of compost for raspberry production.
Yard waste makes excellent compost if composted together with other higher nutrient organic wastes. The volume and characteristics of yard waste changes significantly during the year, which provides a few additional challenges when planning a compost facility.

**Yard waste and food waste from communities**

EBA (2012) estimated that there is a potential of 628,000 tonnes of organic waste currently being produced in Metro Vancouver, with an estimated 171,000 tonnes already being recycled from single family residences. Residential food waste collection was still in its infancy, and the amount of food waste is likely 10% or less at this time. EBA (2012) estimated that 75% of the potential residential organic waste is food scraps. Assuming that not all of the food waste is recoverable, and that 50% of the potential residential organic waste is food scraps, there may be upwards of 300,000 tonnes per year of a combination of food waste and yard waste.

Based on estimates in the Fraser Valley Regional District (2011), residential food waste/yard waste produced in the Fraser Valley Regional District is approximately 65,000 tonnes. This is calculated from a total of 388,220 tonnes disposed or recycled, of which 34% comes from residences, of which 49% is yard waste and food waste. Even if only 50% of this was recovered, it would provide a significant source of organic material to produce quality compost.

The quality of compost produced from a combination of food waste and yard waste is excellent. The NPK content is approximately 1.3% N, 0.5% P₂O₅, and 1% K₂O (District of Mission food waste and yard waste compost). The nutrient concentrations will increase with increased food waste diversion.

One challenge with this material is the inclusion of non-compostable material, primarily plastic. The compost system must be well managed in order to process this material and produce high quality compost that does not contain non-compostable material. This blend of material produces excellent compost that can be used for raspberry production.

**Conclusions**

10. There are many combinations of available organic waste that may result in compost with desired qualities for raspberry production.

11. Additional research is required to assess the potential benefits of various composts, particularly with respect to potential disease suppressive effects.

12. Producing compost from poultry manure alone for raspberries is not recommended because of the high nutrient content of poultry litter and the potential for odor and ammonia emission. If poultry manure is used, it should comprise 25% or less of the compost blend.
13. A combination of horse manure and food waste or poultry processing waste may produce compost with the desired qualities. Consistency in moisture content of the horse manure may be a challenge because of current manure management on horse farms.

14. Spent mushroom compost may produce compost with the desired qualities for raspberries if it can be verified that there are no persistent herbicides in the wheat straw imported from the US.

15. Compost produced from a residential food waste and yard waste program may result in compost with the desired qualities for raspberry production. This compost may provide the greatest long term potential as there is a clearly identified need to find suitable markets for this product.
Composting Options to Produce the Compost with Desired Qualities

Composting options are separated into categories that follow two questions: 1. Is the composting material forced aerated?, and 2. Is the composting material being turned? A composting process without forced aeration or turning is the slowest process, and forced aeration in conjunction with turning is the fastest method of producing compost. Photographs of various composting options are included, all of which have been or are being used in south coastal British Columbia.

Some regulations distinguish between “in-vessel” processes and “turned windrow” processes, where the potential pathogen kill requirement in an “in-vessel” process is 3 days at > 55 C, and a turned windrow process is > 55 C for 15 days and five turns. This is based on the assumption that all of the material in an “in-vessel” process reaches > 55 C, which is unlikely unless the “vessel” is completely insulated. For this reason, and simply because 3 days of composting does not make a quality compost that can be used for raspberries, “in-vessel” processes is not discussed as long term composting in an “in-vessel” system is cost prohibitive.

Environmental and regulatory requirements are important to consider during the composting process. The greatest potential risks regarding composting are odor and leachate management (Schmidt 2010). This has resulted in increased regulation for composting as is discussed in the next section.

Static pile composting (no forced aeration, no turning)

Static pile composting is the simplest type of composting process, but is also the slowest process with the least likelihood of adequate and consistent temperatures for pathogen kill. The finished product may also be of inconsistent quality. The moisture content, porosity of the mix, and pile height and width are important to make this composting process successful. The time required for composting and the lack of control makes this technology impractical for most applications.

Static pile composting is the most commonly used composting process on farms in British Columbia because it is simple and there are few regulatory or process requirements for composting agricultural wastes on farms. Most piles are outdoors with no cover and no leachate collection.

In some cases, static pile composting occurs in a building, using a loader for piling and mixing. In this process, there is some environmental control achieved by being inside a building, but the process is slow, as there is little opportunity for oxygen to enter the piles. A static pile process inside a building does not represent an efficient use of space.

These processes cannot be relied upon to meet potential pathogen kill requirements to produce
quality compost. Static pile compost may become anaerobic and develop objectionable odor, which may be subsequently released when the material is mixed or turned.

It is noteworthy that a static windrow process may function very well and provide excellent odor control. Passively aerated static windrow composting was used successfully with Avian Flu events in 2004, 2005 and 2009. A breathable cover ensures adequate oxygen entry into the composting material. The cover is also designed to ensure that precipitation does not enter the composting material which increases moisture content and develops anaerobic conditions. The shape of the pile allows precipitation to run off the pile, and allows passive air diffusion, taking advantage of the chimney effect that allows the warm air to rise from the peak and cold air to be drawn in at the bottom of the windrows.

The significant challenge with this process involves meeting the requirements of the Agricultural Waste Control Regulation, where an impermeable surface must be used if the material is in process for longer than 9 months (could be defined as manure storage). This composting process requires 12-24 months to produce mature compost for raspberries.

**Turned windrow composting (turning, no forced aeration)**

Turned windrow composting uses a specialized turning machine to mix and provide aeration to the composting material. Turning frequency ranges from daily to weekly depending on the season, the material being composted, moisture content and porosity of the compost, and the stage of composting. The size of the windrow usually depends on the size of the compost turner. If the material is not porous enough, oxygen concentration can be minimal at a depth of 0.5 to 1 m within one hour of turning. Turned windrow composting can produce excellent quality compost.

Turned windrow composting has traditionally been the most commonly used composting method in North America because of the lower capital cost of these systems. A significant disadvantage is the amount of space required, which requires a very large impervious pad and a large leachate collection tank, or a very large building in south coastal British
Columbia. Odor control is difficult with a turned windrow process for three reasons.

1. The composting material is turned and exposed to air – releasing odor.
2. Windrows become anaerobic and produce odorous compounds released when the composting material is turned.
3. Precipitation increases moisture content, limiting oxygen diffusion that increases risk of odor production and emission.

Turned windrow composting is not recommended for producing quality compost for raspberry production in south coastal British Columbia. The primary reason is the potential odor and water quality concerns created in a high rainfall climate.

Aerated static pile composting (forced aeration and no or minimal turning or mixing)

Aerated static pile composting uses forced aeration to speed up the composting process by ensuring adequate oxygen throughout the pile. Preferential air pathways develop, especially if the material has a high moisture content and/or high bulk density. At least one mix is required in an aerated static pile composting process to ensure pathogen kill in the material on the edges of the pile. This technology speeds up the process substantially over static pile composting and is used by many technology providers. Forced aeration will tend to dry the composting material from the aeration pipes upward and outward, which also provides a reason for mixing the material during the composting process.

The forced aeration system includes pipes above ground, embedded in woodchips, embedded in concrete, or located in trenches in the floor. The greatest challenge with an aerated static pile composting process is having a working surface for loaders without risk of damaging air pipes.

There are many variations to this technology including:

1. Aerated bunkers
2. Aerated windrows
3. Aerated covered windrows
4. Aerated windrows inside a building
5. Aerated covered windrows inside a building

Aerated bunkers range in size from 8 ft wide and 10 ft
long, to more than 50 ft wide and 100 ft long. Aerated bunkers are commonly used for mushroom compost preparation. The farm scale aerated bunker on the photograph on the right has been operating in Abbotsford since 1999. Advantages include faster composting and a smaller footprint. Aeration pipes in aerated bunkers are usually embedded in a concrete floor so that the loaders can work effectively without damaging the aeration piping.

A forced aerated windrow system is another version of the aerated static pile. In this case, the composting material is placed in windrows that are up to 15 ft high and 30 ft wide. An aerated windrow process benefits from the natural convection or “chimney effect” where the forced aeration actually creates an aspiration effect that reduces aeration requirements. This is different than aerated bunkers, where sidewalls limit natural convection that augments the forced air system. Aerated windrows have a lower capital cost than aerated bunkers.

Aerated covered windrows is another variation of the aerated static pile composting process, where piles are covered with a semipermeable membrane to allow the composting material to breathe and prevent precipitation from entering the pile. Additional benefits include potential odor reduction and a physical barrier to protect the compost from weed seeds blowing into the material.

There are a number of types of covers including Typar or Tyvec (house wrap), to polyester type covers (Compostex), or the much more expensive ptfe membrane covers. The ptfe membrane covers offer potentially better odor control than the less expensive covers. The less costly covers on a well designed aerated windrow provide excellent odor control. If additional odor control is required, a layer of finished compost or woodchips can be added on top of the windrow under the cover.

