Red raspberry (*Rubus idaeus* L.) cultivars in a Nordic climate - morphological traits and berry quality

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Abstract

Fruit including berries have been demonstrated to exhibit a broad spectrum of benefits including protection against cardiovascular, neurological, and lung diseases, as well as having antioxidant, antimicrobial, anti-inflammatory, antidiabetic and anti-aging properties. These protective effects are reported to be due to their high content of bioactive compounds, such as vitamin C, vitamin E, phenolic acids, ellagitannins, flavonoids and carotenoids.

This thesis has investigated the effect of Nordic climate factors on the concentrations of bioactive compounds in raspberries. The main objective of this thesis was to investigate the effect of environmental factors and potential differences in total amount of bioactive componds, yield, berry weight and corelation between those figures as well as difference in figures between nine (9) different Raspberry cultivars, *Rubus idaeus L.* cultivars which were planted and are grown in nordic climate with special attention in differences between cultivar Glen Ample and other eight cultivars.

Variables that have been studied are Yield, Berry Size, Soluble Solids(SS), pH, Titratable Acids (TA), AA (ascorbic acid-vitamin c), Dry Matter (DM), Color, TPH (total phenols) and Total Monomeric Anthocyanins (TMA).

Concentrations of bioactive compounds in the berries were quantitatively analysed by HPLC. For analyses of FRAP, TMA, and TP, KoneLab 30i (Thermo Electron Corp., Vantaa, Finland), a clinical chemical analyzer was used.

Experimental data were subjected to analyses of variance (ANOVA) and regression analyses by standard procedures. This study demonstrates that a high variation of chemical fruit composition exist among cultivars tested.

ABBREVIATION

AA – Ascorbic Acid

ANOVA – ANalysis Of VAriance

AOC- Anti-Oxidant Capacity

DM – Dry Matter

DRI – Daily Recomended Intake

EMR – East Malling Research

FRAP - Ferric Reducing Antioxidant Power assay

PYO farm – Pick Your Own

RBDV – Raspberry Bushy Dwarf Virus

RMV – Raspberry Mosaic Virus

ROS – Reactive Oxigen Species

SCRI- Scottish Crop Research Institute

SPSS - Statistical Product and Service Solutions

SS – Soluble Solids

TA – Titratable Acid

TMA – Total Monomeric Anthocyanins

TPC – Total Phenol Content

UMB – Universiter for Miljo og Biovitenskap

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1. INTRODUCTION

There are over 200 cultivars of raspberries and all commercially important raspberry species are prized for their unique and delicate fruit flavor and are often used in fresh deserts. Raspberries can be commercially grown in a greenhouse or in the open field, often covered with plastic tunnels. For fresh market, red raspberries are best harvested when they are bright red and can be stored at 0°C only for few days. Red raspberry (*Rubus idaeus L.)* is an economically important small fruit species and a rich source of antioxidants and phytochemicals with potential health benefits. In recent times, dietary antioxidants have received increasing attention because of their important function in mitigating the damaging effects of oxidative stress on cells and tissues (Rao and Snyder, 2010). Raspberries have significantly high levels of phenolic flavonoid phytochemicals such as anthocyanins, ellagic acid (tannin), quercetin, gallic acid, cyanidins, pelargonidins, catechins, kaempferol and salicylic acid (Shahidi and Naczk, 2004). Anthocyanins are the major contributors to the red colour pigment in berry fruits and are also used by consumers to judge the quality of a fruit. The synthesis of anthocyanins depends on many ecological and physiological factors, but also on berry species and cultivars. Scientific studies show that these antioxidant compounds in these berries have potential health benefits against cancer, aging, inflammation, and neurodegenerative diseases.

Fresh raspberries are an excellent source of vitamin C, which is also a powerful natural antioxidant. 100 g berries provides about 47% of DRI of vitamin C. Consumption of fruits rich in vitamin C helps the body develop resistance against infectious agents, counter inflammation, and scavenge harmful free radicals. Large numbers of bioactive coumpounds contribute to the antioxidant capacity (AOC), but the total activity is mainly reflected in their Total Phenolic and AA concentrations. Raspberry contains antioxidant vitamins like vitamin A, and vitamin E. In addition to the mentioned antioxidants, is also rich in several other health promoting flavonoid poly phenolic antioxidants such as lutein, zea-xanthin, and ß-carotene in small amounts. Altogether, these compounds help act as protective scavengers against oxygen-derived free radicals and ROS that play a role in aging and various disease processes (Kalt, Forney, Martin, and Prior, 1999).

Because of the potential health benefits of dietary antioxidants in raspberries, researchers are focused on analytical screening of the AOC raspberry plants. Focus is mainly on on variation among species and cultivars and effects of postharvest handling and storage.

2. SCIENTIFIC NAME

Raspberries (*Rubus ideaus L.),* belong to the genus *Rubus,* are a member of the *Rosaceae* family, grown as a perennial crop. Different species in the *Rubus* genus are native to six continents and have been found from the tops of mountains to coastal locations at sea level (Daubeny, 1996; Thompson, 1995). They grow especially well as cool climate plants, but will also produce worthwhile crops in the subtropics. Raspberries are available commercially in red, yellow, purple, and black forms. Cultivated raspberries have been derived mainly from two species, the wild red raspberry *(Rubus ideaus)* and black raspberry *(Rubus occidentalis).* Purple type is a cross between the black and red raspberry, and yellow type is a mutant of red raspberry. The red or yellow raspberry is classified into two subspecies, *R. idaeus subsp. vulgatus Arrhen.* (European red raspberry) and *R. idaeus subsp. strigosus Michx.* (American red raspberry). Black raspberries found in eastern North America are *R. occidentalis L.; R. glaucus L.* is a South American tetraploid black raspberry. Purple raspberries (*R. neglectus Peck.)* are result from crosses of black and red raspberries. The red raspberries are thought to originate from Asia Minor. Reference to raspberries as food and widespread cultivation in the European countries was reported in the 16th century, although it was the English who cultivated, hybridised and improved the species throughout the MiddleAges (Hummer, 2010; Trager, 1995; Jennings 1988; McGregor, 1976). Berries are compound fruits, made up of many drupelets, and a hollow center where the fruit detaches from the receptacle. Druplets are the small individual sections or drupes that are held together by tiny hair to make one fruit. When inadequate pollination occurs, the druplets are loosely joined and when the fruit is picked, it crumbles. The plant is an erect, semi-erect or trailing, generally thorny, shrub, producing renewal shoots from the ground called canes. *Rubus* berries are not true berries but aggregate fruits and have a number of culinary uses in the modern era, e.g. as a fresh fruit, processed into jams, as a yogurt flavouring, pie filling etc. (Rao and Snyder, 2010; Daubeny, 1996). Although the fruits were undoubtedly popular for food, medicinal uses remained important. Raspberry leaf tea is an ancient, but still popular, herbal infusion.

Modern research has shown that a water-soluble extract from raspberry leaves relaxes the uterine muscles. Raspberries are among the colored fruits that are a very popular and important part of the food consumed in Northern Europe.

These fruit have long been collected and consumed simply because of their taste aspect, but today the increased awareness of health issues has intensified consumer demand. In general, the quality assessment is based on visual aspects of the fruit, texture, flavour and health compounds in the fruit (Pelayo et al., 2003). Raspberries have long been valued for their medicinal and nutritional benefits. It is a rich source of antioxidants and phytochemicals with potential health benefits (Rao and Snyder, 2010).

With today's interest in natural foods and healthy diets, raspberries' popularity remains strong. Recent research supports long-held beliefs that raspberries are a particularly healthy part of the human diet.

3. BIOLOGY

3.1. Growth and Development

Raspberries are shallow rooted with most of their root system in the top 25 cm of soil. Their roots continue to grow and remain active for the life of the planting, while above-ground stems (canes) have a two-year life span. During those two years each shoot passes through vegetative growth, flower initiation and development as well as induction and breaking of bud dormancy. New canes (primocanes) arise from basal buds of old canes or from buds on the roots in the spring. These same canes develop flower buds in the late summer and fall. The following season they are called floricanes and produce fruit on lateral shoots in the late spring and early summer. Varieties that follow this pattern of development are called summer or floricane fruiting. After fruiting, the floricanes die. The morphology and seasonal development of the biennial raspberries were studied and described by Hudson (1959) and in associated series of papers, environmental impacts and factors were investigated by Williams (1959, 1960). Some raspberry varieties also produce fruit on the growing tips of the primocanes. These types of raspberries are called fall fruiting, primocane fruiting, or everbearing raspberries. When the primocanes of these varieties attain a certain number of nodes, the growing tip of the cane switches to a reproductive mode and floral buds are initiated, followed by flowering and fruiting in summer and fall. If not removed during the winter, these canes will also become floricanes the following spring and will produce fruit on shoots that develop from lateral buds that did not grow and fruit in the previous year.

3.2. Climatic Requirements

Raspberries are not well suited to southern climates because most cultivars have relatively high chilling requirements and do not tolerate high summer temperatures. Most of them do not perform well under high temperatures. Both, shoots and roots are sensitive to high temperatures (Jennings 1988). Research has shown that optimal leaf temperatures are near 18°C to 21°C while roots perform well in temperatures up to about 24°C to 26°C. During heat stress, photosynthesis, the process by which plants produce their own food, shuts down once optimal air and soil temperatures are exceeded. This can result in reduced plant and fruit size (Williams 1959). There may also be a reduction in the amount of food that the plant should store to get through the winter. Two aspects of winter temperatures are critical to the survival of raspberries.

These are cold hardiness and accumulation of chilling units. As in many other fruit crops, the short, cooler days of late summer and fall prepare the raspberry plant for the upcoming winter season. The canes stop growing and undergo physiological changes that allow them to endure the cold winter temperatures. This is called cold hardiness (Jennings et al. 1972.. Some raspberry varieties are able to withstand temperatures to -28°C during the coldest period in the winter. Injury from low temperatures can also occur in late winter after chilling has been satisfied and in early spring when the raspberry plant is no longer dormant. Damage to flowers can result when flower or fruit temperatures drop below 0°C.

3.3. Dormancy and cold hardiness

Red raspberry plants frequently suffer winter injury in northern climates. This injury usually occurs from midwinter until freezing temperatures end in April or May.

Symptoms include tip dieback with injured buds on the living part of the cane (Nestby, 1992). Red raspberries develop sufficient cold hardiness in autumn, but the capacity to retain cold hardiness during intermittent short periods of warm weather and to reharden are crucial for their winter survival (Zatylny et al., 1996).

In autumn, leaves turn yellow or yellowish-red, dry up, and fall from the primocanes. Before the falling of the leaves, some nutrients and biochemicals move from the leaves to the canes and roots, where they are stored for next year's growth. The primocane stems and buds remain alive and enter a condition called dormancy, or rest. Once plants enter dormancy, a certain number of chilling hours, generally considered to accumulate at or below 230°C, are required before the plant can resume normal growth and development (Jennings et al. 1972). Because chilling requirements depend greatly on variable environmental conditions, they are hard to predict exactly. Not all tissues within the canes or buds are equally cold hardy. The degree of cold hardiness varies throughout the year. Maaximal cold hardiness has been reported to occur in January or in February, 2 months after the breaking of endodormancy (Zraly, 1978). Hardiness has been positively correlated with the lenght and depth of endodormancy (Bailey, 1948, Jennings, 1964)

Flowers and actively growing tissues may be killed at around 0°C. As plant senescence and winter acclimation begin in fall, hardiness slowly increases. Maximum resistance to freezing injury is found in fully acclimated canes exposed to extended, continuous, nonlethal, subfreezing temperatures. Once chilling requirements have been met, relatively short periods of warm temperatures can decrease the canes' cold hardiness. For example, an unusually warm January can cause canes to lose some of their cold hardiness.

If that warm spell is followed by subfreezing temperatures, the canes can be injured. The seriousness of the injury depends on many factors, including cultivar, when the warm spell occurs, how long it lasts, how high temperatures rise, how rapidly and how low temperatures drop, how long the low temperatures last, and cultural practices, such as weed control and fertilization (Zatylny et al., 1996).

3.4. Influence of temperatures on raspberries

Growth rate in both, biennial and primocane fruiting cultivars increases with temperature (Carew et al. 2000; Kershaw 1991). Increasing temperatures also advanced flowering and fruiting in primocane fruiting cultivars (Kershaw 1991). In biennial fruiting cultivars, where flower initiation is more distinct from flowering and fruiting, the temperature at which flower initiation is delayed or prevented seems to be much lower than in primocane cultivars (Williams 1959).

Resistance of raspberries at low temperature depends on the variety, and on the range and retention of low temperatures (Nestby 1992).

Raspberry shoots of some varieties can also withstand up to -26°C even if the soil surface is not covered with snow. The root is very susceptible to low temperatures because it is widespread very shallow and it can freeze at a temperature of -13°C if the ground is not covered with snow. Fluctuation and change of weather in the early spring can harm developing shoots .The most frequent are frozen roots and shoots, and flowers and saplings are not disadvantaged because of blooms that take place in May, when there is no danger to the inflorescence (Galletta and Himelrick 1990).

3.5. Number of drupelets per berry

The number of drupelets per berry is determined by how many ovules are fertilized. Pollination and subsequent fertilization of the ovules are influenced by weather conditions during bloom, nutrient status, disease, and insect damage (Dale 1989). Cold, wet, and rainy weather greatly reduces bee activity, particularly for domestic bees. Besides reducing bee foraging, rain can dilute the stigmatic fluid on the pistils and, thereby, reduce fruit set. Cold temperatures also affect the plant directly. Even if a flower is pollinated, temperatures below about 16°C slow pollen germination and pollen tube growth. This problem is less common in raspberries, however, than in blueberries, currants, and other fruit crops that bloom in early spring.

Red raspberries have great capacity to compensate for changes in yield components.
If one or more factors are adversely affected, the plant tends to respond in ways that offset the potential yield reduction. If the number of buds per cane is reduced by topping, for example, the remaining laterals tend to bear more fruits (Hudson 1959).

4. CULTURAL PRACTICES

4.1. Pruning

The purpose of pruning and training systems is to remove dying floricanes after harvest and to optimize cane density for the following growing season. In autumn all canes that bore fruit during the summer should be cutted down to soil level. To help with pruning summer raspberries, it may be worth marking the fruiting canes during the summer so you can distinguish between these and the new season's canes (new season's canes are lush and green). Aim is to tie in 6-8 of the strongest new canes and remove the rest. The new canes should be spaced out about 10cm apart on their support to allow each cane as much light and air as possible (Raspberry and Blackberry Production Guide: For the Northeast, Midwest, and Eastern Canada, NRAES-35).

4.2. Soil

Red raspberry grows across a wide range of sites throughout most of the world's temperate regions (Dale and Daubeny 1985). It commonly occurs in clearings or borders in boreal forests and in ravines. Raspberry plants require full sunlight, good air movement, adequate moisture, and protection from wind and frost injury. They will tolerate shading but you're unlikely to get as much fruit as raspberries growing in full sun. Cold, dry air can cause serious winter damage A site that is elevated above the surrounding area should provide adequate exposure to sunlight and protection from late spring frosts (Bare, 1982). Windbreaks can provide some protection from excessive winds on exposed sites. Raspberries planted on south-facing slopes ripen earlier than those on north slopes, but may be prone to flower damage due to late spring frosts. Variations among local environments, microclimates, and cultural conditions can affect a variety performance at different sites. Raspberries are tolerant of a wide range of soil pH and texture but do require adequate soil moisture.

Red raspberry grows on imperfectly to well-drained sandy loam to silty clay loam, but best growth occurs on moderately well-drained soils with good water holding capacity and high organic matter content that is greater than 3 % (Watson, Parker and Polster, 1980). The amount of water available to the raspberry plant during the growing season is very important.

Excess water can result in root disease problems, while a shortage of water can reduce overall plant vigor, especially yield. Raspberry plants need plenty of water, especially during fruiting. Raspberry plants need good soil aeration and are very susceptible to root rots. Although red raspberry grows well on barren and infertile soils, it reportedly has a relatively high demand for soil nutrients and is most abundant on nutrient-rich soils and this shrub is moderately tolerant of acidic soils (Bare, 1982).