There is a further variation of the covered aerated windrow – the enclosed plastic bag composting process. The advantage is that all of the composting material is isolated in a plastic bag. The disadvantages include no capability for mixing the material after it is in...
the bag. The plastic has only one use, and up until now, has not been able to be recycled because of prohibitive cost of cleaning the plastic. Another disadvantage is that the bags are vented and there is no odor control capability with this technology. Filters in the vents have been attempted but have not been successful.

An aerated windrow system inside a building is another version of the aerated static pile. In this case, the entire process is inside a large building that can be negatively ventilated through a biofilter if necessary. The windrows can be up to 15 ft high and 30 ft wide. It is important to mix the composting material at least once to ensure adequate potential pathogen kill, and to redistribute moisture throughout the pile. There are three potential odor control strategies available with this concept.

1. A well designed aeration system provides adequate oxygen to limit production of odorous compounds.
2. A layer of screenings or woodchips on top of the windrow acts as a biofilter for odorous compounds that are produced and may escape the windrow.
3. An external biofilter for the building if there is risk of odors escaping the building.

Aerated covered windrows inside a building is also being promoted. Covering a windrow inside a building may impede the composting process by limiting the ability for moisture to escape the windrows. The rule of thumb is that with every 1000 tonnes of composting material, a water loss of 400,000 litres can be expected and is encouraged. Because the humidity is already high inside a building, an additional barrier may restrict water movement from the composting material.

**Turned and aerated composting (both forced aeration and turning)**

The highest quality product is achieved in the shortest amount of time using a combination of forced aeration and turning. Forced aeration ensures that oxygen concentration remains high enough for optimal composting. The multiple turning events of the compost prevent formation of preferential air pathways and that all of the composting material reaches temperatures required for pathogen kill. A rotating drum and an agitated bed composting systems are two examples of this technology. Rotating drums are used on some dairy farms for composting manure for bedding. It is important to understand that a rotating drum by itself does not produce mature or stable compost.

The first agitated bed composter (turned and aerated) was built on a hog farm in Abbotsford in the mid 1990s. A large commercial facility was also constructed in Abbotsford in the early 1990s initially for poultry manure to produce organic fertilizer, but was then used for municipal organic waste. The agitated bed composting systems make the most efficient use of indoor space, but the specialized compost turner required makes the process more expensive.

![Figure 24. Aerated and turned composting provides the highest quality compost in the shortest time period. Typically, these are flow-through systems where raw material comes in one end, and finished compost exits the other end.](image)
Conclusions

16. The highest quality compost produced in the shortest time period requires a combination of forced aeration and mixing.

17. Static pile composting is currently the most common composting process on farms in BC, but is least likely to produce quality compost for raspberries within a reasonable time period (less than 18 to 24 months).

18. Turned windrow composting will produce great compost, however the land area required and the environmental concerns regarding odor and water pollution from a large land area makes this process too costly.

19. Aerated windrows inside a building hold the most promise for producing compost suitable for raspberries with the least likelihood of environmental concerns.

20. Regardless of technology, a significant period of curing the compost is required to produce compost having optimal qualities for raspberry production.

21. All of the options discussed can be managed to reduce the risk of environmental contamination and excessive odor.

A composting option most likely to provide compost having the desired qualities for raspberry production is a static aerated windrow inside a building with at least two mixes during the process. The windrows can be up to 15 ft high, making efficient use of space. There are no walls required inside the building to separate windrows, which makes capital construction cost effective. The forced aeration system in the floor allows loaders to operate and move product without risk of damaging the aeration system. There are no covers to move or remove from the piles, which is beneficial because covers result in additional labor requirement, as well as being a challenge in very cold weather. There is no need for electrical equipment inside this potentially corrosive environment. Furthermore, odor can be managed through control of the moisture content of the material; a well designed aeration system that provides adequate oxygen and discourages the production of anaerobic and odorous compounds; a layer of woodchips or finished compost on top of the windrows if additional odor control is required; and an external biofilter for the building if additional odor control is required.

This technology also allows the greatest potential for heat recovery during the composting process.

Following an 8 week aerated windrow composting process, the composted material can be further cured outdoors using a breathable cover such as Compostex to allow maturation to continue, while preventing moisture and weed seeds from entering the compost, and preventing leachate losses from the compost.
Regulations Affecting Production of Compost with the Desired Qualities

There are a number of regulations applicable to composting and use of compost. These include:

- Local Government bylaws or incentives
- Regional District bylaws or incentives
- Province of British Columbia
- Agricultural Waste Control Regulation
- Organic Matter Recycling Regulation
- Agricultural Land Commission
- Federal Regulation – Canada Food Inspection Agency
- Organic Standards and Regulations

There are other regulations and guidelines that apply in some cases, including organic certification requirements for organic production, and voluntary compost quality guidelines.

The hierarchy of regulations is such that federal regulations supersede provincial regulations or municipal regulations, and provincial regulations supersede municipal regulations. This means that a local government may be able to pass regulation that is more restrictive than federal regulation, as long as the federal regulation is not compromised. For example, federal compost regulation contains pathogen and metal limits for compost. Any provincial regulation must match or exceed these requirements.

Local Government Bylaws

Local governments have specific bylaws regarding composting, whether it occurs on agricultural land or industrial land. The City of Abbotsford, District of Langley, and District of Kent have specific mushroom composting bylaws. For commercial composting in industrial zones, specific bylaws may apply.

If the composting occurs on agricultural land, for example, Abbotsford’s Zoning Bylaw states that “the processing of livestock wastes into garden compost shall not exceed 465 m$^2$ per farm operation”. For a composting operation to produce compost for the raspberry industry, this would not be defined as garden compost, and therefore this bylaw would not apply.

There are no local government incentives for composting at the scale required for this project.

Regional Government Bylaws

Regional Governments may also have bylaws specific to composting. The Fraser Valley Regional District does not have bylaws specific to animal waste composting, but it does require that municipal solid waste composting be part of the regional Solid Waste Management Plan.

Metro Vancouver has similar requirements in that a municipal solid waste composting facility must be included in the Solid Waste Management Plan. Metro Vancouver has specific regulations for composting in its Municipal Solid Waste Bylaw (Municipal Solid Waste and Recyclable Material Regulatory Bylaw No. 181 as amended by Bylaw No. 183). Facilities within this region must have a Compost Facility License. Metro Vancouver is also developing a bylaw regarding odor from composting and waste management facilities.

Most regional governments implement composting bylaws and regulations to provide additional control over operations having potential to generate odor and cause public concern.

There are no regional government incentives for composting at the scale required for this project.
**Provincial Government Regulations**

There are three provincial government regulations that may apply to composting operations in British Columbia.

**Agricultural Waste Control Regulation**

The purpose of the Agricultural Waste Control Regulation (BC Ministry of Environment 2008) is to "describe practices for using, storing and managing agricultural waste that will result in agricultural waste being handled in an environmentally sound manner."

The Agricultural Waste Control Regulation applies to compost produced from agricultural waste on farms. Part 5 of the Regulation states:

"**15 Agricultural waste may be composted on a farm if**

(a) the agricultural waste being composted consists only of agricultural waste

(i) produced on that farm, or

(ii) produced elsewhere but being composted for use on that farm only,

(b) the composting site is located at least 15 m from a watercourse and 30 m from any source of water used for domestic purposes, and

(c) the agricultural waste is composted in a manner that does not cause pollution."

This regulation defines agricultural waste, but does not provide a definition of compost or provide recommendations for composting or the storage of compost specifically.

When agricultural waste is stored, it must be stored in a storage facility, which must:

"**6 be of sufficient capacity to store all the agricultural waste produced or used on the farm for the period of time needed to allow for:**

the application of agricultural waste as a fertilizer or soil conditioner, or the removal of agricultural waste,

prevent the escape of any agricultural waste that causes pollution, and

be maintained in a manner to prevent pollution"

This regulation is currently under review. It is recommended that modifications include consistency with other regulations and guidelines. Temperature and testing requirements should be included to ensure pathogen kill as required under the Good Agricultural Practice guidelines as required under international Good Agricultural Practice guidelines. It may also become challenging to produce mature compost (composted and cured for 12-24 months), based on current requirements for storage facilities.

The Agricultural Waste Control Regulation is the only provincial regulation that applies if one farm produces compost for raspberry production from manure or other agricultural waste produced on their own farm, or if a raspberry farm imported agricultural waste for composting and subsequent use for the raspberries.
Agricultural Land Reserve Use, Subdivision, and Procedure Regulation


“The Agricultural Land Reserve takes precedence over, but does not replace other legislation and bylaws that may apply to the land. Local and regional governments, as well as other provincial agencies, are expected to plan in accordance with the provincial policy of preserving agricultural land.”