4.3. Harvesting and postharvest treatment

The number of berries and individual berry weights determine total yield. Factors that influence the number of berries are: (1) the number of fruits per lateral, (2) the number of fruiting laterals per cane, and (3) the number of canes per acre. Berry weight is influenced by the number of drupelets per berry and drupelet size (Hudson 1959, Dale 1989). Total yield includes all fruits that form on the plant. In practice, many fruits are not harvested due to disease, pest, or physical damage. In addition, some acceptable fruits fall to the ground during harvest (Waister et al., 1980).

Many factors interact to determine how many fruits will form per lateral. These factors include the following: (Hudson, 1959; Williams 1959, 1960)

• Location of the lateral on the cane

• Percent fruit set (the number of flowers that develop into fruits)

• Cane diameter—Larger diameter canes produce more fruits per lateral.

• Competition with other fruits and laterals on the same plant for water, nutrients, carbohydrates, and plant growth regulators: Reducing competition through primocane suppression (removing the first flush of primocanes in the spring) and managing the number of canes per foot of row or per hill increases the number of fruits per lateral. This effect is especially pronounced at the base of the floricanes.

• Light intensity — Shade by overly dense canopies reduces flower bud initiation on primocanes, reducing the number of flowers per lateral for next year's crop.

Number of fruiting laterals per cane (Dale and Daubeny,1985)

Factors that influence the number of fruiting laterals per cane include the following:

• Winter pruning practices: topping reduces the number of nodes (potential fruiting laterals) per cane.

• Cane vigor (growth rate): vigor influences internode length. If internodes are long, there are fewer nodes or laterals per foot of cane length. Internode length increases in response to shade or high soil nitrogen concentrations.

• Percent bud break: Bud break may be influenced by cane length, cultivar, and limiting factors

• The number of laterals per node, Some cultivars produce as many as three laterals per node. Multiple laterals usually produce fewer fruits per lateral, but often more fruits per node, than single laterals (Crandall et al., 1974; Jennings and Dale, 1982).

Number of canes per acre

The number of canes per acre depends on the following:

• In-row and between-row spacing

• Cultivar: Cultivars differ significantly in vigor, an important point to consider in cultivar selection. Selecting cultivars that are vigorous and productive under your cultural and environmental conditions is an important step in ensuring success.

• Plant age

• Cane vigor: Cane vigor depends on the cultivar and age of the planting. Plantings become more vigorous and cane numbers increase as the plants mature. Full crops normally are attained by the third growing season.

• Pruning system: Some growers reduce the number of canes per foot of row when winter pruning. Primocane suppression also reduces the number of canes per acre.

• Cultural practices: Practices such as irrigation and fertilization affect vigor and cane number (Buskiene and Uselis, 2008)

Close attention to fruit temperatures before, during and after harvest are the most important factors to control for a maximum shelf life. Fruit should be picked in the early morning, before they absorb heat from the sun. It is important to avoid picking fruit during rain or when plants are wet, which encourage the spread of fruit rot diseases. Raspberry fruit are very soft and perishable, but strategies can be taken to extend shelf life.

Raspberries should be harvested at the pink or light red stage for fresh market or at full redness for immediate sale at pick-your-own operations. However, raspberries do not increase in sweetness or flavor after picking. Basic method is to handle the fruit gently, and picking fruit daily during hot or dry weather.

5. POST-HARVEST QUALITY

Many aspects such as genetics, environmental factors and cultural practices affect the post-harvest quality of *Rubus* berries.

5.1. Genetic factors

A number of plant characteristics have been improved in recent years, including enhanced yield potential, improved disease resistance, heat tolerance and winter hardiness. Increased fruit firmness, resistance to rain damage and resistance to viruses and grey mould (*Botrytis cinera*) have been achieved by *Rubus* berry breeding and genetic program. Also, fruit size has been increased from very small to large in new released cultivars

Quality factors more or less genetically controlled, as the level and chemical composition of the bioactive compounds vary according to cultivar (Dale and Daubeny, 1985)

5.2. Cultural regime

Soil type, compost, mulching and fertilisation influence the water and nutrient supply to the plant and can affect nutritional composition and antioxidant activity of the harvested fruit (Kader, 2002). A deficiency of water can influence the yield and post-harvest quality of berry fruits (Prange and DeEll 1997). High rainfall during the fruit growing season is reported to influence the composition of harvested fruit and its susceptibility to mechanical damage during shipment and storage (Kader, 2002). Plant nutrition has a major influence on fruit quality. Nitrogen, potassium phosphorus and calcium in particular have been reported to have pronounced effects on the level of compounds and shelf-life after harvest in berry fruits (Anttonen and Karjalainen, 2009; Goldman et al., 1999; Robert and Jennifer, 1997). Nitrogen is one of the limiting factors for primary production of berry crops, as it is the basic unit for protein synthesis. Nitrogen is the plant nutrient used in the largest quantities and it can regulate cane size and number of *Rubus* berries.

An adequate soil nitrogen supply allows optimal development of fruit colour, flavour, texture and nutritional quality, whereas over-application has been shown to have negative efects on the storage quality of the berry fruit.

High nitrogen doses are also reported to decrease some of the antioxidant content, probably due to rapid plant growth and development, and thus preferential allocation of resources are directed to growth processes rather than secondary metabolism (Ali et al., 2012; Buskiene and Uselis, 2008; Mitchell et al., 2007; Winter and Davis, 2006; Jeppsson, 2000). Although potassium is not directly involved in the synthesis of bioactive compounds or plant structure in berries, it is involved in numerous physiological and biochemical processes vital for plant growth, yield, quality and stress response. Potassium is the most mobile cation in the berry plant and is involved in photosynthesis and stomata regulation during transpiration. Potassium is also involved in pH regulation of the plant, maintenance of turgour, stress tolerance and enzyme activation (Kowalenko, 1994 and Lang, 1983; Morris et al., 1983). Calcium plays an important role in plant cell elongation and division. It also plays an important role for berry fruit quality, as it is reported to maintain cell wall integration, bind together neighbouring cell walls and control the semipermeable properties of membranes.

Calcium deficiency can manifest itself as early as fruit set and can continue to exist if untreated, resulting in poor fruit quality, especially during the shelf-life after harvest (Ferguson et al., 1999). Excess amounts of calcium are reported to be non-toxic and serve as a detoxifying agent.

5.3. Climatic factors

Environmental factors such as light, CO_2, relative humidity, temperature and water availability are major direct or indirect constraints for plant photosynthesis. Environmental factors affect the content of bioactive compounds indirectly by giving the prerequisites for photosynthesis, and thereby providing energy or precursors of the synthesis of the bioactive compounds. Light has been shown to be the most important environmental factor influencing anthocyanin biosynthesis in plants (Grisebach, 1982). The texture of berry fruits is affected by traits such as number of cellular organelles and biochemical constituents such as water content, cell wall composition and turgour pressure (Sams, 1999).

Thus, the external growing environment could lead to changes in the final quality of the berry fruit and its shelf life after harvest.

Temperature and light intensity are reported to have a major influence on the nutritional quality of berry fruits.

The location and season of fruit growth, as well as monthly and yearly variations in weather conditions, define the flavour of berries and their content of vitamin C, carotenoids and especially phenolic compounds. Fruit colour is can also be affected by the mean temperature in the growing season (Wang and Zheng, 2001; Parr and Bolwell, 2000). Abiotic conditions, i.e. soil fertility and water availability, vary from year to year and site to site, and can affect the level and quality of fruit after harvest (Anttonen and Karjalainen, 2009; Wang, 2006; Spiers and Braswell, 2002).

5.4. Physiological factors

Fruit size in general is negatively correlated with firmness and amount of berry phenolics. Smaller fruits are firmer as they have the same number of cells as larger fruit, giving a greater density to the plant tissue. Fruit bearing order may also have a significant effect on the bioactive compounds in berry crops. The phenolics content is reported to be increased by 10-25% from primary to tertiary fruits (Anttonen and Karjalainen, 2009).

6. RASPBERRY PRODUCTION IN NORWAY

Currently three summer fruiting cultivars, Glen Ample from the James Hutton Institute (formerly SCRI), Tulameen from the Pacific Agri-food Research Centre (PARC) in Canada and Octavia from East Malling Research dominate the raspberry industry in Western Europe. The Scottish bred cultivar Glen Ample, released in 1996, dominates the Norwegian market, where the hardy Norwegian variety Veten has been the mainstay for many years (Heiberg et al., 2002). With production of nearly over 3 500 tonnes per year in 2009 (**Figure 5b**), Norway is not important raspberry producer on world scale, but the trend in last 20 years is contious increasing of total raspberry production as well as total area with raspberry crop. Main growing area for raspberries in Norway is in the West, in the fjord district of Sogn og Fjordane where the climate has proved to be very suitable for raspberry production, with high yield and fruit quality and little winter damage.

Going further north along the coastline the summer gets cooler, but the winter climate is similar to the main growing district. As far north as in Brønnøysund in Nordland (65º N) Glen Ample is performing well in organic outdoor production (Bøthun and Heiberg 2004).

However, rain and wind are annually damaging the fruits during harvesting reducing the yield. An important development has been the use of plastic tunnels for out of season production and protection the crop. That agricultural practice enables growers to produce quality fruit under protection from established plantations from May to late July and by using several plantings of long cane plants each year from late April to October. In the open field they provide a harvest period from late June/early July to early August each year. The trial planted at Rectory Farm, Stanton St John, Oxford (Allen, Roberts and Dyer 2012) reports significantly higher berry size for Glen Ample, Glen Fyne, Octavia, Cascade Delight and Tulameen than in our trial at UMB in 2012. Considering results like this, suggestion can be that the tunnel production will be the answer for succesfull, profitabil raspberry cropping for Norway.

All of these new developments greatly influenced on raspberry production and extended the harvesting season and improved the profitability of the crop (Raffle, 2004). Octavia and Malling Hestia are among those cultivars with extended and later fruiting season.

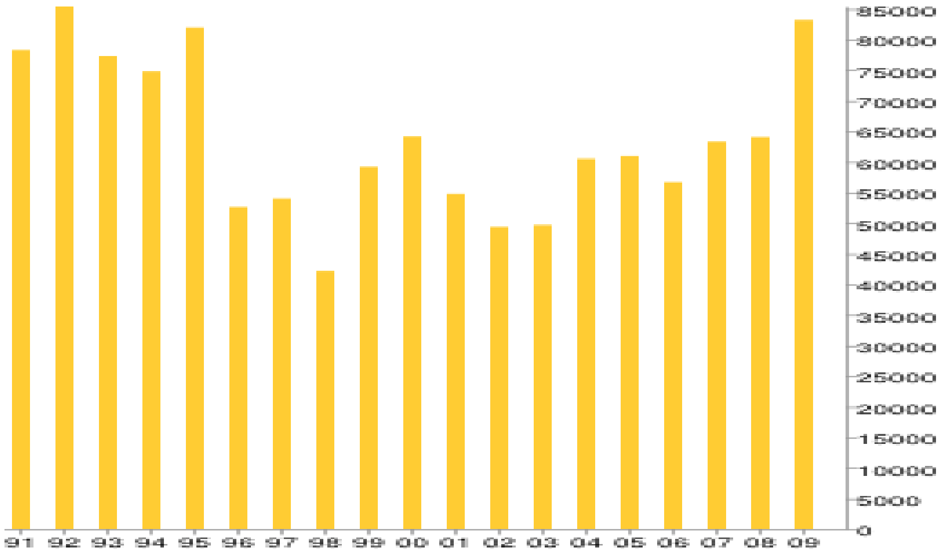

Figure 5a: Raspberry yield, Hg/Ha; (1991-2009) Norway (source: faostat.fao.org)

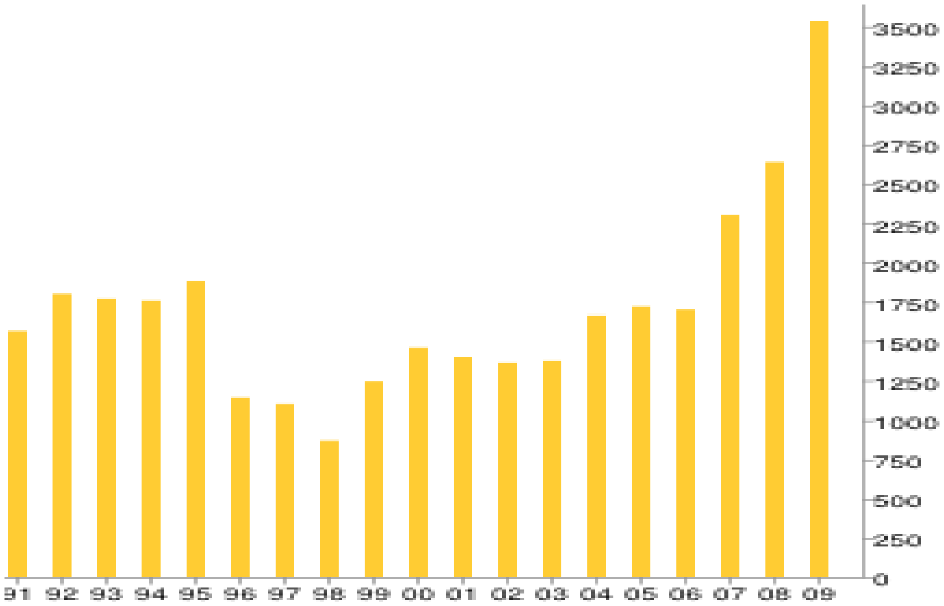

Figure 5b: Raspberry production quantity, tones (1991-2009), Norway
(source: faostat.fao.org)

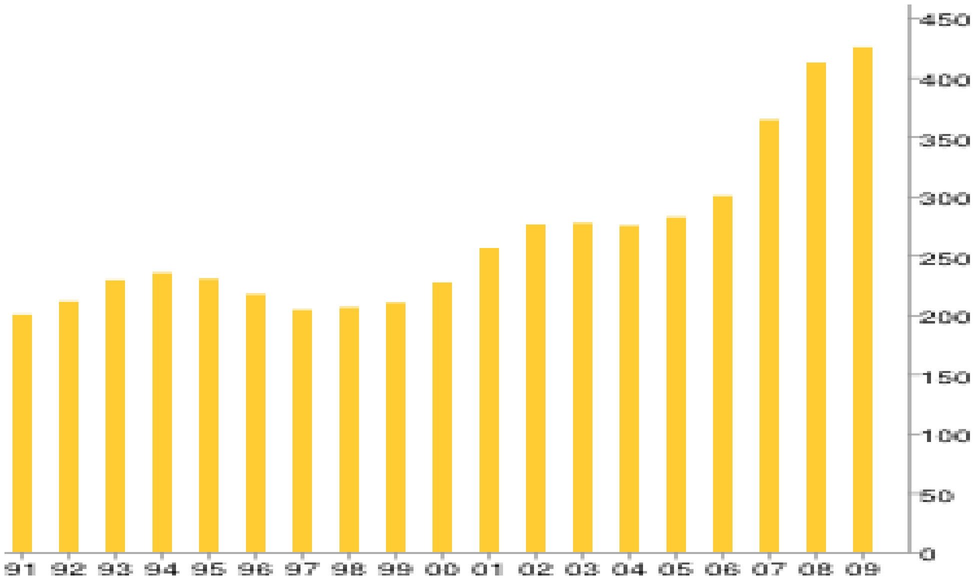

Figure 5c: Raspberry Area harvested, Ha (1991-2009): Norway
(source: faostat.fao.org)

In recent years, consumer demand for fresh raspberries outwith the main production season has increased with high premiums being paid for fresh market raspberries.
The majority of fresh market production goes to large supermarket chains and the demand for good fruit quality, flavour and shelf life is high.

Also, health benefits from raspberry plays important role for consumers.

New cultivars and new production methods increased raspberry production for fresh consumption significantly (Raffle, 2004).

Those facts were the guidelines for this research, trying to study potentials of less represented or even not yet introduced cultivars in Norway and compare them with Norwegian leading cultivar Glen Ample.