This regulation defines compost as: “a product that is

(a) a stabilized earthy matter having the properties and structure of humus,

(b) beneficial to plant growth when used as a soil amendment,

(c) produced by composting, and

(d) derived only from organic matter;”

This regulation allows composting on a farm if agricultural wastes are being composted for use on the farm, or if agricultural waste produced on the farm is composted and marketed off farm as per the Agricultural Waste Control Regulation. Importing of non-agricultural organic wastes for composting is allowed if the compost is used on the farm and the operation is in compliance with the Organic Matter Recycling Regulation.

If a farm wishes to compost off-farm waste, the farm may export up to 50% of the compost if the operation is in compliance with the Organic Matter Recycling Regulation.

“Part 2. Permitted uses

Activities designated as farm use

2. (2) The following activities are designated as farm use for the purposes of the Act and may be regulated but must not be prohibited by any local government bylaw except a bylaw under section 917 of the Local Government Act

(k) the production, storage and application of compost from agricultural wastes produced on the farm for farm purposes in compliance with the Agricultural Waste Control Regulation, B.C. Reg. 131/92;

Permitted uses for land in an agricultural land reserve

(1). The following uses are permitted in an agricultural land reserve unless otherwise prohibited by a local government bylaw, or for lands located in an agricultural land reserve that are treaty settlement lands, by a law of the applicable first nation government:

(p) the production, storage and application of Class A compost in compliance with the Organic Matter Recycling Regulation (BC Reg. 18/2002), if at least 50% of the compost measured by volume is used on the farm.”

All other composting facilities fall under the category of commercial composting facilities and require a non-farm use exclusion if this is to occur on agricultural land. Producing compost for raspberry production to enhance crop growth, and minimize use of pesticides and fertilizers would seem to be beneficial for agriculture.

The Agricultural Land Reserve Use, Subdivision and Procedure Regulation takes precedence over, but does not replace other legislation and bylaws that apply to land in the Agricultural Land Reserve. Local
and regional governments, as well as other provincial agencies, are expected to plan in accordance with the provincial policy of preserving agricultural land.

**Organic Matter Recycling Regulation**


“The British Columbia Organic Matter Recycling Regulation (OMRR) governs the production, quality and land application of certain types of organic matter. OMRR (B.C. Reg. 18/2002) was enacted on February 5, 2002. The regulation was developed by the Ministry to provide clear and effective guidance for local governments and other compost and biosolids producers, to protect soil quality and drinking water sources, and to provide an opportunity to beneficially use organic material.”

This regulation governs the construction and operation of compost facilities, as well as production, storage, sale and use of compost. This regulation does not require a permit. Compliance with the regulation is the responsibility of the compost facility operator.

Producing compost from agricultural waste is normally exempt from the Organic Matter Recycling Regulation (OMRR) if it is in accordance with the Agricultural Waste Control Regulation (compost produced from agricultural wastes for use on the farm, or agricultural wastes composted on farm for export from the farm).

The OMRR requires plans and specifications for the compost facility, an operations plan, an odor control plan, a leachate control plan, and a closure plan. For facilities over 20,000 tonnes annual capacity, an environmental impact assessment is required.

The OMRR also has specific requirements for potential pathogen destruction, vector attraction reduction, and final compost quality in terms of potential pathogens and heavy metals.

Potential pathogen reduction requirements include (Schedule 1, OMRR):

“4 One of the following pathogen reduction processes specified in paragraphs (a) to (c) is required to produce Class A compost:

(a) the windrow composting method whereby organic matter is processed in a windrow involving periodic aeration and mixing of the windrow, with a temperature of not less than 55° Celsius maintained for at least 15 days and not fewer than 5 turnings of the windrow made during the high temperature period to promote uniform exposure of the compost to thermophilic temperatures;

(b) the static aerated pile composting method consisting of a compost process involving mechanical aeration of the compost pile, with the compost pile insulated and a temperature of not less than 55° Celsius maintained throughout the compost pile for at least 3 consecutive days;

(c) the enclosed vessel method consisting of a confined compost process involving mechanical aeration of compost under controlled environmental conditions, with a temperature of not less than 55° Celsius maintained for at least 3 days during the composting process.”

Vector attraction reduction requirements include (Schedule 2, OMRR)

“2 One of the following vector attraction reduction processes are required for Class A compost:

(a) Class A compost must be treated in an aerobic process for 14 days or longer. During that time, the temperature of the compost must be higher than 40° Celsius and the average temperature of the compost must be higher than 45° Celsius. After the vector attraction reduction process is completed
the carbon to nitrogen ratio of the compost must be greater than or equal to 15:1 and less than or equal to 35:1;

(b) Class A compost must be retained in curing piles for at least 21 days. After the 21 day period, the carbon to nitrogen ratio of the Class A compost must be greater than or equal to 15:1 and less than or equal to 35:1 and must not re-heat, upon standing, under the following conditions:

(i) compost is aerated and formed into a pile no smaller than 3 meters in diameter and 2 meters high with compost having a moisture content between 35 percent and 60 percent;

(ii) the pile must be formed in a location where the ambient temperature remains in the range of 5° to 30° Celsius;

(iii) 3 days after the pile has been formed, the temperature of the compost is measured at a depth of 60 cm into the pile from the outside surface of the pile;

(iv) the compost must not re-heat upon standing to greater than 20° Celsius above ambient temperature. more than 14 days at temperatures greater than 40 C, or 21 days curing.”

Finished compost is either Class A which can be sold or distributed without restriction, or Class B which requires a land application plan. Class A compost requirements include fecal coliforms less than 1000 MPN/g total solids, heavy metal concentrations below those identified in Schedule 4 of the regulation, and no more than 1% foreign matter in retail grade product.

The OMRR does not clearly define maturity for compost, nor does it specify requirements to report nutrient concentrations. This regulation is primarily to protect the environment during the composting process, and to ensure that Class A compost is safe for use.

Federal Government Regulations

The Canadian government also regulates compost under the Canadian Food Inspection Agency Trade Memorandum T-4-120 Regulation of Compost under the Fertilizers Act and Regulations (Canadian Food Inspection Agency 2009).

“The purpose of this document is to provide information on the regulatory requirements for compost under the Fertilizers Act and Regulations, and describe the safety, efficacy and labeling standards that must be met in order to legally sell or import compost into Canada.”

Under the Fertilizers Act and Regulations, compost is classified as a supplement and exempt from registration. Compost is required to have a label that includes:

“1. product name
2. net weight
3. name and address of the registrant or the responsible packager
4. lot number
5. guaranteed analysis(maximum moisture and minimum organic matter)
6. directions for use
7. cautionary statements (if applicable)”

This trade memorandum also addresses compost safety including:

- physical contaminants (compost should not contain sharp objects that may cause injury)
- chemical contaminants (heavy metals – the BC OMRR is more restrictive)
- biological contaminants (fecal coliforms less than 1000 MPN/g, and non-detectable Salmonella
- maturity (as defined by the compost producer using scientifically valid methods)
- specified risk materials – compost containing specified risk materials may not be sold. Specified risk materials include:
  - the skull, brain, trigeminal ganglia, eyes, tonsils, spinal cord and dorsal root ganglia of cattle aged 30 months or older, and
  - the distal ileum of cattle of all ages.
- prohibited material – includes products derived from most mammalian proteins which require warning labels and must be able to be recalled. Compost that contains food grade animal protein in the form of restaurant waste, grocery store waste, or household organic collection waste will not be subject to the new warning statements, recall and record keeping requirements.

The key elements of this federal regulation that is not necessarily included in provincial regulations include labeling requirements, the requirement for testing the compost for Salmonella, and the restrictions on specified risk material.

**Organic Standards and Regulations**

Organic standards include national organic standards, and those of specific agencies. Canada has a national standard for Organic Production Systems (Government of Canada 2008).

In this regulation, compost is defined as:

> “the product of a carefully managed aerobic process by which non-synthetic materials are digested by micro-organisms. Organic material for compost shall be managed appropriately to reach temperatures for the duration necessary to effectively stabilize nutrients and kill human pathogens.”

This regulation also provides instructions on non-composted manure use:

> “Under section 5.5.2.5 The non-composted solid or liquid manure shall be:

  - incorporated into the soil at least 90 days before harvesting of crops for human consumption that does not come into contact with soil;
  - incorporated into the soil at least 120 days before the harvesting of crops having an edible part that is directly in contact with the surface of the soil or with soil particles.”

The specific requirements for the composting process are included in the companion document “Organic Production Systems Permitted Substances List” (Government of Canada 2011). This document provides the following for compost:

> “Compost obtained from off-farm sources shall conform to the criteria in Composting Feedstocks. In addition,

  - shall not exceed the maximum acceptable levels of trace contaminants (mg/kg) and foreign matter outlined for unrestricted use (Category A) compost as specified in the Canadian Council of Ministers of the Environment (CCME) publication Guidelines for Compost Quality,
  - shall not cause a buildup of heavy metals in soil over repeated applications
  - shall meet criteria for acceptable levels (MPN/g total solids) of human pathogens as specified in the CCME publication Guidelines for Compost Quality
Compost produced on the farm shall conform to the criteria in Composting Feedstocks. In addition, if made from animal manures or other likely sources of human pathogens, compost produced on the farm shall:

- reach a temperature of 55 C (130 F) for a period of four consecutive days or more. The compost piles shall be mixed or managed to ensure that all of the feedstock heats to the required temperature for the minimum time, or
- meets limits for acceptable levels (MPN/g total solids) of human pathogens specified in the Canadian Council for Ministers of the Environment publication Guidelines for Compost Quality, or
- be considered as aged or raw manure rather than compost.”