7. PLANT MATERIAL AND METHODS

Raspberries and blackberries are classified botanically as follows:

Kingdom – *Plantae*, plants

Subkingdom – *Tracheobiota*, vascular plants

Superdivision – *Spermatophyt*a, seed plants

Division – *Magnoliophyta*, dicotyledons

Class – *Magnoliophyta*

Subclass – *Rosidae*

Order – *Rosales*

Family– *Rosaceae*, Rose family

Genus – *Rubus*

Species – *Rubus idaeus L.* (raspberries) and *Rubus fructicocus L.* (blackberries)

The raspberry cultivars used in this study were grown in field at UMB, Ås, about 100m above sea level with coordinates: 59°39′37″N, 10°47′1″E. Raspberries had been planted in 2009. Plants are planted in three rows divided in eleven plots with 6 plants. Planting was arranged in a randomized complete block design with a cultivar represented in three replicates with 6 plants in plots with distance of 0,5 m between plants, 1m between plots and 4 rn between rows. First and last plot in each row, planted with Glen Ample as a control, has been not the part of experiment (**Figure 1, Picture 1**). Nine different cultivars took part in the experiment. These are: Tulameen, Glen Ample, Glen Fyne, Glen Doll, Malling Hestia, Octavia, Cowichan, Glen Magna and Cascade Delight.

7.1. Tulameen

Tulameen has been introduced in 1989. Fruit is very large, long conic, medium red, glossy and firm. This mid/late season selection was bred in Canada, and is now one of the world's most popular summer fruiting cultivar in a whole range of climates. Raspberry Tulameen has extremely high yields of very large fruit with a lovely sweet flavor. It has longest fruiting season of all summer varieties (50 days).

Cultivar is excellent for fresh market due to flavor and size. It is moderately susceptible to root rot, resistant to the common strain of raspberry mosaic virus complex and to powdery mildew. [1]

7.2. Cascade Delight

Cascade Delight was produced from a cross of Chilliwack and WSU 994 made in 1989 at the Washington State University (WSU) Puyallup Research and Extension Center. In trials in the Pacific Northwest (PNW) of the USA the midpoint of harvest for Cascade Delight is similar to Meeker and Tulameen, but the length of the harvest season is slightly shorter. Cascade Delight is very vigorous with long fruiting laterals and produces an adequate number of canes, similar to Meeker. Although the basal portions of young canes (less than 30 cm tall) have 20-40 spines per cm of cane, the upper portions of taller canes (over 1 m in height) have much smaller and fewer spines (<5 spines per cm).

Cultivar produces very large, long conic shaped berries, which are glossy and very firm. In trials in the PNW of the USA the fruit of Cascade Delight have been 20% larger than Tulameen and produced similar yields. The berries have an excellent fresh red raspberry flavour and shelf life, being firmer than Tulameen.

Cascade Delight is susceptible to the large raspberry aphid (*Amphorophora agathonica*), the vector for the mosaic virus complex and to raspberry bushy dwarf virus (RBDV) via pollen transmission. In some years it has shown high levels of *Botrytis* fruit rot in unsprayed plots, but when observed for several years, did not differ significantly from other cultivars. In unsprayed plots, the canes had a low incidence of anthracnose (*Elsinoe veneta*) and cane botrytis (*B. cinerea*) and moderate incidence of spur blight (*Didymella applanata*).

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[1] http://www.meiosis.co.uk/fruit/cascade_delight.htm 22.04.2013.

Cascade Delight exhibits some degree of field resistance to root rot (*Phytophthora fragariae var. rubi*). In research plots established at WSU Mt. Vernon in 1998, adjacent plots of several cultivars, including Tulameen, were all killed or severely damaged by root rot by 2001, but Cascade Delight remained vigorous.

The fruit of Cascade Delight is very large, very firm and glossy with excellent fresh flavour. These characters would make Cascade Delight ideally suited for fresh markets. Cascade Delight does not appear to be suited for machine harvesting even though the fruit releases very easily from the receptacle. It is very vigorous and has long fruiting laterals that may interfere with machine harvesting[2].

7.3. Cowichan

Cowichan was produced from a cross of Newburgh x Qualicum and made in 1987 at the Pacific Agri-Food Research Centre (PARC) of Agriculture and Agri-Food Canada (AAFC) in British Columbia. It is mid-season, similar to Tulameen.

Cowichan is a vigorous growing cultivar with a strong upright habit and canes bare long, strong, upward-growing laterals allowing fruit to be well spaced. Spines are present in the bottom 40 cm but there are very few spines on top. Cowichan fruit are long and conical with bright, medium red colour, while the flavour is not as distinct as Tulameen. The percent post-harvest fruit rot of Cowichan is lower than that of Tulameen. Fruit was rated as very good when hand harvested for fresh market under extreme heat conditions. In replicated machine harvesting trials planted in 2001, Cowichan produced the highest yield and had the highest rated fruit quality.

Cultivar is resistant to the common biotype of *Amphorophora agathonica*, the North American aphid vector of the raspberry mosaic virus (RMV) complex. Cowichan has never tested positive to the common strain of RBDV that is present in North America. However, it was never exposed to the other strains and therefore its reaction is unknown. Exposure to *Phytophthora fragariae var. rubi* in greenhouse pot tests showed that Cowichan was more resistant than its parent Qualicum and less resistant than Newburgh. In field conditions it appears to be relatively resistant to root rot causing organisms. Cowichan has been moderately susceptible to spur blight *Didymella applanata*, has low susceptibility to cane Botrytis (*B. cinerea*) and is much less susceptible to anthracnose (*Elsinoe veneta*) than its parent Qualicum.

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[2] http://www.meiosis.co.uk/fruit/cascade_delight.htm 22.04.2013.

Cowichan is a multi-purpose cultivar suited for both fresh market and processing uses. The cultivar is very quick to establish and produce high yields after the first planting year.

In large-scale grower trials in British Columbia and Washington State, Cowichan has show that is very suited for mechanical harvesting. [3]

7.4. Glen Fyne

This cultivar is from a breeding programme funded by the Scottish Raspberry Breeding Consortium, comprising members from the UK raspberry industry with additional funds provided by the Horticultural Development Company (HDC) and the Scottish Government. Glen Fyne has a sweet and aromatic raspberry flavour which is consistent throughout the season. Fruit is bright red and attractive, slightly conical in shape and berries are firm and cohesive with a shelf life similar to Glen Ample. It is mid season cultivar. Canes are spine free and easy to manage with moderate vigour. Fruit is well presented on strong laterals and plugs easily from the receptacle. Glen Fyne is suitable for harvest by machine. Glen Fyne carries the A10 gene, conferring resistance to four biotypes of the large raspberry aphid (*Amphorophora ideai*). [4]

7.5. Glen Doll

Glen Doll is from a programme funded by a consortium comprising of members from the UK raspberry industry with additional funds being provided by Horticultural Development Council (HDC) and Scottish Government.

Berry is bright red with excellent flavour supported by independent sensory testing. It is slightly more conical in shape than Glen Ample. Glen Doll is spine free variety with moderate vigour. Growth habit is upright with long and strong laterals which present its fruit well for picking.

Average yield data from trials at SCRI over 5 harvested plots has shown yield of 6.2 T/Ha.

Glen Doll carries the A10 gene, conferring resistance to the large raspberry aphid

It is late season cultivar, 5 to 7 days later than Glen Ample when grown outside at SCRI.

The quality of the fruit and the outstanding flavour of this variety means that it will do extremely well in the fresh market but is also suitable for the processing market as it machine harvests well, producing a high yield of good quality whole fruit. [5]

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[3] http://www.meiosis.co.uk/fruit/cascade delight.htm

[4] http://www.mrsltd.com/sitepix/downloads/fruit-glen-fyne-ra.pdf

[5] http://www.mrsltd.com/sitepix/downloads/fruit-glen-doll-ra.pdf

7.6. Glen Magna

Glen Magna is a high yielding, late main season cultivar which produces very large meaty fruit, conical in shape.

Glen Magna has the gene Bu, giving resistance to the common strain of raspberry bushy dwarf virus. It also carries the gene A1, conferring resistance to 2 biotypes of the large raspberry aphid (*Amphorophora idaei).*

Glen Magna makes an excellent cultivar for the amateur market due to its large attractive fruit and aromatic flavor with very large meaty fruit, 6.5g to 7g in size and conical in shape. Fruit is bright red and has a sweet aromatic flavour.

Glen Magna has very vigorous canes with large cane diameter. Laterals are long and upright. Dense spines at base of cane, very few spines at cane tip. Overall presentation is excellent.[6]

7.7. Glen Ample

This versatile cultivar consistently produces a high yield with large fruit and excellent quality. This variety is protected by Plant Variety Rights in Europe, Switzerland and South Africa. Glen Ample is a mid season raspberry suitable for both the fresh and processing market.

Glen Ample has the gene A1, giving resistance to 2 biotypes of the large raspberry aphid (*Amphorophora idaei*). Cultivar is susceptible to *Phytophthora* root. It is also susceptible to the cane diseases, cane botrytis, spur blight and cane blight and to raspberry bushy dwarf virus. Trials at SCRI showed yields of 7 – 10 t/Ha, with fruit size being between 4g – 6g. Glen Ample is a spine free variety with long and upright laterals. Cultivar has an excellent overall presentation. Berry is bright red in colour with a lovely aromatic and sweet flavor and excellent shelf life. [7]

[6] http://www.mrsltd.com/sitepix/downloads/fruit-glen-magna-ra.pdf
[7] http://www.mrsltd.com/sitepix/downloads/fruit-glen-ample-ra.pdf

7.8. Octavia

Octavia was derived from Glen Ample x EM 5928/114 (family 6512) from a cross-made in 1992. The original seedling (6512/50) was selected in 1996.

The fruit is large, of uniform size, firm, cohesive, blunt and conic to round in shape. It is easily plugged and meaty with fairly good colour and good flavour. The shelf life of Octavia is good, generally better then Glen Ample and consistently much better than Tulameen.

Mean fruit weight of Octavia was intermediate between that of Glen Ample and Tulameen. The results reflect big differences between seasons, largely due to the weather. The mean fruit weights are generally more reliable than the yield figures when comparing genotypes.

Octavia is a very late ripening summer fruiting type cropping approximately 10 days after Glen Ample and Tulameen. Octavia has a reasonably good habit, it crops to the base of the canes, and upright, rather leafy laterals and the fruit is slightly clumped at the end of the lateral.

It is resistant to biotypes 1-4 of *Amphorophora idaei* and moderately resistant to cane *Botrytis* and cane spot but moderately susceptible to spur blight. It is susceptible to Raspberry Bushy Dwarf Virus at East Malling but has not shown leaf yellows. In a glasshouse test at East Malling, 2003, Octavia was susceptible to raspberry root rot (*Phytophthora fragaria var. rubi*).

Octavia will extend the summer fruiting season beyond that of Glen Ample and Tulameen and will produce fruit well into August. The fruit quality attributes of Octavia, especially its shelf life, are suitable for fresh market. [8]

7.9. Malling Hestia

Malling Hestia comes from the raspberry breeding programme at East Malling Research and was originally selected as EM5928/114 in 1986.

Malling Hestia is a very late season summer fruiting raspberry, the 50% of harvest being some 10 -14 days later than Glen Ample. It produces medium to large conical shaped berries, which are very easily plugged. The berries have a good bright, mid-red colour. Berries are firm with a strong skin and have a good, slightly acid flavour. The fruit has an excellent shelf life, better than Glen Ample and Tulameen, with a superior appearance and texture.

Malling Hestia has a good habit, with moderate height new canes and the laterals are well spaced out across the canopy. The fruit is very well presented to the pickers.

Canes are spiny towards the base, but with few spines on the laterals, and are pleasant to handle. It breaks bud late in the spring so is not prone to frost damage.

Malling Hestia is resistant to biotypes 1-4 of *Amphorophora idaei*, the main aphid vector of raspberry viruses. It is moderately susceptible to cane *Botrytis*, cane spot and *Phytophthora* root rot (in glasshouse tests at EMR). It appears to be resistant to pollen infection of raspberry bushy dwarf virus; it was very slow to become infected in the field at EMR.

Malling Hestia will extend the picking season beyond Glen Ample and Tulameen, producing easily picked fruit with a superb shelf life. As well as being suited for fresh market outlets, tests have shown that Malling Hestia has potential for processing, particularly for freezing (IQF). It will also be well suited for PYO growers and the amateur market. [9]

Picture 1: Raspberry field, Umb, Ås, Norway

[8] http://www.meiosis.co.uk/fruit/octavia.htm
[9] http://www.meiosis.co.uk/fruit/malling_hestia.htm

Replicate	Sort	Sort	Sort	Replicate
	Glen Ample (rand)	**Glen Ample (rand)**	**Glen Ample (rand)**	
III	**Glen Magna (3)**	**Glen Fyne (9)**	**Malling Hestia (4)**	**III**
III	**Cascade Delight (8)**	**Glen Doll (6)**	**Tulameen (5)**	**III**
III	**Glen Ample (1)**	**Cowichane (7)**	**Octavia (2)**	**III**
II	**Cowichane (7)**	**Octavia (2)**	**Glen Magna (3)**	**II**
II	**Malling Hestia (4)**	**Glen Fyne (9)**	**Tulameen (5)**	**II**
II	**Glen Doll (6)**	**Glen Ample (1)**	**Cascade Delight (8)**	**II**
I	**Octavia (2)**	**Cowichane (7)**	**Tulameen (5)**	**I**
I	**Glen Doll (6)**	**Glen Ample (1)**	**Glen Fyne (9)**	**I**
I	**Malling Hestia (4)**	**Glen Magna (3)**	**Cascade Delight (8)**	**I**
	Glen Ample (rand)	**Glen Ample (rand)**	**Glen Ample (rand)**	

Figure 1: Map of raspberry experimental field UMB, Ås, Norway

7.10. Harvest and Storage.

In all treatments, berries were harvested two times weekly from week 28 to 34 and the total yield and weight of berries were recorded. Berries, harvested when the each cultivar reached the “top” (maximum yield), have been sampled for chemical analyses. The average mean temperature during the harvest season was 15.5°C and despite that it is not recommended to pick raspberries during the rain, weather conditions were poor so some of the harvests got done during heavy rain (**Figure 2**). Variations between years may be due to climate or other environmental factors if the cultural practices remain consistent.

Total yield as well as berry weight, based on average weight of 50 randomly choosed berries, was performed immediately after harvest (**Picture 2**).

Also, two more harvests, week before and week after reaching the maximum yield, were also sampled for chemical analyses. The samples (minimum of 25 fruits) were frozen and stored at -20°C until processed. Harvesting season started in week 28, July 12th with harvesting three cultivars, Glen Ample, Glen Doll and Glenn Fyne. Glen Doll was the only cultivar in experiment that was harvested for the whole period, from July 12th (week 28) till August 22nd (week 34), twelve harvests in total.

week	Temp mid°C	Temp min°C	Temp max°C	rainfall(mm)
26				
27	17,0	13,1	20,4	2,7
28	15,1	11,8	18,1	4,2
29	13,5	7,8	18,1	2,2
30	16,5	12,8	19,8	6,5
31	15,5	11,7	19,0	6,3
32	14,9	10,3	19,3	3,8
33	16,8	11,4	22,3	0,2
34	15,2	12,0	18,8	3,1

Figure 2: meteorological data, UMB, Ås, Norway July and August 2012[10]

Picture 2: Yield and Berry Size Measurment, UMB, Ås, Norway

[10] (http://www.umb.no/statisk/fagklim/veret_pa_aas2012.pdf)

7.11. Methods

Soluble Solids (SS), pH, Titratable Acidity (TA), Color, and Dry Matter (DM). The berries were thawed overnight at room temperature prior to analyses. Berry juice was obtained by squeezing the berry samples by hand and then filtered (Whatman 125 mm, Schleicher & Schuell, Germany). The juice was used for SS (Atago Palette PR-100, Japan), pH (Methrom 691 pH Meter, Herisau, Switzerland), TA (Methrom 716 DMS Titrino and 730 Sample Changer), and color analyses. Prior to the color analyses, the juice was diluted to a 5% solution with distilled water. The juice color was determined as optical density (OD) at 515 nm in a spectrophotometer (Shimadzu UV mini 1240, Japan). For the DM content, 6-7 g of homogenized berry mass was dried at þ100 C for 24 h in a drying oven followed by stabilization in a desiccator.

Ascorbic Acid (AA). Frozen raspberries (25 g, 6-12 fruits depending on temperature and harvest time) were added up to 150 g with 1% (w/v) oxalic acid. The material was homogenized for 1 min, filtered (B 1/2, folded, Schleicher & Schuell), and semipurified using a Sep-Pak C18 cartridge (Waters Corp., United States).

The samples were then filtered through a 0.45 μm Millex HA filter (Millipore, MolsHeim, France) before HPLC analysis. HPLC analyses was performed according to Williams et al. (34), using an Agilent Technologies 1100 Series HPLC system (Waldbronn, Germany) comprising a quaternary pump, an inline degasser, an autosampler, a column oven, and a ultraviolet (UV) light detector. HPLC operation was performed by means of Chemstation software (Agilent, Germany). Separation was achieved using a 4.6 mm250 mm long Zorbax SB-C18 5 Micron column (Agilent Technologies, United States). The injection volume (5 μL) and isocratic elution were performed with 0.05 M KH2PO4 at 1 mL min-1 and 25 C. AA was measured at 254 nm, and the identity of the peak and quantification of AA was performed by an authentic standard (AA in 1% oxalic acid) and by using calibration curves of freshly prepared standard solutions, respectively.

Ferric Reducing Activity Power (FRAP), Total Monomeric Anthocyanins (TMA), and TPC. Total monomeric anthocyanins by the ph-differential method.

Anthocyanins are the pigments responsible for the bright colors of most fruits and flowers. There are hundreds of anthocyanins occurring in nature, but the anthocyanins occuring in any particular species are distinctive enough to be used to identify the species (chemotaxonomy).

Differences in anthocyanins between different cuitivars within a species are generally quantatative rather than qualitative. The anthocyanins occuring in red raspberries (Rubus ideaus) have been identified, and the anthocyanin distributions in many different cuitivars have been reported. Also, the total anthocyanin content of different varieties of red raspberries can determine their suitability for use in certain products.

Theoretical: Anthocyanins display reversibly different absorbance spectra dependent on the ph environment. A coloured oxonium form exists at pH 1.0 and a colourless hemiketal form exists at pH 4.5. An absorbance maximum exists at 520 nm of the colored form and the difference in absorbance at this wavelength is proportional to the amount of anthocyanins present. Polymeric anthocyanins are resistant to changes in colour and hence will not be included in the measurements as they also absorb at both pH 1.0 and pH 4.5.

Reagents: pH 1.0 buffer – KCL 0.025M (1.86 g KCL, add approx. 980 ml distilled water in a beaker and adjust the acidity with a pH meter 1.0 with concentrated HCL (32%). Transfer to volumetric flask and dilute to 1000 ml.

pH 4.5 – $NaC_2H_3O_2$ 0,4M (54,34g $CH_3CO_2Na*3H_2O$) , add approx 960 ml distilled water and adjust pH to 4.5 with concentrated HCL (32%). Transfer to volumetric flask and dilute to 1000 ml.

Reagents are stable for few months.

Dilutions: The samples must be within the linear absorbance range of the instrument and the appropriate dilution factor must be determined. The ratio sample to total volume should be 1:5 or less as not to compromise the buffer capacity. Dilutions are performed using the corresponding buffer and identical dilution factor for both pH values.Measure the samples diluted with pH 1.0 and pH 4.5 buffers at both 520 nm and 700nm incubated for 5min prior to measurements. Samples should be centrifuged before measurements. The samples are analysed with two test definitions (pH 1.0 and pH 4.5).

The samples and the standards are pipette directly into the cyvettes in the following order: pH 1.0 (or pH 4.5) buffer solution, 20 yl sample, mixing and incubations for 300s, bichromatic measurement at main wavelength 520 nm and side wavelength 700nm. The samples are analysed using two different buffers according to the testflow, two consecutive runs with two different methods/tests. The methods are implemented and labeled TMA pH 1.0 and TMA pH 4.5 in the test definition.

Result. The total monomeric anthocyanins content is normally expressed as cyaniding-3-glucosides equivalents.

Total Phenols by the Folin-Ciocalteu's reagent: Konelab 30 is a random access clinical chemistry system for routine and special chemistries. Workload dependent, being in typical routine use up to 300 tests/hour. Time to first result is typically 3 to 12 Minutes.Continuous access to samples without interrupting test processing

The underlying principle is the chemical reduction of the FCR, a mixture of tungsten and molybdenum oxides, resulting in blue coloured products with absorption maximum at 765 nm. The intensity of absorption is equivalent to the sum of the individual contribution of the different classes of phenols present in the mixture.

Reagents: Gallic acid calibration standard – Dissolve 50 mg Gallic acid in 100 ml water, 500 yg/ml, note exact mass and use this for calibration curve. If a few ml of methanol or ethanol is added prior to the water it will dissolve more easily, then the solution can be prepared on the day of analysis. Otherwise, leave the solution overnight with continuous stirring on dark and cool place. The solution can be used for two consecutive days if it is stored properly.

Sodium carbonate – 7.5 % Sodiumcarbonate is made dissolving 7.5 g Na_2CO_3 in 100 ml distilled water. (Must be made on the day of analysis)

Folin – Ciocalteu's phenol reagent – Use pre-prepared FC reagent and dilute 1:10 with distilled water. (Must be made on the day of analysis)

Procedure:

Samples: Aqueuous and methanolic extracts of material are amenable for analysis

Dilutions: The samples must be within the linear absorbance range of the instruments up to concentration of around 300 mg GAE/L

Measurment. The measurements are performed on Konelab 30i reading the absorbance at 765 nm and automatically calculating the concentrations present in the samples. The samples and the standard solutions are pipetted directly into the cyvettes in the following order: 100 yl FC reagent, 20 yl of samples, mixing and incubation at 37°C for 60s, 80 yl 7.5 % sodiumcarbonate solution, Mixing and incubation at 37°C for 15min, measurement of absorbance at 765 nm, measurement is made after 15 min in which there is no more significant increase in absorbance.

Calculations: The total phenolic content is calculated as mg/L gallic equivalents

Ferric Reducing Activity Power (FRAP) Assay. Analysis of antioxidant activity using a slightly modified FRAP assay on a Konelab 30i. The principle relies on the absorbance change when Iron(III)2,4,6-tripyridil-s-triazine Fe (TPTZ)$^{3+}$ is reduced to Fe (TPTZ)$^{2+}$ (intense blue) at 595 nm. The reaction occurs at low pH colour change.

Iron sulphate is used for quantification purposes. Electron donation antioxidans can induce colour change and depending on quantities present may be used as measure of the integrated antioxidans.

Reagents and solutions: Acetate buffer, 300 mM, pH3.6 (1.79g sodiumacetate added to 16ml acetic acid glaciale diluted to 1L with distilled water. TPTZ, 10 mM in 40 mM HCl (31.23 mg TPTZ dissolved in 10 ml 40 mM HCl; 0.456 g HCl diluted to 1L with distilled water, $FeCl_3*6H_2O$, 20 mM (54.06 mg $FeCl_3*6H_2O$ dissolved in 10 ml distilled water)

The reagents are stabile when stored dark on 4°C. New solutions must be made every month.

The FRAP working solution is not mixed in advance but directly in the cyvettes of the instruments. This ensures that the solutions deteriorating properties is minimized and that all the samples are treated in more equal manner.

Slightly thawed berries were homogenized with a blender (Braun MR400, Karlsruhe, Germany). The homogenized berry mass (3 g) was extracted with 1 mM HCl (37%) in methanol (30 mL). The samples (30 mL) were flushed with nitrogen, capped, and vortexed (Vortex-T Genie 2, Scientific Industries Inc., NY), followed by sonication at 0 C for 15 min in an ultrasonic bath (Bandelin SONOREX RK 100, Bandelin Electronic GmbH & Co., Berlin, Germany). The 30 mL samples were stored at -20 C until analyzed. Prior to analysis, the samples were poured into a 2 mL Sarstedt micro tube (Nurnbrecht, Germany) and € centrifuged at 13200 rpm for 2 min at 4 C (Eppendorf 5415 R, Germany). The raspberry samples were extracted in triplicate.For analyses of FRAP, TMA, and TP, KoneLab 30i (Thermo Electron Corp., Vantaa, Finland), a clinical chemical analyzer was used. The FRAP assay was carried out as described by Benzie and Strain (1996), with some modifications as previously reported (Volden, Borge, Bengtsson, Hansen, Thygesen,and Wicklund, 2008). TMA was determined by the pH differential method based on the spectral characteristics of anthocyanins (Giusti and Wrolstad 2005), and TP was determined using the Folin-Ciocalteu method as described in Keahkonen et al. (e 38), with modifications described in Volden et al. (2008). Results are reported as mmol Fe2þ per 100 g of fresh weight (FRAP), mg cyanidin-3-glucoside equivalents (CGE) per 100 g of fresh weight (TMA), and mg gallic acid equivalents (GAE) per 100 g of fresh weight (TP).

Despite the small number of measurements, calculation of correlation and one-way analysis of variance were used in order to obtain information about potential statistically significant differences among the different varieties and different planting in the measured variables. Recommendations for future research certainly include the use of larger number of planting in order to confirm the study's research. The difference between the different varieties in all the studied variables has been statistically significant at less than 1%.

Experimental data were subjected to analyses of variance (ANOVA) and regression analyses by standard procedure using SPSS (IBM SPSS Statistics), Software Package used for Statistical Analyses (IBM SPSS Statistics 21.0 - August 2012).

Tukey post hoc test has been performed to find significant differences between each cultivar.

8. RESULTS AND DISCUSSION

Morphology. Hudson (1959) and Williams (1959, 1960) have studied and described the morphology and seasonal development of the biennial raspberry as well as environmental control of various stages. Raspberry is a species that in biennial fruiting cultivars bears shoots with a two-year life cycle during which each shoot passes through vegetative growth, flower initiation and development and induction and breaking bud dormancy.

One of the most important features determining cultivar suitability for growing is its productivity.Raspberry plant yield can be increased by optimizing several key components of yield. These include: cane (shoot) number per plant, fruiting lateral number per cane, fruit number per lateral and fruit size. Final cane number per plant is influenced by the total number of canes a given plant produces initially and also by the ability of the plant to grow new canes after the application of the spring–early summer sucker removal practices, which are commonly used in raspberry production (Waister et al., 1980). In some instances, application of nitrogen fertilizers can increase both cane growth and the number of flowers produced per node (Lockshin and Elfving 1981). However, in other situations fertilizers appear to be of little benefit (Goode 1970). Following the addition of nitrogen fertilizer, Lawson and Waister (1972) observed increased yields for two years, little effect during the third year, and decreased yields during the next two years. Similarly, irrigation appears to increase yields in some locations while having little effect elsewher (MacKerron 1982).

Fruit lateral number per plant is determined by node number, which in turn can be influenced by the cane height and cane diameter (Crandall et al., 1974; Jennings and Dale, 1982) as well as the amount of successful bud break. Fruit number per lateral is influenced by lateral length and nodes per lateral (Dale, 1976). Fruit size is influenced by ovule number, drupelet size, and number (Dale, 1989). Dale (1989) summarized first-year cane and second-year fruiting yield components for raspberry.

Dale and Daubeny (1985) showed that high yield in raspberries was closely related to high lateral numbers in Abbotsford, British Columbia, Canada, and thick canes in Invergowrie, Scotland. In our study, three canes were sampled from each replicate.

Figures that had been measured are: length of canes, number of nodes per cane, number of laterals per cane and length of each lateral (**Figure 3 a-d**; **appendix table 1**)

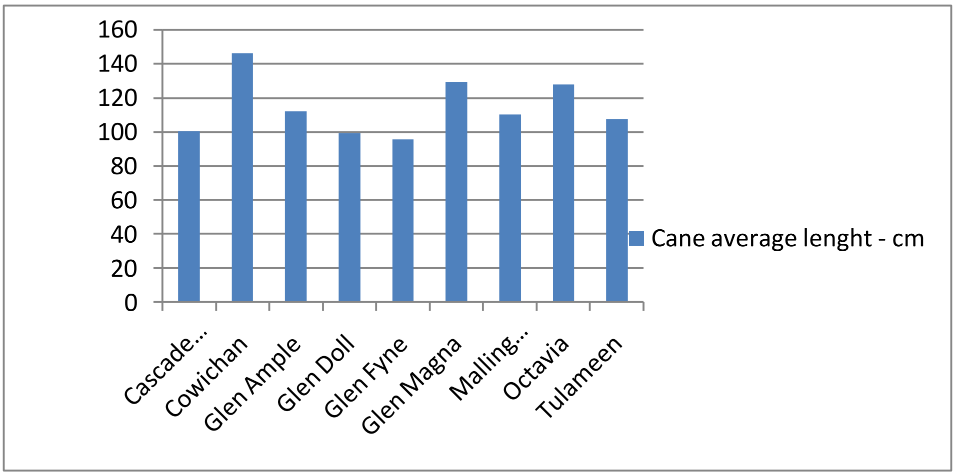


Figure 3a: average length of canes

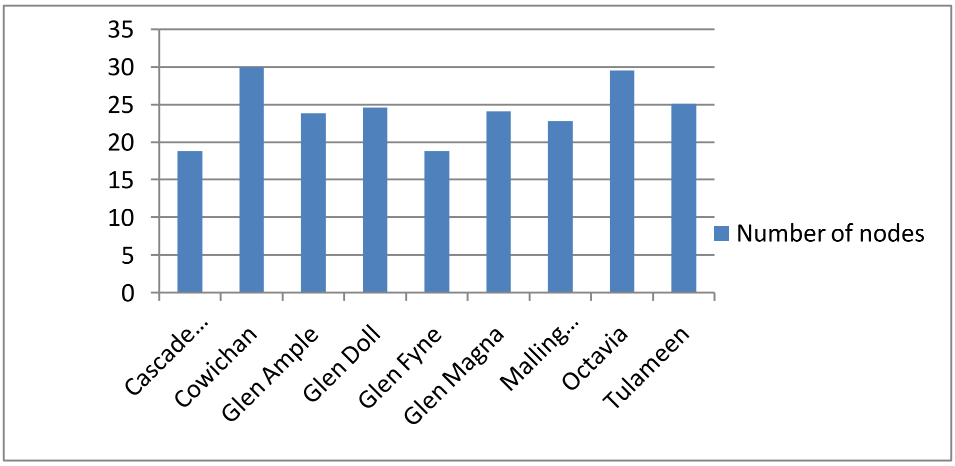


Figure 3b: average number of nodes per cane

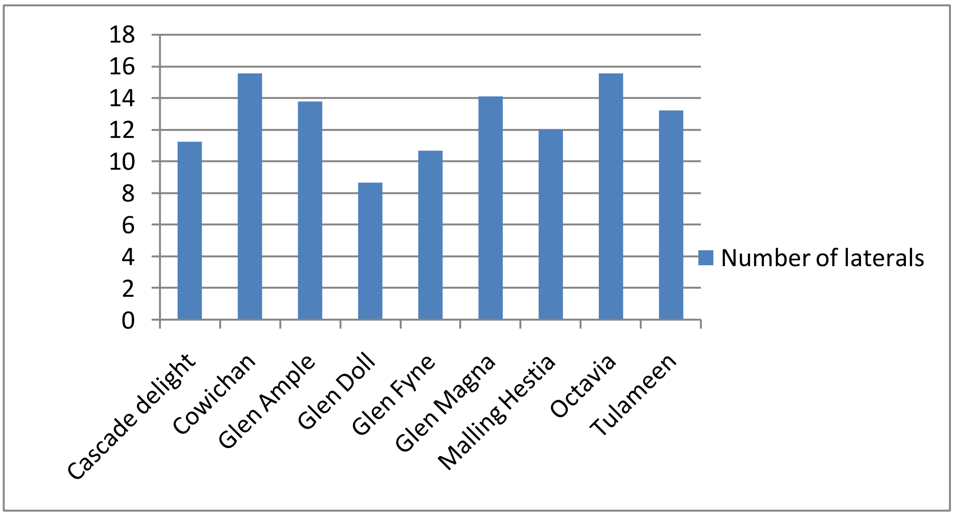


Figure 3c: average number of laterals per cane

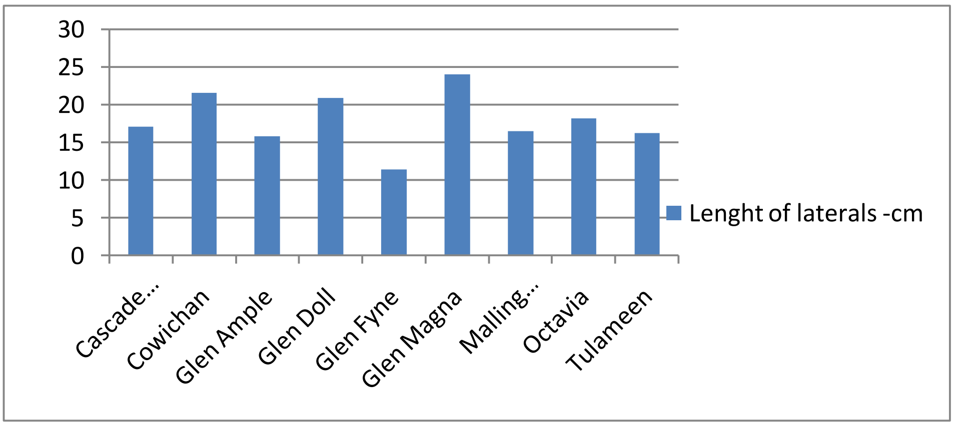


Figure 3d: average length of laterals

Results have shown that the highest yield was performed by cultivars which are more vigorous, producing canes that have an upright habit and in the same time have more nodes per cane and relatively longest laterals. Cowichan, which has had the highest yield in total, also performed the longest laterals, the biggest number of nodes, the biggest number of laterals and the longest laterals as well (**Figure 3a, 3b, 3c, 3d, 4a**). The results are consistent with those of Dale and Daubeny (1985) who found that total yield is highly correlated with lateral number per cane.