Under Canadian Organic standards, compost made from sewage sludge (biosolids) is not permitted. The organic standards make no mention of compost maturity requirements. The Organic standards are similar to that of the requirements for compost under international Good Agricultural Practice Guidelines.

The most common independent standard for compost and other crop amendments is the Organic Materials Review Institute (OMRI 2012).

The OMRI standards separate windrow composting and in-vessel composting as well, requiring similar process requirements as the BC Organic Matter Recycling Regulations for Potential Pathogen Kill (3 days > 55 C for in-vessel and 15 days > 55 C and 5 turns for windrow composting). As with all other regulations, there are no specific maturity requirements. Composts produced from biosolids (sewage sludge) or mixed municipal waste are prohibited for organic use.

Conclusions

22. There are municipal, provincial and federal regulations that apply in producing compost for raspberry production.
23. There are no current regulations that specify the production of mature and stable compost as has been identified for raspberry production.
24. The least amount of regulation applies if compost is produced from agricultural waste on farms where it is produced (e.g., poultry or dairy farms) or if compost is produced on the raspberry farm.
25. The present Agricultural Waste Control Regulation does not require compost be produced in accordance with requirements for compost as required under internationally accepted Good Agricultural Practice guidelines, or the maturity identified as being most beneficial for raspberries.
26. The Organic Matter Recycling Regulation provides the greatest guidance for producing compost that is safe and free of potential pathogens, but does not specify compost stability or maturity.
27. The current regulatory framework creates challenges to finding a suitable location for commercial composting to produce compost suitable for raspberry production. The Agricultural Land Commission is discouraging commercial composting on agricultural land (Schmidt 2010), and finding industrial land that can accommodate a commercial composting facility in the Fraser Valley may be challenging. The cost of industrial land may also be prohibitive to producing compost at a reasonable price.
Economic Analysis of Producing and Using Compost for Raspberry Production

Cost of Producing Compost for Raspberry Production

Producing quality compost for the raspberry industry will cost money. The process must meet:

1. requirements for raspberry production,
2. environmental regulations for composting,
3. compost requirements to meet Good Agricultural Practice guidelines

An argument can be made that compost is already being produced, therefore only the application costs and fertilizer value of the compost needs to be evaluated.

Only yard waste compost and food waste/yard waste compost is currently being produced that may meet requirements for raspberry production. Of this production, some of this production may meet the environmental regulations for composting.

In Abbotsford, or anywhere in south coastal British Columbia, it is important to compost under a roof or other type of cover for two reasons:

1. Precipitation rates are high, limiting the composting process and resulting in excess leachate production. For example, if the Organic Matter Recycling Regulations for composting were being adhered to, a one hectare outdoor composting site would be required to collect up to 1,029,000 L or 2,300,000 gallons of leachate during the period from October through March.
2. Because precipitation rates are high during the winter months, it is unlikely to obtain compost with a moisture content less than 60% for early spring applications. Wet composts are more difficult to screen and apply, and cost more to transport.

Composting of any type of organic material will be assumed to require a roof or other type of cover to reduce overall costs associated with leachate collection and storage, and to meet requirements for early spring application of compost.

An economic analysis will be based on an annual compost requirement of 11,900 tonnes. Assuming a 50% weight reduction during composting (water and dry matter loss), this will require a process with a capacity of 23,800 tonnes of organic material entering the composting process.

Compost Technology Costs

Technologies acceptable in terms of composting process and process control will be considered to compare costing. Large stockpiles of material inside a building do not represent a composting process that meets Good Agricultural Practice requirements, nor the OMRR requirements for temperature and process control.

For this comparison, only the actual compost process building costs will be considered for comparison. It is assumed that preprocessing, storage and curing requirements are similar for the various technology options. There are variations in the cost of equipment for the various technologies, but these are not considered in the comparison.
The building size can be smallest with the larger agitated channels as shown by the building efficiency measured in tonnes of composting material per square meter of space (Table 5). However, the net building cost is higher with agitated channels than with larger aerated windrows. These costs also do not include the cost of equipment required, or the operations costs.

The least cost option for composting this amount of product is using larger aerated windrows (12 ft. high and 23 ft. wide), estimated at $28.13 per square foot (Table 5). Agitated channels are also cost efficient in terms of building cost, but require more expensive and specialized turning equipment.

Capital and operations costs for aerated windrow composting using two different products will be compared. The first will be a blend of food waste and yard waste, which have a lower shrink factor and a higher tipping fee that may cover the cost of the composting process (Table 6). The second is a spent mushroom compost, which has a high shrink factor and typically no tipping fee (Table 9).

**Composting Costs for a Blend of Food Waste and Yard Waste**

The composting process for a blend of food waste and yard waste assumes that the process is in an enclosed building with a biofilter. It also assumes that there is a $100,000 annual cost for the land. Tip fees for the green waste and food waste are $55 per tonne. This assumes a 50/50 blend of food waste and green waste. There are also some residuals that need to be separated as well as some overs from the screening process that will be recirculated in the process. The size of the structure needs to account for this.

The total building and equipment cost is estimated at $2.8 million, which includes the receiving building, the composting building, outdoor curing and storage (under Compostex fabric), and biofiltration of the exhaust air from the composting process.

Some of the assumptions used in calculating the operations cost of a compost facility that produces compost from a blend of food waste and yard waste are summarized in Table 6. Important factors to consider in comparing Table 6 (food and yard waste composting), and Table 9 (spent mushroom composting) is the amount of shrinkage during the composting process, and the tipping fee obtainable for receiving food waste and yard waste.
In Table 7, the operations cost per tonne of incoming material are shown for food waste and yard waste composting, where the total cost is $44 per tonne, which includes the capital ($15 per tonne) and the operations cost ($29 per tonne).

Table 7. Capital and operations cost per tonne of food waste and yard waste processed for a facility producing 11,900 tonnes of product.

<table>
<thead>
<tr>
<th>General Waste Information</th>
<th>Tipping Fees and Compost Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste Amount</td>
<td>28400 tonnes/yr</td>
</tr>
<tr>
<td>Bulk Density after mix</td>
<td>684 kg/m³</td>
</tr>
<tr>
<td>Composting time</td>
<td>6 weeks</td>
</tr>
<tr>
<td>Shrinkage during mixing</td>
<td>10%</td>
</tr>
<tr>
<td>Shrinkage during composting</td>
<td>40%</td>
</tr>
<tr>
<td>Shrinkage during screening</td>
<td>20%</td>
</tr>
<tr>
<td>Food waste Tipping Fee</td>
<td>55 $/tonne</td>
</tr>
<tr>
<td>Greenwaste Tipping fee</td>
<td>55 $/tonne</td>
</tr>
<tr>
<td>Bulking Agent costs</td>
<td>$ -  $/m³</td>
</tr>
<tr>
<td>Compost sales</td>
<td>10 $/m³</td>
</tr>
</tbody>
</table>

Table 6. Input values and assumptions for a food waste and yard waste composting process that will produce 11,900 tonnes of finished compost per year.

<table>
<thead>
<tr>
<th>General Waste Information</th>
<th>Loader Information</th>
<th>Operating Cost Information</th>
<th>Financials Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste Amount</td>
<td>Bucket Size on Loader</td>
<td>Cost of Electricity</td>
<td>Interest Rate</td>
</tr>
<tr>
<td>Bulk Density after mix</td>
<td>Time per load</td>
<td>Cost of Diesel Fuel</td>
<td>Capital Base</td>
</tr>
<tr>
<td>Composting time</td>
<td>Loader Fuel Consumption</td>
<td>Labor Cost</td>
<td>5 %</td>
</tr>
<tr>
<td>Shrinkage during mixing</td>
<td></td>
<td></td>
<td>100 %</td>
</tr>
<tr>
<td>Shrinkage during composting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shrinkage during screening</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food waste Tipping Fee</td>
<td>6 yds</td>
<td>0.08 $/kwh</td>
<td>5 %</td>
</tr>
<tr>
<td>Greenwaste Tipping fee</td>
<td>1 minute</td>
<td>1.30 $/L</td>
<td>Capital Base</td>
</tr>
<tr>
<td>Bulking Agent costs</td>
<td>40 L/hr</td>
<td></td>
<td>100 %</td>
</tr>
<tr>
<td>Compost sales</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating Cost Information</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity</td>
<td>75 yds/hour</td>
<td>15 yr</td>
<td>Interest Rate</td>
</tr>
<tr>
<td>Screenhorsepower</td>
<td>57 m³/hour</td>
<td>Depreciation - Building</td>
<td>5 yr</td>
</tr>
<tr>
<td>Size of blowers</td>
<td>50 hp</td>
<td>Depreciation - Equipment</td>
<td>5 yr</td>
</tr>
<tr>
<td>Blowers per windrow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biofilter</td>
<td>Number of blowers</td>
<td>Repair &amp; Maintenance - Building</td>
<td>1 %</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Size of blowers</td>
<td>Repair &amp; Maintenance - equipment</td>
<td>10 %</td>
</tr>
<tr>
<td></td>
<td>50 hp</td>
<td>Repair &amp; Maintenance - other</td>
<td>10 %</td>
</tr>
</tbody>
</table>

Table 7. Input values and assumptions for a food waste and yard waste composting process that will produce 11,900 tonnes of finished compost per year.