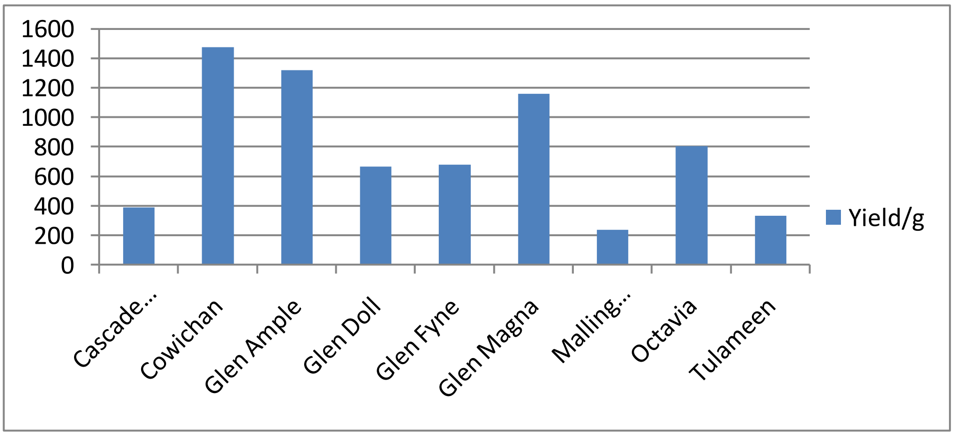


Figure 4a: average yield/g per cultivar

	Cowichan	G.Ample	G.Magna	Octavia	G.Fyne	G.Doll	C. Delight	Tulameen	M. Hestia
Cowichan				+	+	+	+	+	+
G.Ample					+	+	+	+	+
G.Magna							+	+	+
Octavia	+								
G. Fyne	+	+							
G.Doll	+	+							
C.Delight	+	+	+						
Tulameen	+	+	+						
M. Hestia	+	+	+						

Figure 4b: Yield, statistically significant differences between cultivars, Tukey test

Results represent that Cowichan, G.Ample and G. Magna, among which there were no statistically significant differences, are the cultivars with highest yield. Octavia, G. Fyne, G. Doll, C. Delight, Tulameen and M. Hestia are the next group by yield, among which there were no statistically significant differences, but they have a significantly lower yield than Cowichan, G. Magna and G. Ample.

Berry weight. The results of berry weight measurements show that the raspberry fruit weight is reduced with progress of harvest season in all cultivars except Octavia. (**Figure 6, a-i**).

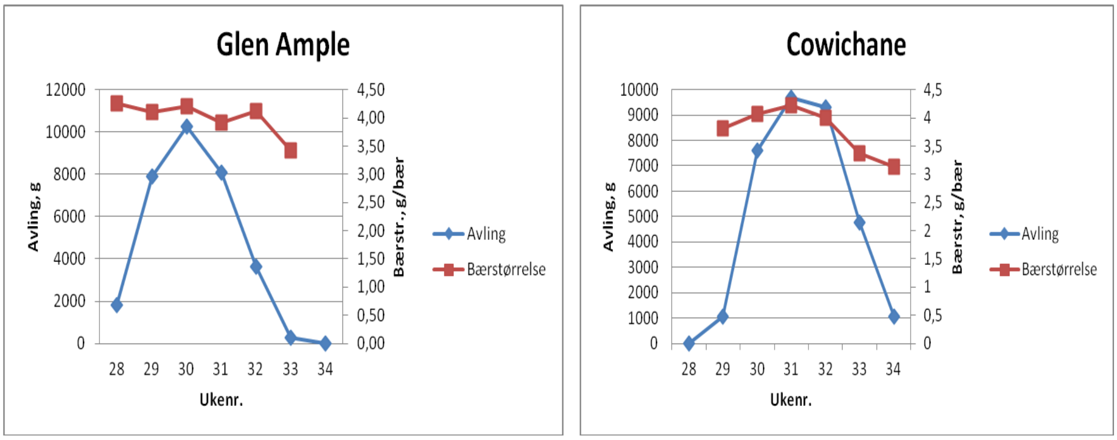


Figure 6a and 6b: Yield in grams per week of harvest (blue color) and berry size per harvest weeks (red color)

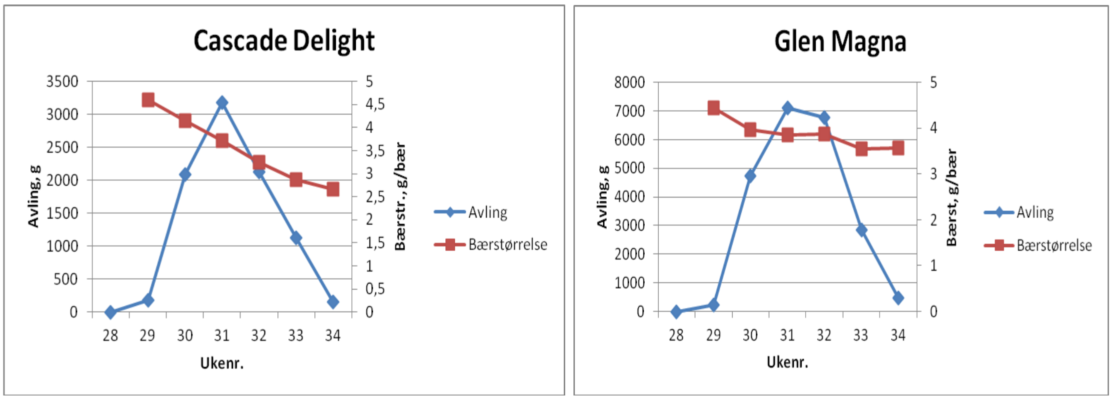


Figure 6c and 6d: Yield in grams per week of harvest (blue color) and berry size per harvest weeks (red color)

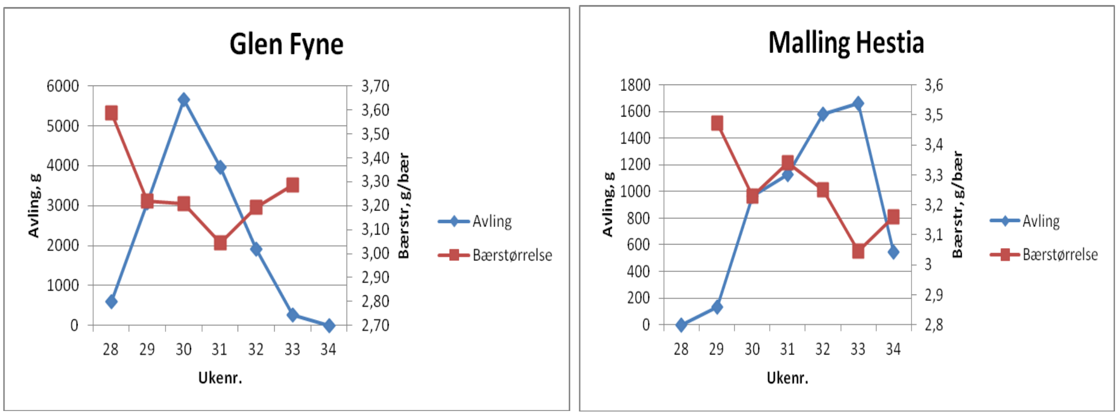
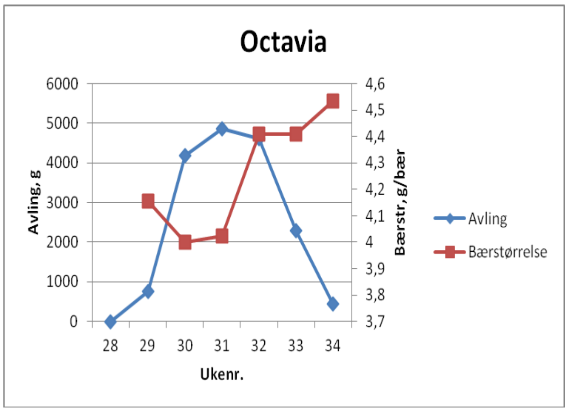


Figure 6e and 6f: Yield in grams per week of harvest (blue color) and berry size per harvest weeks (red color)



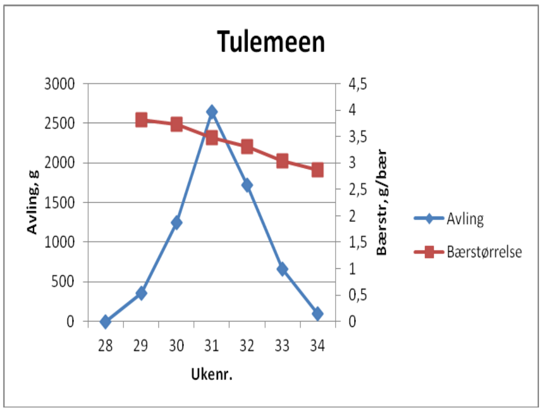


Figure 6g and 6h: Yield in grams per week of harvest (blue color) and berry size per harvest weeks (red color)

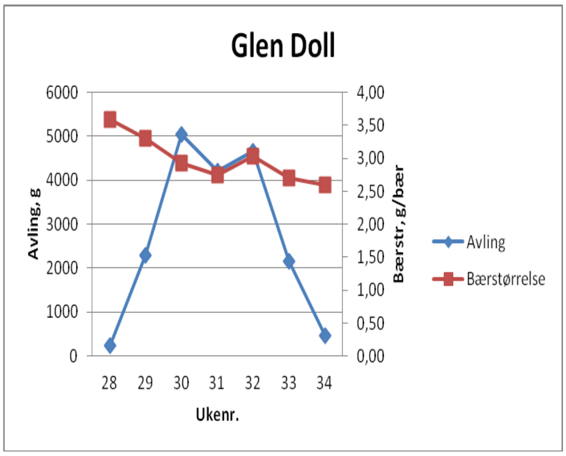


Figure i: Yield in grams per week of harvest (blue color) and berry size per harvest weeks (red color)

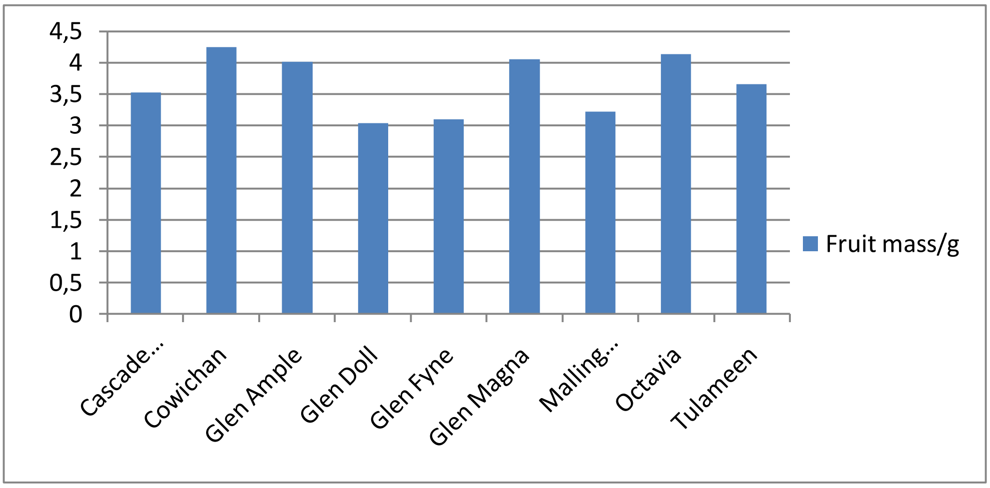


Figure 5a: average berry weight/g per cultivar

Despite that Glen Ample and Octavia are among cultivars with significantly biggest berry size (**Figure 5b**) three year measurment at SCRI shows significantly bigger berrie weight. Average berrie weight at SCRI was 5,4g for Glen Ample and in our trial little bit over 4g per berry. Comparing the berrie weight measurements for Glen Doll and Glenn Fyne cultivars again we can see significantly bigger berries grown at SCRI than in Ås. Average berry weight for Glen Doll at SCRI was 4,5g and 5,0g for Glen Fyne comparing with little bit over 3g of berry mass for both cultivars at UMB trial. The same was noticed for Tulameen (SCRI 5,1g comparing with 3,65g at UMB). Several studies have shown that raspberry yield is highly positively correlated with fruit size (Cormack and Woodward, 1977; Dale, 1976; Dale and Daubeny, 1985).

Thus, results have shown that varieties Cowichan and G. Ample which have had significantly highest yield in gramms also have significantly highest berry size expressed as mass in grams (**Figure 4a and 5a**). Also, our results show significantly high positive correlation between yield and berry size (**appendix Table 14**).

Though that in all morphological measurements as well as in berry size Glen Fyne has had the poorest performance, total yield was higher than yield of Tullameen and Malling Hestia which have had significantly lowest yield performance of all cultivars that were measured (**Figure 4a**). But, observing the map of experimental field, we can notice that all three replicates of Tulameen cultivar are planted in third row of orchard.

Also, Malling Hestia’s replicate from third row have not had yield at all, with very poor plant performances and vigournes (**Picture 3**). In addition, comparing the yield between replicates of Cascade Delight and Octavia, results have shown the highly significant difference in yield between replicates that are planted in third row with replicate from the first and second row. On the other side, performance of Glen Fyne and Glen Magna replicates from third row has not shown significant difference in total yield amount comparing with replicates from other two rows and Glen Fyne replicate performed even significantly higher yield than other two replicates. Probable cause could be micronutrient stress on which Glen Fyne and Glen Magna have higher tolerance but clear answer is not known and recommendation would definitely be to make any necessary additional tests which could give reason and answer why some of the cultivars on that micro location perform poorer results in yield. Further, at Pacific Agri-Food Research Center (PARC) of Agriculture and Agri-Food Canada (AAFC) Kempler, Daubeni and Harding (2007), after plantings that were evaluated for three years each, measured average weight of Cowichane cultivar 4.2g per berry and Tulameen cultivar 4.4g per berry.

Those results show significantly higher berry weight for Tulameen cultivar in Canada comparing with UMB trial (4,4g > 3,65g), but berry weight for Cowichane cultivar was equal.

As a final result of testing, cultivars Cowichan, Octavia, G. Magna and G. Ample are cultivars with largest berry size and there is no significant difference between them. On the other side, G. Fyne, G. Doll, C. Delight and M. Hestia are the cultivars with statistically smaller berry size (**Figure 5b**).

	Cowichane	Octavia	G.Magna	G.Ample	Tulameen	C.Delight	M.Hestia	G.Fyne	G.Doll
Cowichane					+	+	+	+	+
Octavia						+	+	+	+
G.Magna							+	+	+
G.Ample							+	+	+
Tulameen	+								+
C.Delight	+	+							
M.Hestia	+	+	+	+					
G.Fyne	+	+	+	+					
G.Doll	+	+	+	+	+				

Figure 5b: berry size, statistically significant differences between cultivars, Tukey test

Picture 3, Growth habit in row 2 and row 3, UMB, ÅS, Norway

Although, berry weight is an important yield component (Dale, 1976) and useful criteria in breeding for high yield potential in red raspberries, the health attributes of berries have become important to consumers fueled by research into the benefits of increased consumption of phenolic and phytochemical compounds in humans, and *Rubus* species berries have been found as a fruit with high AOC and as a good source of phenolic compounds (Deighton et al., 2000; Wada and Ou, 2002; Wang et al., 1996). Fruit weight and decreasing of it during harvest season has implications for berry chemical composition and the concentration of chemical compounds.

Because that larger berries have higher moisture content, fruit phytochemical concentration could be easily compromised when it is selected for larger yield and berry size. Our study shows significant negative correlation which was found between berry size and antioxidant capacity (FRAP) ($r = -0.320$, $p <0.001$) and total phenols content ($r = -0.320$, $p <0.01$) (**Figure 8**). The higher berry weight in grams, less FRAP and phenol content. As a result of that Cowichan and Glen Ample express lowest levels FRAP and TPC among all cultivars in the trial (**Figure 6 and 7**).

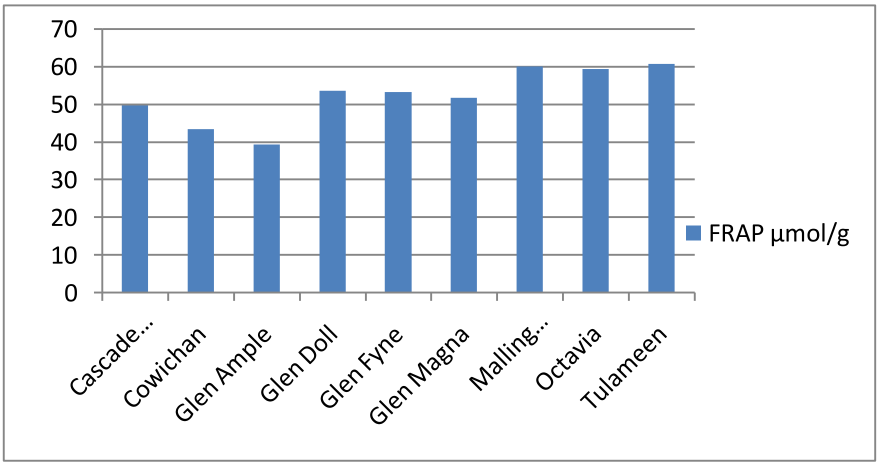


Figure 6a: average FRAP per cultivar

	Tulameen	M.Hestia	Octavia	G.Doll	G.Fyne	G.Magna	C.Delight	Cowichane	G.Ample
Tulameen						+	+	+	+
M.Hestia						+	+	+	+
Octavia						+	+	+	+
G.Doll								+	+
G.Fyne								+	+
G.Magna	+	+	+					+	+
C.Delight	+	+	+						+
Cowichane	+	+	+	+	+	+			
G.Ample	+	+	+	+	+	+	+		

Figure 6b: FRAP level, statistically significant differences between cultivars, Tukey

Post hoc test has shown that the varieties Tulameen, M. Hestia, Octavia, G. Doll and G. Fyne, among which there were no statistically significant differences, are the cultivars with the highest FRAP - mmol / g level. At the same time C. Delight, Cowichan, G. Ample and G. Magna have significantly lower FRAP - mmol / g than the first group, but among them there were no statistically significant differences.

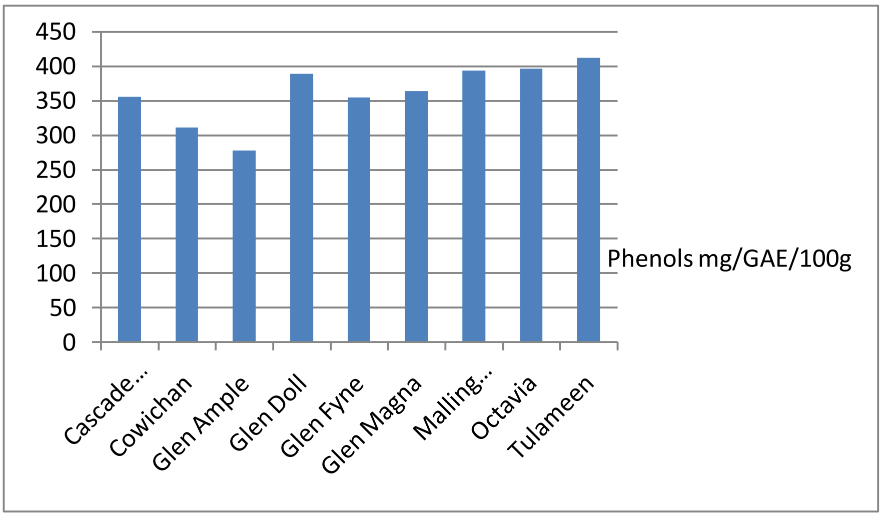


Figure 7a: average TPC per cultivar

	Tulameen	Octavia	M.Hestia	G.Doll	G.Magna	C.Delight	G.Fyne	Cowichane	G.Ample
Tulameen							+	+	+
Octavia								+	+
M.Hestia								+	+
G.Doll								+	+
G.Magna									+
C.Delight									+
G.Fyne	+								+
Cowichane	+	+	+	+					
G.Ample	+	+	+	+	+	+	+		

Figure 7b: TPC , statistically significant differences between cultivars, Tukey

Results show that the cultivars Tulameen, Octavia, M. Hestia, G. Doll and G. Magna, among which there were no statistically significant differences, have the highest total phenol content. G. Fyne results in significantly lower phenol content than Tulameen and significantly more phenols than G. Ample.

Cowichan and G. Ample have significantly lower phenol content from the other cultivars, but among them there were no statistically significant differences. Finally, G. Ample has significantly lower phenol content than other cultivars except Cowichan.

Proportion and quantity of bioactive compounds is related to the genetics and environmental factors. Environmental factors affect the content of bioactive compounds indirectly by giving the prerequisites for photosynthesis, and thereby providing energy or precursors of the synthesis of the bioactive compounds. Light has been shown to be the most important environmental factor influencing anthocyanin biosynthesis in plants (Grisebach, 1982). In strawberry, it was shown that the total AOC was lower in berries that were grown on lower temperature than in berries grown on higher temperature (Wang and Zheng 2001). Report from our experiment shows the similar trend. Comparing the results of our trial from vegetional season 2012th with the trial from season 2010th (Remberg et al. 2010), where Glen Ample cultivar from the same site was tested for AOC, result presents significantly lower content of TMA in season 2012 than in 2010. Observing meteorological data for the both season and especially for June, July and August in both years, it is clear that temperature was in average 1.5°C higher in 2010th.[11]

[11] (http://www.umb.no/statisk/fagklim/veret_pa_aas2012.pdf)

Temperature, light intensity and light quality are generally extremely influential in regulating the fruit and vegetable vitamin content (Lester 2006). In strawberry, the content of sugars and antioxidants was strongly influenced by the light levels. (Atkinson et al. 2006) Generally, combined effect of higher temperature and lower light intensity, results in lower levels of most phytonutrients (Lester 2006). However, individual compounds are differently affected. Atkinson et al. (2006) found that use of highly reflective mulches increased the concentration of ellagic acid and ascorbic acid in strawberries, due to increased light intensity. The light intensity decreases with latitude, but on the other hand long days might compensate for the lower light intensity.

There is a great annual variation in concentration of many compounds in raspberries (Burrows and Moore 2002). Most of plant antioxidant phytochemicals such as anthocyanins and other phenolics have a protective role against biotic (e.g.disease) and abiotic (e.g. ultraviolet light) stresses in plants. Photosynthate used for polyphenol production would thus be unavailable for vegetative growth and fruit production.

Connor et al. (2005a, 2005b) found significant year effects for TPC, antioxidant activity (FRAP) and anthocyanin content.

	weight	**L-AA**	**pH**	**color**	**TPC**	**FRAP**	**TMA**	**TA**	**SS**
DM	-0.111	0.512***	-0.143	-0.018	0.685***	0.598***	0.070	0.176	0.731***
SS	0.019	0.537***	-0.394***	-0.031	0.357**	0.276*	0.595	0.356***	
TA	0.251	0.399***	-0.718***	0.529***	-0.011	0.010	0.260*		
TMA	0.089	-0.386***	-0.061	0.842***	-0.221	-0.216			
FRAP	-0.320***	0.267*	0.015	-0.190	0.968***				
TPC	-0.313**	0.346**	-0.012	0.185					
Color	0.065	-0.192	-0.333**						
pH	-0.449**	-0.276**							
L-AA	0.154								

***p ≤ 0.001, **p≤0.01, *p≤0.05

Figure 8: Pearson Correlation Coefficients Between the Various Fruit Quality Attributes Being Investigated

In relation with some previous studies (Beekwilder et al. 2005), anthocyanins and ellagatannins were the major classes of phenolic compound in raspberries. There was significant correlation between AOC (FRAP) and the concentrations of TPC (r = 0.968, p < 0.001) (**Figure 8**) indicating that phenolic compounds are the most important contributors to the AOC of raspberry fruits. Corelation between AOC (FRAP) and AA (vitamin C) was less significant (r = 0.267, p <0.05). Observing Cowichan cultivar in our trial, results show that Cowichan is among cultivars with significantly lower content of TPC and AA (vitamin C) as well as lower AOC (FRAP). At the same time, total anthocyannins content of Cowichan was among those cultivars with significantly higher content of it as well as the fact that Cowichan had significantly most coloured berry. Conclusion will go in direction that Cowichan could be poorer in level of other phenolic compounds.

Anthocyanin content is significantly highest in G. Fyne, Cowichane, Cascade Delight and Tulameen cultivars and there is no significant difference in level of anthocyanin among them. Octavia has statistically lowest anthocyanins content. Other cultivars are between them.

	G. Fyne	Cowichane	C.Delight	Tulameen	G.Magna	G. Doll	G.Ample	M.Hestia	Octavia
G.Fyne					+	+	+	+	+
Cowichane					+	+	+	+	+
C.Delight					+	+	+	+	+
Tulameen					+	+	+	+	+
G.Magna	+	+	+	+					+
G.Doll	+	+	+	+					+
G.Ample	+	+	+	+					+
M.Hestia	+	+	+	+					+
Octavia	+	+	+	+	+	+	+	+	

Figure 9: anthocyannins level, statistically significant differences between cultivars

As the color and TMA are in high significant correlation (r = 0.842, p <0.001), Octavia performed the lowest value of color as well and the berry is brightest of all.

After performing Tukey post hoc test, Cowichan, Tulameen and C. Delight are in the group of cultivars with significantly highest value of coloration and their berries are darkest. G. Fyne has the statistically significant less value of coloration than Cowichan, same as Tulameen and C. Delight and significantly higher than other cultivars. Other cultivars express less coloration and there is no significant difference among them.

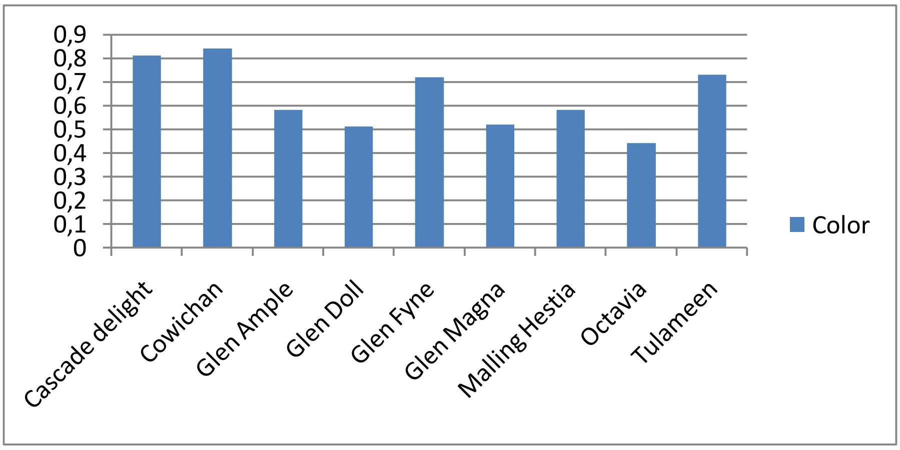


Figure 10: 5% color

Because Octavia is among cultivars with highest AOC, it is clear that the lower TMA content Octavia compensates with some other phenolic compounds. With high level of AA and TPC are among group of cultivars with significantly highest content of them. In contrast with other AOC compounds and phenolic compounds as well, AA concentration has not correlated with berry weight. As a result, Octavia, which is in group of cultivars with largest berry size, has significantly higher content of AA among all cultivars.

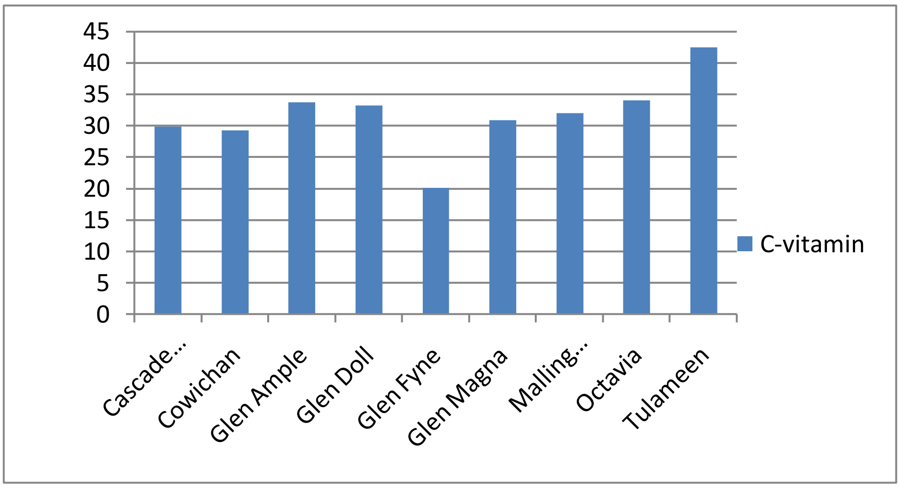


Figure 9a: average C-vitamin (L-AA) content per cultivar

	Tulameen	Octavia	G.Ample	G.Doll	M.Hestia	G.Magna	C. Delight	Cowichane	G.Fyne
Tulameen			+	+	+	+	+	+	+
Octavia									+
G.Ample	+								+
G.Doll	+								+
M.Hestia	+								+
G.Magna	+								+
C.Delight	+								+
Cowichane	+								+
G.Fyne	+	+	+	+	+	+	+	+	

Figure 9b: vitamin C content, statistically significant differences between cultivars, Tukey

Result presents that Tulameen and Octavia have significantly highest vitamin C content. The rest of cultivars have significantly lower vitamin C content but there is no difference among them within.

Although, Remberg et al. (2007) found a highly significant positive correlation between berry weight and AA concentration, our research does not follow those results.

Soluble Solids. Tulameen has significantly highest conent of sugars expressed as SS measured by degrees Brix, while G. Fyne and G. Ample have the lowest content of sugar (**Figure 9a and 9b**). Considering the fact that Tulameen at the same time performs the smallest berry size and that larger berries have higher moisture content, it could be the reason why the SS content is highest in Tulameen.

Results for Cowichan and Tulameen show lower level of sugar content than for the same cultivars in the results represented by Kempler, Daubeni and Harding (2007).

Because of significantly high positive corelation between levels of SS and pH, the level of pH are lower in berries grown in our field. Overall, Soluble Solids content highly signifficantly corelated with pH and TA level, and with total content of DM, TPC, Frap and vitamin C content (**Figure 8)**.