<table>
<thead>
<tr>
<th>Production Costs</th>
<th>$/Tonne</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costs per tonne of organic waste</td>
<td>43.89</td>
</tr>
<tr>
<td>Breakdown</td>
<td></td>
</tr>
<tr>
<td>Purchased Inputs</td>
<td>$0.00</td>
</tr>
<tr>
<td>Labor</td>
<td>$6.57</td>
</tr>
<tr>
<td>Fuel/Elec</td>
<td>$9.73</td>
</tr>
<tr>
<td>Repair and Maintenance</td>
<td>$3.52</td>
</tr>
<tr>
<td>Equipment-Interest and Depreciation</td>
<td>$7.04</td>
</tr>
<tr>
<td>Buildings -Interest and Depreciation</td>
<td>$8.22</td>
</tr>
<tr>
<td>Lease and Other</td>
<td>$5.28</td>
</tr>
<tr>
<td>Leasing</td>
<td>$3.52</td>
</tr>
<tr>
<td>Total</td>
<td>$43.89</td>
</tr>
</tbody>
</table>

Table 7. Capital and operations cost per tonne of food waste and yard waste processed for a facility producing 11,900 tonnes of product.
Table 8. Revenue and Expenses for a food waste/yard waste composting facility producing 11,900 tonnes of compost per year (for comparative purposes only – not for business planning).

<table>
<thead>
<tr>
<th>Revenue</th>
<th>Compost for Raspberry production</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tipping Fees</strong></td>
<td><strong>Sub Total</strong></td>
</tr>
<tr>
<td>Foodwaste 14,200</td>
<td>$781,000</td>
</tr>
<tr>
<td>greenwaste 14,200</td>
<td>$781,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$1,562,000</strong></td>
</tr>
<tr>
<td><strong>Compost Sales</strong></td>
<td><strong>Total</strong></td>
</tr>
<tr>
<td>Bulk 19,557 m3 $10</td>
<td>$195,573</td>
</tr>
<tr>
<td><strong>Total Revenue</strong></td>
<td><strong>$1,757,573</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Expenses</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Cost</td>
<td>$713,021</td>
</tr>
<tr>
<td>Purchased Bulking Agent</td>
<td>$0</td>
</tr>
<tr>
<td>Labor</td>
<td>$186,646</td>
</tr>
<tr>
<td>Fuel</td>
<td>$159,119</td>
</tr>
<tr>
<td>Electricity</td>
<td>$117,256</td>
</tr>
<tr>
<td>Management</td>
<td>$100,000</td>
</tr>
<tr>
<td>Rent</td>
<td>$100,000</td>
</tr>
<tr>
<td>Insurance</td>
<td>$50,000</td>
</tr>
<tr>
<td>Other</td>
<td>$0</td>
</tr>
<tr>
<td>Total</td>
<td>$713,021</td>
</tr>
<tr>
<td>Repair &amp; Maintenance</td>
<td>$100,000</td>
</tr>
<tr>
<td>Equipment</td>
<td>$80,000</td>
</tr>
<tr>
<td>Infrastructure/Buildings</td>
<td>$20,000</td>
</tr>
<tr>
<td>Total</td>
<td>$100,000</td>
</tr>
<tr>
<td>Interest</td>
<td>$140,000</td>
</tr>
<tr>
<td>Equipment</td>
<td>$40,000</td>
</tr>
<tr>
<td>Infrastructure/Buildings</td>
<td>$100,000</td>
</tr>
<tr>
<td>Total</td>
<td>$140,000</td>
</tr>
<tr>
<td>Depreciation</td>
<td>$293,333</td>
</tr>
<tr>
<td>Equipment</td>
<td>$160,000</td>
</tr>
<tr>
<td>Infrastructure/Buildings</td>
<td>$133,333</td>
</tr>
<tr>
<td>Total</td>
<td>$293,333</td>
</tr>
<tr>
<td><strong>Total Annual Expenses</strong></td>
<td><strong>$1,246,354</strong></td>
</tr>
<tr>
<td><strong>Net Revenue</strong></td>
<td><strong>$511,218</strong></td>
</tr>
</tbody>
</table>

The balance sheet for a food waste/yard waste composting facility is shown in Table 8. The tipping fee at $55 per tonne together with a compost price of $10 per cubic meter would provide an adequate return on investment.

**Composting Costs for Further Composting Spent Mushroom Compost**

For a composting process for spent mushroom compost, the process can be done on a farm, and no biofiltration is required for the process. A higher shrinkage rate for the compost will also be assumed.
There is also no tipping fee. The shrinkage during composting and curing is estimated at 60%. There is also no mixing or grinding required at the beginning of the process.

Some of the assumptions used in the composting cost calculation are shown in Table 9. The assumptions are similar to the food waste/yard waste scenario with the exception of a higher shrinkage factor, and no tipping fees.

*Table 9. Input information and assumptions for a spent mushroom compost process producing 11,900 tonnes of finished product per year.*

<table>
<thead>
<tr>
<th>General Waste Information</th>
<th>Tipping Fees and Compost Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste Amount</td>
<td>Food waste Tipping Fee</td>
</tr>
<tr>
<td>Bulk Density after mix</td>
<td>Greenwaste Tipping fee</td>
</tr>
<tr>
<td>Composting time</td>
<td>Bulking Agent costs</td>
</tr>
<tr>
<td>Shrinkage during mixing</td>
<td>Compost sales</td>
</tr>
<tr>
<td>Shrinkage during composting</td>
<td>$ 42 $/m³</td>
</tr>
<tr>
<td>Shrinkage during screening</td>
<td>$ 0 $/m³</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Loader Information</th>
<th>Operating Cost Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bucket Size on Loader</td>
<td>Cost of Electricity</td>
</tr>
<tr>
<td>Time per load</td>
<td>Cost of Diesel Fuel</td>
</tr>
<tr>
<td>Loader Fuel Consumption</td>
<td>Labor Cost</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Screener Information</th>
<th>Financials Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>Interest Rate</td>
</tr>
<tr>
<td>Screening horsepower</td>
<td>Capital Base</td>
</tr>
<tr>
<td>Aeration System</td>
<td>Depreciation - Building</td>
</tr>
<tr>
<td>Size of blowers</td>
<td>Depreciation - Equipment</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Biofilter</th>
<th>Repair &amp; Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of blowers</td>
<td>Repair &amp; Maintenance - Building</td>
</tr>
<tr>
<td>Size of blowers</td>
<td>Repair &amp; Maintenance - Equipment</td>
</tr>
</tbody>
</table>

In this case, the compost price is set at $ 42 per cubic meter to cover the cost of the composting process. If there is no tipping fee for the incoming material, this revenue from sales is required to offset the cost of composting. The result is only a slightly positive cash flow in the process, assuming compost could be sold at this price.

The capital cost for the building and equipment was assumed to be $ 2 million compared with the estimated capital cost of $ 2.8 million for the food waste and yard waste composting facility. The actual capital cost difference between the two systems is expected to be greater but these are preliminary estimates of capital costs. Actual capital costs will depend on the site and the specific equipment and systems chosen.
Table 10. Revenue and expenses for a spent mushroom compost facility producing 11,900 tonnes of finished compost for raspberry production (for comparative purposes only, not for business planning).

<table>
<thead>
<tr>
<th></th>
<th>Compost for Raspberry production</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Revenue</strong></td>
<td></td>
</tr>
<tr>
<td>Tiping Fees</td>
<td>Mushroom compost 35,000 tonnes $0.00 $0</td>
</tr>
<tr>
<td></td>
<td>Compost Sales m3 $/m3 sold Bulk 19,619 $42 100% $824,009 $824,009</td>
</tr>
<tr>
<td><strong>Total Revenue</strong></td>
<td>$824,009</td>
</tr>
</tbody>
</table>

| **Expenses**       |                                  |
| Operating Cost     |                                  |
| Purchased Bulking Agent | $0                   |
| Labor              | $203,195                         |
| Fuel               | $110,653                         |
| Electricity        | $9,409                           |
| Management         | $75,000                          |
| Rent               | $0                               |
| Insurance          | $25,000                          |
| Other              | $0                               |
| **Total**          | $423,256                         |

| Repair & Maintenance |                                  |
| Equipment           | $50,000                          |
| Infrastructure/Buildings | $15,000                   |
| **Total**           | $65,000                          |

| Interest            |                                  |
| Equipment           | $25,000                          |
| Infrastructure/Buildings | $75,000                   |
| **Total**           | $100,000                         |

| Depreciation        |                                  |
| Equipment           | $100,000                         |
| Infrastructure/Buildings | $100,000                   |
| **Total**           | $200,000                         |

| **Total Annual Expenses** | $788,256 |
| **Net Revenue**          | $35,752  |

Total revenues from further composting spent mushroom compost (Table 10) are much lower than with the food waste/yard waste composting scenario. The price of compost had to be increased to $42 per cubic meter to cover the costs of the composting process. Because this process occurs on a mushroom farm, there is no rent cost associated with the land. Annual expenses are 63% of expenses for the food waste and yard waste composting process, mostly because no biofilter is required, and the screening process for the final product is simpler because there are very few non-compostable materials in spent mushroom compost.
These factors are reflected in Table 11, where the actual operations costs are reduced from $29 to $14 per tonne, and the capital costs are reduced from $15 to $9 per tonne, as compared with the food waste/yard waste composting scenario.

Table 11. Production costs per tonne for a spent mushroom compost facility producing 11,900 tonnes of finished compost.

<table>
<thead>
<tr>
<th>Production Costs</th>
<th>$/Tonne</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costs per tonne of organic waste</td>
<td>$22.52</td>
</tr>
<tr>
<td>Breakdown</td>
<td></td>
</tr>
<tr>
<td>Purchased Inputs</td>
<td>$0.00</td>
</tr>
<tr>
<td>Labor</td>
<td>$5.81</td>
</tr>
<tr>
<td>Fuel/Elec</td>
<td>$3.43</td>
</tr>
<tr>
<td>Repair and Maintenance</td>
<td>$1.86</td>
</tr>
<tr>
<td>Equipment-Interest and Depreciation</td>
<td>$3.57</td>
</tr>
<tr>
<td>Buildings -Interest and Depreciation</td>
<td>$5.00</td>
</tr>
<tr>
<td>Lease and Other</td>
<td>$0.71</td>
</tr>
<tr>
<td>Management</td>
<td>$2.14</td>
</tr>
<tr>
<td>Total</td>
<td>$22.52</td>
</tr>
</tbody>
</table>

Actual operating costs per tonne of organic waste | $13.95
(doesn't include interest and depreciation)

Equipment and Building Cost | $8.57

The cost per tonne to process spent mushroom compost is approximately 50% of the cost to process a blend of food waste and yard waste. The reason for this is that the composting process requires no material preparation such as mixing or grinding. It also did not require an external biofilter as the potential odor is not high and the process is assumed to be on a farm.

Summary of Scenarios of Costs to Produce Compost

The production cost to produce the green waste/yard waste compost is higher than the production cost for the spent mushroom compost. Because the cost of composting is offset by the tipping fee, there is potential for profit when selling the green waste/food waste compost for $10 per cubic meter, and no profit when selling the mushroom compost for $42 per cubic meter.

These cost evaluations assume that both processes are meeting all of the requirements of the Organic Matter Recycling Regulation, all requirements to meet Good Agricultural Practice guidelines, and are being processed inside a building and stored under covers to keep precipitation from saturating the compost.

Cost of Utilizing Compost for Raspberry Production

Estimated fertilizer value of the compost

It is difficult to assess the fertilizer value of compost because compost provides nutrients in a controlled release form and compost also supplies micronutrients that may be required by the plants. The value of the micronutrients and the nutrient release characteristics are complex to define. Compost also provides additional non-nutrient benefits which cannot readily be quantified.
It may be beneficial to evaluate inorganic fertilizer costs for comparison. The annual fertilizer costs for raspberry production were defined as being $327 per hectare ($133/acre – Terralink 2012 prices). This includes two applications of 140 kg/ha of 16-16-16 at a cost of $0.84 per kg and one application of 112 kg/ha of 46-0-0 at $0.82 per kg as per BC Ministry of Agriculture recommendations. The actual costs of inorganic fertilizer may be higher if slow release formulations or other special formulations that include micronutrients are used. For example, one recommendation included 800 lb/acre of 15-8-11 + micros for the first application, and 500 lb per acre of 16-16-16 + micros for the second application for a total fertilizer cost of $1108 per hectare (plus application cost) for an application of 91 kg N, 65 kg P₂O₅ and 76 kg K₂O per acre.

In comparison, an application of a green waste/yard waste compost containing 1.3% N, 0.5% P₂O₅ and 1% K₂O at a rate of 40 tonnes per hectare (32 yd³ per acre) for a replant application would supply 208 kg total N, 80 kg P₂O₅ and 160 kg K₂O per acre and cost $1600 per hectare applied (assumes a moisture content of 60%). The nutrient value of this application of compost needs to be considered when evaluating need for fertilizer application.

An application of 7 tonnes per hectare of this same compost (60% moisture content) as an annual compost application would contribute 36 kg total N, 14 kg P₂O₅ and 28 kg K₂O, which is a significant application of nutrients. In both cases, nutrients from cumulative applications need to be considered.

**Other potential value of compost**

There are a number of non-nutrient benefits to compost application. The potential value for compost includes the potential disease suppressive affect and the potential of compost to reduce the requirements for pesticides and to replace fumigants. According to the BC Ministry of Agriculture (2007), the cost of fumigation at replanting was estimated at $1200 per acre ($2964 per hectare). The annual costs of pesticides was $546 per acre ($1349 per hectare).

**Cost of Compost Application**

The cost of compost application includes the transportation cost of the compost and the spreading cost. Transportation cost of compost will range between $3 and $10 per tonne depending on the hauling distance and the size of truck used. Assuming a truck with a capacity of 40 tonnes and a roundtrip hauling time of one hour (including loading, unloading and travel), the cost is $3 per tonne ($120 per hour for transportation). Assuming a smaller truck hauling 10 to 15 tonnes and assume a 45 minute round trip (faster loading and unloading), the cost is $8.50 per tonne ($85 per hour for transportation).

The cost of compost application may be in the range of $200 per hectare ($80 per acre for the preplant application (BC Ministry of Agriculture 2007), although this estimate did not identify the rate of product applied. The cost of annual application of spring applied compost can be expected to be greater because the spreading requires more attention and banding along the raspberry rows.

**Preliminary Lifecycle Cost/Benefit of Using Compost**

In order to evaluate the potential value of compost, a preliminary lifecycle analysis of raspberry production using compost was prepared (Table 12). It assists in keeping compost costs in perspective, as well as reviewing options that may result in decreased costs for pesticides and fertilizers. The base model is taken from the costing and revenue formulated by the BC Ministry of Agriculture (2007), and upgraded to reflect 2012 berry prices and costing (pers. comm. Mark Sweeney, BCMA, pers. comm. Terralink). It assumes a 10 year production cycle and raspberry prices of $0.60 per lb. This provides a base case for a net annual return of $2,174 per acre.
Table 12. Revenue and cost formula for a 10 year cycle of raspberry production (from BC Ministry of Agriculture 2007), upgraded with 2012 information on fumigants, pesticides and fertilizers (most of the "other expenses" are similar to the 2007 model).

<table>
<thead>
<tr>
<th>Summary of Raspberry Production Revenue and Expenses (Per Acre) 2007 Model with 2012 Upgrade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Establishment Year 1  Year 2  Year 3  Year 4  Year 5  Year 6  Year 7  Year 8  Year 9  Year 10  Total</td>
</tr>
<tr>
<td>Yield  0  8,000  10,000  10,000  10,000  10,000  10,000  10,000  10,000  10,000  88,000</td>
</tr>
<tr>
<td>Price  $0.60  $0.60  $0.60  $0.60  $0.60  $0.60  $0.60  $0.60  $0.60  $0.60  $0.60</td>
</tr>
<tr>
<td>Total  $4,800  $6,000  $6,000  $6,000  $6,000  $6,000  $6,000  $6,000  $6,000  $6,000  $52,800</td>
</tr>
<tr>
<td>Expenses</td>
</tr>
<tr>
<td>Fumigation  $1,200</td>
</tr>
<tr>
<td>Pesticides  $523  $587  $587  $587  $587  $587  $587  $587  $587  $587  $5,809</td>
</tr>
<tr>
<td>Fertilizer  $95  $133  $133  $133  $133  $133  $133  $133  $133  $133  $1,292</td>
</tr>
<tr>
<td>Manure  $80</td>
</tr>
<tr>
<td>Compost</td>
</tr>
<tr>
<td>Other expenses  $4,735  $1,994  $1,994  $1,994  $1,994  $1,994  $1,994  $1,994  $1,994  $1,994  $22,681</td>
</tr>
<tr>
<td>Margin per year  $2,174</td>
</tr>
</tbody>
</table>

The model can be used to address the following questions:

1. How would the annual return be affected by addition of compost?
2. What if the addition of compost allowed an additional two years of production?
3. What if the life cycle of raspberries without compost was 8 years instead of ten?
4. What if the addition of compost reduced the need for fumigation and reduced pesticide costs by 50%?
5. What if additional compost could eliminate pesticide and fertilizer use completely?
6. What if the berry production could become organic and obtain higher prices for the berries?
7. What happens if the yield for the berries decreases by 25% because of no fertilizer and pesticide use?