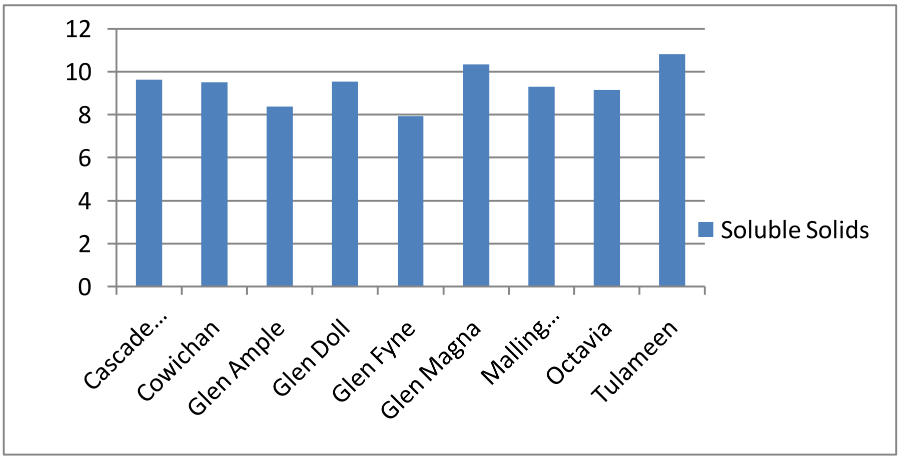


Figure 9a: average level of SS per cultivar

	Tulameen	G.Magna	C.Delight	G.Doll	Cowichane	M.Hestia	Octavia	G.Ample	G.Fye
Tulameen			+	+	+	+	+	+	+
G.Magna							+	+	+
C.Delight	+							+	+
G.Doll	+							+	+
Cowichane	+							+	+
M.Hestia	+								+
Octavia	+	+							+
G.Ample	+	+	+	+	+				
G.Fyne	+	+	+	+	+	+	+		

Figure 9b: SS content, statistically significant differences between cultivars, Tukey test

Tulameen and G. Magna, among which there were no statistically significant differences, are the cultivars with the highest content of sugar.

Significantly, the lowest content of sugar perform group of cultivars, Octavia, G. Ample and G. Fyne. G. Doll, C. Delight, Cowichan and M. Hestia have significantly lower content of sugar than the firtst group but significantly higher content than second group.

Usually, larger berries have higher moisture content and because of that there is high negative correlation between berry weight and DM concentration.

Glen Fyne, athough, it has smallest berry, has the lowest content of DM. On the other side, Cowichan and Glen Ample with the highest yield and berry size together with lowest content of DM support usual negative correlation between berry size and yield and DM.

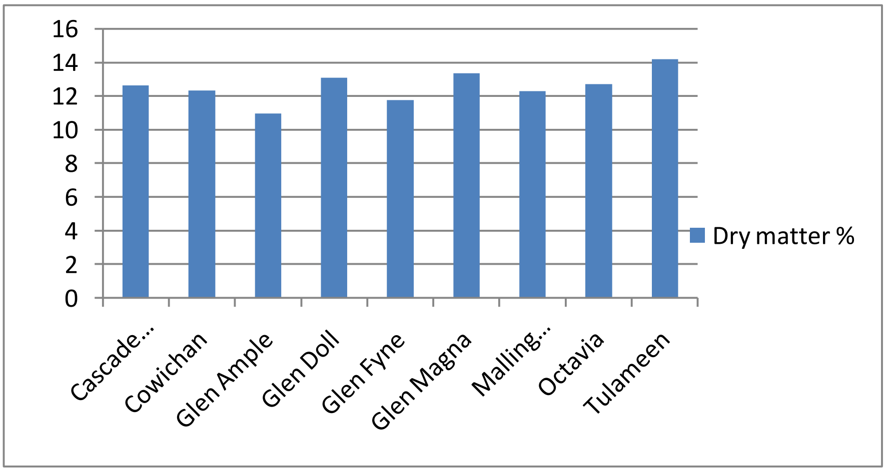


Figure 10a: average DM content per cultivar

Tulameen, G. Magna, G. Doll and Octavia have the highest percentage of DM content with no significant difference among them. Cowichane, M Hestia, G. Fyne and G. Ample have stastically lower DM content than the cultivars from the same group but there is no significant difference among them

Although, pH level shows significant negative correlation with berry size ($r = -0.449$, $p < 0.01$), Remberg et al. (2011) suggested that the changes in pH were not simply dilution effect related to berry size but due to other mechanism. For example, comparing the results for Tulameen and Cowichan in already mentioned experiment by Kempler, Daubeni and Harding (2007), despite the same weight of Cowichan berry, pH is on lower level in UMB planting (2,87 < 2,97).

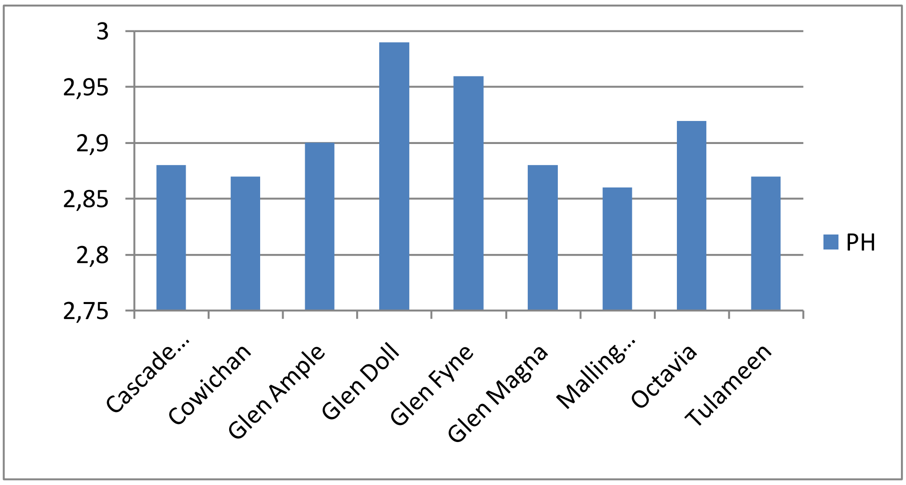


Figure 7a: average pH level per cultivar

	Tulameen	G.Magna	G.Doll	Octavia	C.Delight	Cowichane	M.Hestia	G.Fyne	G.Ample
Tulameen					+	+	+	+	+
G.Magna								+	+
G.Doll								+	+
Octavia									+
C.Delight	+								+
Cowichane	+								+
M.Hestia	+								+
G.Fyne	+	+	+						
G.Ample	+	+	+	+	+	+	+		

Figure 10b: DM content, statistically significant differences between cultivars, Tukey

	G.Doll	G.Fyne	Octavia	G.Ample	C.Delight	G.Magna	Tulameen	Cowichane	M.Hestia
G.Doll				+	+	+	+	+	+
G.Fyne					+	+	+	+	+
Octavia									
G.Ample	+								
C.Delight	+	+							
G.Magna	+	+							
Tulameen	+	+							
Cowichane	+	+							
M.Hestia	+	+							

Figure 7b: pH level, statistically significant differences between cultivars, Tukey test

Among cultivars G. Fyne, G. Doll and Octavia is no significant difference on pH level and those are cultivars with significantly highest pH content. Between all other cultivar we have not found differences and all of them have lower pH level.

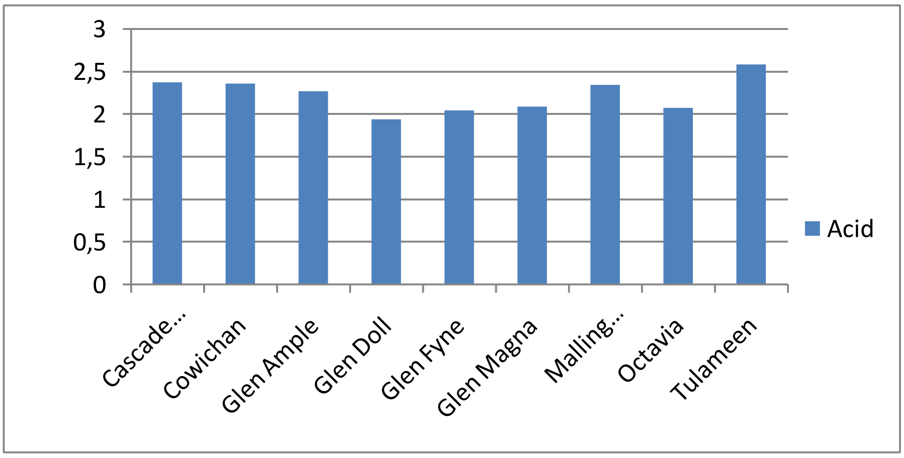


Figure 8a: average TA content per cultivar

	Tulameen	C.Delight	Cowichane	M.Hestia	G.Ample	G.Magna	Octavia	G.Fyne	G.Doll
Tulameen			+		+	+	+	+	+
C.Delight						+	+	+	+
Cowichane	+					+	+	+	+
M.Hestia						+	+	+	+
G.Ample	+							+	+
G.Magna	+	+	+	+					
Octavia	+	+	+	+					
G.Fyne	+	+	+	+					
G.Doll	+	+	+	+	+				

Figure 8b: TA content, statistically significant differences between cultivars, Tukey

Total acid content in raspberries is related to cultivar, location and agricultural practice. Literature data confirm substantial effect of genetic, climatic and production factors on acidity of raspberries (Orhan et al. 2006).

Tulameen and C. Delight have the highest TA content and there is no significant difference among them. Cowichan, G. Ample and M. Hestia are cultivars with significant lower content of TA than Tulameen, but higher level than G. Doll, G. Fyne, G. Magna and Octavia.

The evaluation of raspberry fruit nutritional quality represents an important task for better identification of suitable cultivars as well as their commercial exploitation. Summerized results of total concentrations of bioactive compounds do not differ from previous researches (Rao and Snyder, 2010) and confirm that red raspberry has high AOC. According to the results the main contributors of AOC are phenolic compounds with larger share than AA content.

Unfortunately, quality of the fruit is often associated with negative agronomic traits and, in this study a negative correlation was found between fruit size and most of the nutritional quality parameters. In particular, raspberry cultivar with the smallest fruit size, Tulameen, showed the highest nutritional value expressed through high AOC. Similar results have been reported by Remberg (2006), who found a negative correlation between fruit weight and its antioxidant capacity in other berries.

9. CONCLUSION

Considering the aim of not only measuring yield with connected morphological values, berry size and content of bioactive compound of all cultivars but also comparison between Glen Ample as by far leading cultivar in Norway, with eight other cultivars, some results for the vegetional year 2012 could be shortly presented.

Glen Ample. The first of all cultivars that performs high yield capacity in Nordic climate.. On 16th of July (second harvest) has already recorded higher yield than G. Fyne, Tulameen, Cascade Delight and Malling Hestia at the moment of reaching top (**appendix table 1)**. Although with second highest yield (Cowichan was 1st), demonstrated the poorest resuls in almost all of measurements of bioactive compounds except content of AA. That is consistent with researches where DM, SS, FRAP, TMA and TPC were significantly negatively correlated with berry weight and yield, and where AA did not express correlation with berry size and yield.

Cowichan. Harvest started and finished 7 days later than Glen Ample. It performs similar good value of yield like Glen Ample, but like Glen Ample has poor overall content of bioactive compounds. Because of darker color, it contents higher proportion of TMA, but at the same time lower AA value and the total result is the same AOC.

Glen Magna. Cultivar has performed high yield and large berry as well. Harvesting started seven days after Glen Ample. Overall performances of other values are at mean level of all examined cultivars. It expresses significantly higher content of TPC than Glen Ample. Among cultivars with significantly highest content of DM and SS.

Octavia. Also, approximately seven days later cultivar than Glen Ample. Despite that Octavia are among the group of cultivars with significantly largest berry size, yield was significantly lower than Cowichan, Glen Magna and Glen Ample. AOC has been significantly higher than in Glen Ample (possible relation with total yield). Because of lowest value of TMA, color is brighter than in other cultivars.

Glen Fyne. It has not performed high yield largely due the small berry size. Total AOC was among significantly richer cultivars with highest content of TMA among all cultivars. At the same time content of the AA was the lowest. Although, berry size was significantly smallest, content of DM and SS followed that values and also has been among lowest values.

Glen Doll. Harvest started on the same date as G. Ample and G. Fyne but similar to yield and berry performance to G. Fyne (both of the cultivars with signifintly smallest berries) rather than G. Ample. Total AOC was higher than Glen Ample's largely due to high TPC.

Cascade Delight. Significantly lower yield and berry weight than G. Ample. On almost every parameter, except TMA content and related darker berry color, is among cultivars with significantly poorer results.

Tulameen. As it has been mentioned before, all three of Tulameen replicates are grown in the third row. Yield was poor, berry size also significantly smaller than Glen Ample's. Because of very small yield, measurements of all parameters (SS, AA, TA, DM, FRAP, TMA and TPC) presents that Tulameen is among cultivars with significantly highest content of all parameters.

Malling Hestia. Similar to Tulameen, performed poor yield (two replicates in third row, one replicates without yield at all). But, as a difference from Tulameen, performance of other parameters has been on the poor level to.

10. REFERENCES

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APENDIX:

Table 1: Morphological measurements of raspberry plants (UMB), mean

	length of canes (cm)	number of nodes	number of laterals	length of laterals (cm)
Cascade Delight	100,44	18,88	11,22	17,10
Cowichan	146,22	30,00	15,55	21,58
Glen Ample	112,00	23,88	13,77	15,88
Glen Doll	99,22	24,66	8,66	20,93
Glen Fyne	95,55	18,88	10,66	11,40
Glen Magna	130,44	24,11	14,11	24,00
Malling Hestia	110,00	22,85	12,00	16,5
Octavia	127,88	29,55	15,55	18,21
Tulameen	107,66	25,11	13,22	16,30

Table 2: Descriptive statistics of examined variables on the total sample (N=81)

	N	Minimum	Maximum	arithmetic mean	Standard deviation
Yield/g	81	,00	2450,00	786,9259	584,02673
Fruit/g	78	2,48	4,98	3,6815	,57365
ref	78	6,60	11,60	9,4321	1,07528
pH	78	2,78	3,06	2,9067	,06270
acid	78	1,74	2,91	2,2346	,24008
5% colour	78	,39	1,00	,6437	,15203
C vitamin	72	16,03	48,84	31,4962	6,46350
Dry matter-%	72	10,40	15,09	12,5883	1,10319
FRAP - µmol/g	72	33,88	71,62	52,0396	8,47388
FRAP - mmol/100 g	72	3,39	7,16	5,2040	,84744
Anthocyanins - mg/l cyd-3-glu	72	18,74	49,23	32,1539	7,15971
phenols - mgGAE/ 100g	72	238,78	473,44	359,0681	52,47486
N (listwise)	72				

Table 3: Descriptive statistics of examined variables, divided by varieties (N=81)

		N	Arithmetic mean	Standard deviation	Standard mistake
Yield/g	C.Delight	9	389.4444	428,34773	142,78258
	Cowichane	9	1480.4444	548,82696	182,94232
	G.Ample	9	1321.3333	559,02750	186,34250
	G.Doll	9	666.0000	280,97598	93,65866
	G.Fyne	9	682.7778	269,23910	89,74637
	G.Magna	9	1161.6667	638,48258	212,82753
	M.Hestia	9	239.0000	212,75514	70,91838
	Octavia	9	807.8889	394,36197	131,45399
	Tulameen	9	333.7778	240,35483	80,11828
	Total	81	786.9259	584,02673	64,89186

Table 4: Descriptive statistics of examined variables, divided by varieties (N=81)

		N	Arithmetic mean	Standard deviation	Standard mistake
Berry weight/g	C.Delight	9	3,5267	,63693	,21231
	Cowichane	9	4,2578	,46567	,15522
	G.Ample	9	4,0111	,27406	,09135
	G.Doll	9	3,0333	,29428	,09809
	G.Fyne	9	3,0911	,18496	,06165
	G.Magna	9	4,0511	,19264	,06421
	M.Hestia	6	3,2200	,35077	,14320
	Octavia	9	4,1356	,40507	,13502
	Tulameen	9	3,6533	,37014	,12338
	Total	78	3,6815	,57365	,06495

Table 5: Descriptive statistics of examined variables, divided by varieties (N=81)

		N	Arithmetic mean	Standard deviation	Standard mistake
Ss	C.Delight	9	9.6556	,94487	,31496
	Cowichane	9	9.5333	,89163	,29721
	G.Ample	9	8.4111	,69542	,23181
	G.Doll	9	9.5667	,68920	,22973
	G.Fyne	9	7.9556	,70020	,23340
	G.Magna	9	10.3667	,53385	,17795
	M.Hestia	6	9.3167	,50761	,20723
	Octavia	9	9.1889	,47813	,15938
	Tulameen	9	10.8556	,51505	,17168
	Total	78	9.4321	1,07528	,12175