Estimates of how net revenue per acre is affected by various management changes are summarized in Table 13.

The various scenarios were chosen with the following assumptions.

- Scenario 1 is the base scenario, which is the same as the 2007 model produced by the BC Ministry of Agriculture updated to reflect 2012 fumigant, pesticide and fertilizer prices.
- Scenario 2 assumes addition of compost for raspberry production, both for planting and annual spring applications. There is no reduction in fumigant, pesticides or fertilizer costs associated with this scenario.
- Scenario 3 assumes that fumigation costs are eliminated and pesticide costs reduced by 50%. It is understood that compost may be effective in reducing the incidences of root diseases, but may have less effect on leaf and stem diseases. In this scenario, fertilizer costs are also decreased by 50%.
• Scenario 4 assumes that all fumigation and pesticide and fertilizer costs are eliminated by using compost. The annual cost of compost is doubled. “Other expenses” are increased by 25% to reflect increased weeding or other costs associated with elimination of pesticides.

• Scenario 5 assumes the same scenario as scenario 4, except that the price of raspberries is increased by 25% to reflect “organic” production.

• Scenario 6 assumes the same as scenario 5, except with 75% of raspberry yields due to “organic” production.

Annual revenue decreases by 13% if the crop has to be removed after 8 years instead of 10, demonstrating the expense of replanting and establishing a new crop.

Compost additions used in this model include compost costs of $1,600 per acre during the year of establishment and $200 per acre in the following years. The model shows that net returns from applying compost are slightly less if the raspberry plants gain another two years of production (for example 10 years instead of 8, or 12 years instead of 10). This scenario assumes no economic value of the fertilizer provided by the compost, or any net benefit from increased disease resistance. Gaining an additional two years of production when using compost is a realistic possibility. Miles et al. (2004) observed that annual application of poultry or dairy manure increased raspberry yields and decreased occurrence of raspberry root rot in Western Washington. There appears to be no data available on the effects of annual compost application on the life of the raspberry plant.

Table 13. Net revenue ($ per acre) with various scenarios including compost application and reduced fertilizer or pesticides.

<table>
<thead>
<tr>
<th>Net Revenue from Raspberry Production ($ per Acre per Year)</th>
<th>8 year cycle</th>
<th>10 year cycle</th>
<th>12 year cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Base Scenario</td>
<td>$1,896</td>
<td>$2,174</td>
<td>$2,359</td>
</tr>
<tr>
<td>2 Compost, no benefits assigned</td>
<td>$1,531</td>
<td>$1,842</td>
<td>$2,049</td>
</tr>
<tr>
<td>3 Compost reduced pesticides</td>
<td>$2,035</td>
<td>$2,317</td>
<td>$2,505</td>
</tr>
<tr>
<td>4 Compost no pesticides</td>
<td>$1,777</td>
<td>$2,043</td>
<td>$2,221</td>
</tr>
<tr>
<td>5 Organic with compost</td>
<td>$3,052</td>
<td>$3,363</td>
<td>$3,571</td>
</tr>
<tr>
<td>6 Organic with compost (75% yield)</td>
<td>$1,458</td>
<td>$1,713</td>
<td>$1,883</td>
</tr>
</tbody>
</table>

1 Based on 2007 information (BC Ministry of Agriculture 2007)
2 Addition of $1,600 per acre of compost in year of establishment and $300 in following years
3 Scenario # 2 but with no fumigants and 50% reduction in pesticide use
4 Scenario # 3 but with no pesticides and 25% increased expenses (weeds etc), 2x compost
5 Scenario # 4 but with 25% greater revenue due to organic production
6 Scenario # 5 but with 75% production compared to # 1-5

If the use of compost decreases the cost of pesticides by 50%, and eliminates need for fumigation, the increased cost of the compost results in a net annual revenue increase of 6.5% compared with the base scenario. If the use of compost further increases the life of the planting from 10 to 12 years, revenue per acre increases by 15%.

If all use of pesticides and fumigants were eliminated, expenses due to weed management may increase. In this case, a 25% higher expense cost was assumed. It was also assume that the annual application of compost would double to cost $400 per acre. In this case, assuming similar yields, the
increased cost of the compost, and the additional 25% expenses for weed control resulted in a 6% decrease in annual revenue. However, if the raspberry plants could be harvested for 12 years instead of 10 years, annual revenue increases by 2%.

By eliminating all pesticides and fumigants, berry production could be certified for organic production. If it is assumed that a 25% price premium could be achieved, the net revenue increases by 55% over the base scenario, and by 64% if an additional two years of production can be achieved.

In the last scenario, it is assumed that organic production, or no use of pesticides and fumigants would result in 25% lower yields compared to the base scenario. In this case, revenues are decreased by 21% when assuming a 10 year life cycle, and 13% if the raspberry plants can be harvested for an additional two years.

It is interesting to note that the total cost of fumigants and pesticides on the 1012 ha over the Abbotsford aquifer is $1.75 million dollars, assuming that the 2007 costs still apply in 2012. The cost increases to $1.82 million if the raspberries require replanting every eight years instead of every ten years.

**Conclusions**

28. Compost produced from food waste and green waste will have the lowest cost because much of the composting cost is offset from tipping fee revenue.

29. The cost of producing compost from green waste and food waste is higher than the cost of producing compost from spent mushroom compost, or other clean agricultural wastes. This is because the green waste/food waste requires additional processing before composting and may contain more non-compostable material. It also requires a more stringent odor control system.

30. Producing a compost from spent mushroom compost, or separated dairy solids does not require the same odor control, requires no preprocessing. The cost of producing high quality compost produced from spent mushroom compost may be up to $53 per cubic meter.

31. The fertilizer value of compost is difficult to define because some of the nitrogen may be released more slowly, and the compost also contains micronutrients. The net value of compost may be greater for disease resistance and extending the life cycle of the raspberry plant than for its fertilizer value.

32. A cost of $20 per cubic yard for compost was assigned, as this is a realistic market price for the compost. Based on this, and assuming an annual application of 7 tonnes per hectare, and a spreading cost of $80 per acre, the cost of providing and applying compost was $200 per acre.

33. A lifecycle analysis using published revenue and expenses data from 2007 demonstrated that the most significant variable appears to be the effect of life cycle of the berry crop, where an additional two years of life increases the annualized revenue by up to 15%.

34. Although application of compost may have a higher cost than fertilizer and pesticides, an increased life expectancy of the raspberry plant offsets these costs. Additional scenarios demonstrate the economics of compost utilization on the annualized cost of a raspberry crop.
Conclusions, Recommendations and Identifying Gaps

Conclusions

Defining Qualities of Compost for Raspberry Production

1. Organic material should be properly composted for the required times and temperatures to reduce potential pathogens as required under the Good Agricultural Practice guidelines.

2. Compost should be fully mature (6-18 months, depending on manure and on process) to have the greatest likelihood of exhibiting disease suppressive effects.

3. Compost produced from poultry manure only is not likely the best product for disease suppression, as it may result in too much nitrogen loss during composting, and may pose a risk of nitrate leaching if used as an amendment at high rates.

4. Modest annual applications of compost may supply the annual phosphorus and potassium requirements of the raspberries, but may not supply the annual nitrogen requirements, particularly during the period of rapid growth. This is true in particular if the C/N ratio of the compost is higher than 15. Compost should be applied in the spring for optimal nutrient benefit.

5. While compost applications may not meet crop nitrogen requirements in the year of application, cumulative applications and accumulation of mineralizable nitrogen may reduce fertilizer requirements. The potential for reduced fertilizer inputs may be monitored using an end of season nitrate test “report card” approach (BC Berry Production Guide 2012).

Identifying Quantities of Compost Required for Raspberry Production

6. Raspberry production may benefit from a larger application of compost (50 to 100 tonnes per ha) during replant (every 8-10 years) as well as from annual spring application (7 tonnes per ha) to supply some or all of the annual nutrient requirements.

7. The amount of compost applied depends on soil phosphorus and potassium concentrations, as compost will supply both of these nutrients as well as many micronutrients.

8. Compost must be added in the spring to provide optimal nutrient benefit for the raspberries and reduce the risk of nutrient loss through leaching.

9. The amount of compost required annually for 1012 ha of raspberry production over the Abbotsford aquifer is estimated to be 5,600 tonnes for replant (50 tonnes per ha) and 6,300 tonnes for annual spring applications (7 tonnes per ha) for a total compost requirement of 11,900 tonnes per year.

Investigating Potential Feedstocks for Producing Compost with Desired Characteristics

10. There are many combinations of available organic waste that may result in compost with the desired qualities for raspberries.

11. Additional research is required to assess the potential benefits of various composts, particularly with respect to potential disease suppressive effects.

12. Composted poultry manure has a high nitrogen content and has the potential for odor and ammonia emission during production.
13. A combination of horse manure and food waste or poultry processing waste may produce compost with the desired qualities. Consistency in moisture content of the horse manure will be a challenge because of current manure management on horse farms.

14. Spent mushroom compost may produce compost with the desired qualities for raspberries if it can be verified that there are no persistent herbicides in the wheat straw imported from the US.

15. Compost produced from a residential food waste and yard waste program may be able to produce a compost with the desired qualities. This type of compost may provide the greatest long term potential as there is a clearly identified need to find suitable markets for this product.

### Composting Options to Produce Compost with Desired Qualities

16. The highest quality compost produced in the shortest time period requires a combination of forced aeration and mixing.

17. Static pile composting, which is currently the most common composting process on farms in BC, will be least likely to produce quality compost for raspberries within a reasonable time period (less than 18 to 24 months).

18. Turned windrow composting will produce great compost, however the land area required and the environmental concerns regarding odor and water pollution from a large land area makes this process too costly.

19. Aerated windrows inside a building hold the most promise for producing compost suitable for raspberries with the least likelihood of environmental concerns.

20. Regardless of the technology, a significant period of curing the compost is required to produce a compost having the qualities that are optimal for raspberry production.

21. All of the options discussed can be accommodated to reduce the risk of environmental contamination and excessive odor.

### Regulations Affecting Production of the Compost with Desired Qualities

22. There are municipal, provincial and federal regulations that apply in producing compost for raspberry production.

23. There are no current regulations that specify the production of mature and stable compost as has been identified for raspberry production.

24. The least amount of regulation applies if compost is produced from agricultural waste on farms where it is produced (e.g., poultry or dairy farms) or if compost is produced on the raspberry farm.

25. The present Agricultural Waste Control Regulation does not require compost be produced in accordance with requirements for compost as required under internationally accepted Good Agricultural Practice guidelines, or the maturity identified as being most beneficial for raspberries.

26. The Organic Matter Recycling Regulation provides the greatest guidance for producing compost that is safe and free of potential pathogens, but does not specify compost stability or maturity.

27. The current regulatory framework creates challenges to finding a suitable location for commercial composting to produce compost suitable for raspberry production. The Agricultural Land Commission is discouraging commercial composting on agricultural land (Schmidt 2010), and finding industrial land that can accommodate a commercial composting facility in the Fraser Valley may be challenging. The cost of industrial land may also be prohibitive to producing compost at a reasonable price.
Economic Analysis of Producing and Using Compost for Raspberry Production

28. Compost produced from food waste and green waste will have the lowest cost because much of the composting cost is offset from tipping fee revenue.

29. The cost of producing compost from green waste and food waste is higher than the cost of producing compost from spent mushroom compost, or other clean agricultural wastes. This is because the green waste/food waste requires additional processing before composting and may contain more non-compostable material. It also requires a more stringent odor control system.

30. Producing a compost from spent mushroom compost, or separated dairy solids does not require the same odor control, requires no preprocessing. The cost of producing high quality compost produced from spent mushroom compost may be up to $53 per cubic meter.

31. The fertilizer value of compost is difficult to define because some of the nitrogen may be released more slowly, and the compost also contains micronutrients. The net value of compost may be greater for disease resistance and extending the life cycle of the raspberry plant than for its fertilizer value.

32. A cost of $20 per cubic yard for compost was assigned, as this is a realistic market price for the compost. Based on this, and assuming an annual application of 7 tonnes per hectare, and a spreading cost of $80 per acre, the cost of providing and applying compost was $200 per acre.

33. A lifecycle analysis using published revenue and expenses data from 2007 demonstrated that the most significant variable appears to be the effect of life cycle of the berry crop, where an additional two years of life increases the annualized revenue by up to 15%.

34. Although application of compost may have a higher cost than fertilizer and pesticides, an increased life expectancy of the raspberry plant offsets these costs. Additional scenarios demonstrate the economics of compost utilization on the annualized cost of a raspberry crop.

Recommendations

Defining Qualities of Compost for Raspberry Production

1. Source or produce a fully mature compost that is most likely to provide disease suppressive effects for use in replant as well as annual application. The optimal compost used for replant (e.g. lower nitrogen concentration, higher C/N ratio) may be different than that for annual applications (e.g. higher nitrogen concentration).

2. Compost used for raspberries should meet the internationally accepted standards for safety.

3. Evaluate nitrogen release from the compost in relation to the nitrogen uptake requirements of the crop.

4. Perform long term experiments to determine the potential benefit of annual applications of compost on the life of the raspberry plant.

Identifying Quantities of Compost Required for Raspberry Production

5. Determine optimal rates of compost depending on the nutrient contents of the compost. This may include developing a decision making process that includes nitrogen content, expected nitrogen availability and considering soil and compost phosphorus concentrations.

6. Consider the phosphorus and potassium contributions of the compost in relation to soil phosphorus and potassium concentrations.
7. Annual compost applications should not be based on available nitrogen applications similar to the current rates of fertilizer nitrogen application.
8. Compost should be spring applied as a band along the raspberry row for optimal nutrient benefit for the raspberry plants.

**Investigating Potential Feedstocks for Producing Composts with Desired Characteristics**

9. Assess the potential benefits of various composts, particularly with respect to potential disease suppressive effects. Ensure that there is a proper composting process and maturation period.
10. Establish whether there is a benefit to further composting spent mushroom compost and if it has the potential to suppress root diseases.
11. Consider yard waste/food waste compost as it will become a very available product in the coming years as our urban neighbours recycle their food waste. This product is most likely to meet regulatory requirements and requirements under the Good Agricultural Practice guidelines.
12. Determine whether additional maturation is beneficial for potential disease suppression with applications of wood waste/food waste on raspberries.

**Composting Options to Produce the Compost with the Desired Qualities**

13. An aerated static windrow process inside a building with at least two mixes during the process is mostly likely to produce compost with the desirable qualities for raspberries in a cost effective manner.
14. A well designed aeration system that provides adequate oxygen and discourages the production of anaerobic and odorous compounds, a layer of woodchips or finished compost on top of the windrows if additional odor control is required, and an external biofilter on the building in case still more odor control is recommended.
15. Following aerated windrow composting, the compost should be further cured outdoors using a Compostex or equivalent cover to allow maturation to continue, while preventing moisture and weed seeds from entering the compost.

**Regulations Affecting Production of the Compost with the Desired Qualities**

16. Compost for raspberry production must meet the process requirements and the product requirements as required in the Organic Matter Recycling Regulation.
17. Compost for raspberry production must meet the standards as per international acceptance of Good Agricultural Practice guidelines.
18. Producing quality compost for raspberries is most likely to succeed if it is done commercially, but this may become cost prohibitive if it is required to occur on industrial land.

**Economic Analysis of Producing and Using Compost for Raspberry Production**

19. Determine fertilizer value of various composts in terms of nitrogen, phosphorus, potassium and some of the micronutrients.
20. Compost should be spring applied and banded on the raspberry row for optimal nutrient benefit.
21. Perform longer term trials using annual spring applications of compost to determine whether the nutrients and organic matter increases the life expectancy of the raspberry plant.
Identifying Gaps

1. There are very few composts produced in south coastal British Columbia that would meet the process and quality requirements recommended for optimal disease suppressive benefits for raspberries. These will become more available if disease suppressive benefits could be demonstrated. There is a need for assessment of the disease suppressive benefits of composts, and for identification of the compost properties or process which are most likely to provide such benefits.

2. The short term and long term effects of annual compost applications on potential nitrate contamination of the groundwater requires additional evaluation. The effect of annual application on plant vigor and life expectancy has not been established. The effect of annual application of compost on nitrogen use efficiency of any additional inorganic fertilizer has also not been established.

3. The effect of a quality compost application during replant to potentially eliminate the use of fumigants has not been demonstrated. It is not valid to assume that the application of compost will be similar to the application of poultry litter.

4. The disease suppressive effects of mature compost have not been demonstrated with raspberries, in part because of the lack of quality compost available.

5. Life cycle analysis using actual production data with annual spring applications of compost have not been done. The net economic and environmental benefit of compost applications needs to be evaluated.

6. There is little economic incentive to produce composts at this time as the cost of producing the compost is greater than the current perceived value. There is a need to provide consistent regulation of the composting process that will allow quality composts to be produced and education on the value of producing quality composts.
References


http://www.ccme.ca/assets/pdf/pn_1440_contam_invt_rvw.pdf


http://www.globalgap.org/uk_en/


http://www.unitedfresh.org/assets/food_safety/Harmonized_Standard_pre-farm_gate_110722.pdf

http://www.fda.gov/Food/GuidanceComplianceRegulatoryInformation/GuidanceDocuments/Producean
dPlanProducts/ucm064574.htm#iii