Table 6: Descriptive statistics of examined variables, divided by varieties (N=81)

		N	Arithmetic mean	Standard deviation	Standard mistake
pH	C.Delight	9	2,8833	,05074	,01691
	Cowichane	9	2,8711	,04649	,01550
	G.Ample	9	2,9000	,02550	,00850
	G.Doll	9	2,9900	,05292	,01764
	G.Fyne	9	2,9656	,05199	,01733
	G.Magna	9	2,8800	,02062	,00687
	M.Hestia	6	2,8617	,06113	,02496
	Octavia	9	2,9200	,03969	,01323
	Tulameen	9	2,8733	,07106	,02369
	Total	78	2,9067	,06270	,00710

Table 7: Descriptive statistics of examined variables, divided by varieties (N=81)

		N	Arithmetic mean	Standard deviation	Standard mistake
TA	C.Delight	9	2.3816	,08828	,02943
	Cowichane	9	2.3608	,13569	,04523
	G.Ample	9	2.2792	,04998	,01666
	G.Doll	9	1.9453	,13065	,04355
	G.Fyne	9	2.0583	,14317	,04772
	G.Magna	9	2.0983	,13596	,04532
	M.Hestia	6	2.3543	,14544	,05938
	Octavia	9	2.0831	,12093	,04031
	Tulameen	9	2,5900	,26279	,08760
	Total	78	2.2346	,24008	,02718

Table 8: Descriptive statistics of examined variables, divided by varieties (N=81)

		N	Arithmetic mean	Standard deviation	Standard mistake
5% colour	C.Delight	9	,8108	,14474	,04825
	Cowichane	9	,8414	,06950	,02317
	G.Ample	9	,5810	,03387	,01129
	G.Doll	9	,5136	,08443	,02814
	G.Fyne	9	,7282	,07224	,02408
	G.Magna	9	,5276	,04243	,01414
	M.Hestia	6	,5872	,03745	,01529
	Octavia	9	,4469	,02437	,00812
	Tulameen	9	,7380	,04313	,01438
	Total	78	,6437	,15203	,01721

Table 9: Descriptive statistics of examined variables, divided by varieties (N=81)

		N	Arithmetic mean	Standard deviation	Standard mistake
C vitamin	C.Delight	5	29.7980	4,51452	2,01896
	Cowichane	9	29.1778	4,32568	1,44189
	G.Ample	9	33.7411	1,36586	,45529
	G.Doll	9	33.1967	1,81927	,60642
	G.Fyne	9	20.0956	3,33209	1,11070
	G.Magna	9	30.8267	3,74270	1,24757
	M.Hestia	6	31.9317	2,57993	1,05325
	Octavia	9	34.0467	4,15144	1,38381
	Tulameen	7	42.4843	4,25567	1,60849
	Total	72	31.4962	6,46350	,76173

Table 10: Descriptive statistics of examined variables, divided by varieties (N=81)

		N	Arithmetic mean	Standard deviation	Standard mistake
Dry matter-%	C.Delight	5	12,6560	,61437	,27475
	Cowichane	9	12,3492	,88709	,29570
	G.Ample	9	10,9716	,32784	,10928
	G.Doll	9	13,1328	,60206	,20069
	G.Fyne	9	11,8053	,71399	,23800
	G.Magna	9	13,3747	,82190	,27397
	M.Hestia	6	12,3195	,37314	,15233
	Octavia	9	12,7582	,81719	,27240
	Tulameen	7	14,2336	,55802	,21091
	Total	72	12,5883	1,10319	,13001

Table 11: Descriptive statistics of examined variables, divided by varieties (N=81)

		N	Arithmetic mean	Standard deviation	Standard mistake
FRAP - µmol/g	C.Delight	5	49,8590	4,18304	1,87071
	Cowichane	9	43,4700	2,50064	,83355
	G.Ample	9	39,3492	4,61377	1,53792
	G.Doll	9	53,7082	3,40028	1,13343
	G.Fyne	9	53,4284	5,70515	1,90172
	G.Magna	9	51,8147	3,02981	1,00994
	M.Hestia	6	60,0982	4,04574	1,65167
	Octavia	9	59,4394	7,74405	2,58135
	Tulameen	7	60,8677	5,98634	2,26262
	Total	72	52,0396	8,47388	,99866

Table 12: Descriptive statistics of examined variables, divided by varieties (N=81)

		N	Arithmetic mean	Standard deviation	Standard mistake
Anthocyanins - mg/l cyd-3-glu	C.Delight	5	39.4928	3,43975	1,53830
	Cowichane	9	40.3229	4,65257	1,55086
	G.Ample	9	28.7573	1,65569	,55190
	G.Doll	9	28.8321	3,80247	1,26749
	G.Fyne	9	40.3772	2,75709	,91903
	G.Magna	9	28.9343	3,18253	1,06084
	M.Hestia	6	27.9103	2,12279	,86663
	Octavia	9	21.2194	1,32708	,44236
	Tulameen	7	36.3089	1,96334	,74207
	Total	72	32.1539	7,15971	,84378

Table 13: Descriptive statistics of examined variables, divided by varieties (N=81)

		N	Arithmetic mean	Standard deviation	Standard mistake
Phenols - mgGAE/ 100g	C.Delight	5	355,2370	32,13013	14,36903
	Cowichane	9	310,6878	24,41251	8,13750
	G.Ample	9	277,4671	30,83910	10,27970
	G.Doll	9	388,3597	22,15217	7,38406
	G.Fyne	9	354,8410	36,58940	12,19647
	G.Magna	9	363,9858	21,70959	7,23653
	M.Hestia	6	393,8640	24,23287	9,89303
	Octavia	9	396,5487	45,14160	15,04720
	Tulameen	7	412,3603	45,46022	17,18235
	Total	72	359,0681	52,47486	6,18422

Gray - the lowest value of the examined variables

Yellow - the highest value of the examined variables

Table 14: Analysis of variance of examined variables, comparison between different varieties (N=81)

		Sum of squares	df	Arithmetic mean-squares	F	P
Yield/g	Between groups	14368111,111	8	1796013,889	10,010	,000
	Within groups	12918866,444	72	179428,701		
	Total	27286977,556	80			
Fruit mass/g	Between	15,471	8	1,934	13,522	,000
	Within groups	9,868	69	,143		
	Total	25,339	77			
SS	Between groups	56,417	8	7,052	14,920	,000
	Within groups	32,613	69	,473		
	Total	89,030	77			
pH	Between groups	,141	8	,018	7,473	,000
	Inside groups	,162	69	,002		
	Total	,303	77			
acids	Between groups	2,985	8	,373	17,714	,000
	Within groups	1,453	69	,021		
	Total	4,438	77			
5% colour	Between groups	1,425	8	,178	34,587	,000
	Within groups	,355	69	,005		
	Total	1,780	77			

C vitamin	Between groups	2212,831	8	276,604	23,132	,000
	Within groups	753,323	63	11,958		
	Total	2966,153	71			
Dry matter-%	Between groups	57,455	8	7,182	15,627	,000
	Within groups	28,954	63	,460		
	Total	86,409	71			
FRAP - µmol/g	Between groups	3605,014	8	450,627	19,012	,000
	Within groups	1493,255	63	23,702		
	Total	5098,269	71			
Anthocyanins - mg/l cyd-3-glu	Between groups	3079,879	8	384,985	43,335	,000
	Within groups	559,689	63	8,884		
	Total	3639,567	71			
Phenols - mgGAE/ 100g	Between groups	128956,273	8	16119,534	15,260	,000
	Within groups	66550,082	63	1056,351		
	Total	195506,355	71			

F - F ratio
Df - degrees of freedom
P - statistical significance of differences
Yellow - a statistically significant difference at less than

Table: 15 Correlation between variables

		Fruit mass/g	SS.	PH	acids	5%colour	C vitamin	Dry matter-%	FRAP - µmol/g	FRAP - mmol/100 g	Anthocyanins - mg/l cyd-3-glu	phenols-mgGAE/100g
Yield/g	r	,497	,-361	-,054	-,201	-,019	-,196	-,444	-,520	-,520	,042	-,495
	p	,000	,001	,640	,077	,871	,100	,000	,000	,000	,729	,000
	N	78	78	78	78	78	72	72	72	72	72	72
Fruit mass/g	r	1	,019	-,449	,251	,065	,154	-,111	-,320	-,320	-,089	-,313
	p	,	,869	,000	,027	,574	,197	,353	,006	,006	,459	,008
	N	78	78	78	78	78	72	72	72	72	72	72
SS	r	,019	1	,394	,356	,031	,537	,731	,276	,276	-,064	,357
	p	,869	,	,000	,001	,787	,000	,000	,019	,019	,595	,002
	N	78	78	78	78	78	72	72	72	72	72	72
PH	r	-,449	-,394	1	-,718	-,333	-,276	-,143	-,015	-,015	-,061	-,012
	p	,000	,000	,	,000	,003	,019	,230	,900	,901	,609	,922
	N	78	78	78	78	78	72	72	72	72	72	72
acids	r	,251	,356	-,718	1	,529	,399	,176	,010	,010	,260	-,011
	p	,027	,001	,000	,	,000	,001	,139	,999	,999	,027	,930
	N	78	78	78	78	78	72	72	72	72	72	72
5%colour	r	,065	,031	-,333	,529	1	-,192	-,018	-,190	-,190	,842	-,185
	p	,574	,787	,003	,000	,	,107	,879	,110	,110	,000	,120
	N	78	78	78	78	78	72	72	72	72	72	72
C vitamin	r	,154	,537	-,276	,399	-,192	1	,512	,262	,262	-,386	,346
	p	,197	,000	,019	,001	,107	,	,000	,026	,026	,001	,003
	N	72	72	72	72	72	72	72	72	72	72	72
Dry matter-%	r	-,111	,731	-,143	,176	-,018	,512	1	,598	,598	-,070	,685
	p	,353	,000	,230	,139	,879	,000	,	,000	,000	,559	,000
	N	72	72	72	72	72	72	72	72	72	72	72
FRAP - µmol/g	r	-,320	,276	-,015	,000	-,190	,262	,598	1	1,000	-,216	,968
	p	,006	,019	,900	,999	,110	,026	,000	,	,000	,069	,000
	N	72	72	72	72	72	72	72	72	72	72	72
FRAP - mmol/100 g	r	-,320	,276	-,015	,000	-,190	,262	,598	1,000	1	-,216	,968
	p	,006	,019	,901	,999	,110	,026	,000	,000	,	,069	,000
	N	72	72	72	72	72	72	72	72	72	72	72
Anthocyanins - mg/l cyd-3-glu	r	-,089	-,064	-,061	,260	,842	-,386	-,070	-,216	-,216	1	-,221
	p	,459	,595	,609	,027	,000	,001	,559	,069	,069	,	,062
	N	72	72	72	72	72	72	72	72	72	72	72
Phenols - mgGAE/100g	r	-,313	,357	-,012	-,011	-,185	,346	,685	,968	,968	-,221	1
	p	,008	,002	,922	,930	,120	,003	,000	,000	,000	,062	,
	N	72	72	72	72	72	72	72	72	72	72	72

Table 16 : 5% color, statistically significant differences between cultivars, Tukey

	Cowichane	C.Delight	Tulameen	G.Fyne	M.Hestia	G.Ample	G.Magna	G.Doll	Octavia
Cowichane				++	+	+	+	+	+
C.Delight					+	+	+	+	+
Tulameen					+	+	+	+	+
G.Fyne	+				+	+	+	+	+
M.Hestia	+	+	+	+		+			+
G.Ample	+	+	+	+	+				+
G.Magna	+	+	+	+					
G.Doll	+	+	+	+					
Octavia	+	+	+	+	+	+			

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gul farge= avling på topp

Avling 2012

		28			29						30						31						32						33						34								
		torsdag			mandag			torsdag			mandag			torsdag			mandag			torsdag			tirsdag			fredag			mandag			fredag			onsdag								
		1.høsting			2.høsting			3.høsting			4.høsting			5.høsting			6.høsting			7.høsting			8.høsting			9.høsting			10.høsting			11.høsting			12.høsting			total-					
		12.07			16.07			19.07			23.07			26.07			30.07			02.08			07.08			10.08			13.08			17.08			22.08			avling			gj.snitt		
Sort	Gj.tak	Avl.	råtne	g/bær	Avl.	råtne	g/bær	Avl.	råtne	g/bær	Avl.	råtne	g/bær	Avl.	råtne	g/bær	Avl.	råtne	g/bær	Avl.	råtne	g/bær	Avl.	råtne	g/bær	Avl.	råtne	g/bær	Avl.	råtne	g/bær	Avl.	råtne	g/bær	Avl.	råtne	g/bær	g/rute	kg/rute	råtne	g/bær	ant planter pr rute	Avl, g/pl
Cascade Delight	I													57	0	3,35	133	0	3,41	167	0	3,00	193	21	2,88	52	0	2,48	40	0	3,08	23	0	2,09	32	0	2,67	697	0,70	21	2,87	5	139
	II							80	22	4,83	167	0	4,28	172	0	3,91	332	0	3,18	231	0	3,48	224	40	3,10	86	6	3,08	54	0	2,70	84	0	2,71	8	0	2,67	1438	1,44	68	3,39	6	240
	III							99	16	4,37	582	13	4,86	1113	0	4,30	1227	0	4,80	1084	0	4,46	1031	155	4,22	543	45	3,68	553	23	3,66	377	0	3,00	114	0	2,65	6723	6,72	252	4,00	6	1121
Cowichane	I				74	0	3,36	259	14	3,36	963	27	3,52	1965	0	3,34	1758	0	3,82	1428	0	3,60	1614	236	3,88	1166	127	3,60	757	13	2,88	738	0	2,96	245	0	2,86	10967	10,97	417	3,38	6	1828
	II				128	6	3,70	208	15	4,11	788	31	4,26	1606	0	4,14	1736	0	4,76	1795	0	4,28	1598	196	4,50	1267	155	4,04	627	21	3,88	680	0	3,52	392	0	3,32	10825	10,83	424	4,05	6	1804
	III				111	0	4,11	286	0	4,28	761	0	4,40	1525	0	4,74	1656	0	4,98	1308	0	3,86	2450	430	4,20	1211	79	3,78	1165	0	3,76	818	0	3,24	426	0	3,24	11717	11,72	509	4,05	6	1953
Glen Ample	I	433	0	4,44	1870	0	4,28	1328	0	4,44	2173	0	4,50	2300	0	4,04	1938	0	3,94	1988	0	3,76	1021	0	4,34	641	22	4,24	147	0	3,50							13839	13,84	22	4,15	6	2307
	II	644	5	4,14	1504	0	3,90	942	0	4,04	1376	0	4,16	1450	0	4,04	1414	0	3,96	601	0	3,54	610	47	4,06	359	58	3,96	53	0	3,31							8953	8,95	110	3,91	6	1492
	III	721	33	4,20	1223	0	4,10	1020	0	3,84	1483	0	4,20	1489	0	4,32	1373	0	4,24	774	0	4,08	762	68	4,22	220	0	3,86	73	0	3,48							9138	9,14	101	4,05	6	1523
Glen Doll	I	131	0	3,36	495	7	3,44	553	0	3,48	1031	0	3,26	955	0	3,14	702	0	2,94	718	0	2,78	1103	55	3,18	633	11	3,10	361	0	3,10	344	0	2,74	178	0	2,51	7204	7,20	73	3,09	6	1201
	II	81	0	3,52	342	0	3,44	384	0	3,04	778	0	2,80	616	0	2,74	640	0	2,80	409	0	2,58	744	18	3,10	411	0	2,78	298	0	2,34	207	0	2,66	48	0	2,82	4958	4,96	18	2,89	6	826
	III	31	0	3,88	187	6	3,10	324	0	3,30	900	0	2,90	757	0	2,70	913	0	2,62	833	0	2,76	1231	71	3,10	534	0	2,94	486	0	2,90	458	0	2,48	230	0	2,44	6884	6,88	77	2,93	6	1147
Glen Fyne	I	102	0	3,19	240	0	2,98	498	0	3,04	754	0	3,12	1035	0	3,14	788	0	2,68	545	0	2,68	345	0	2,76	165	0	2,68	97	0	3,13							4569	4,57	0	2,94	6	762
	II	344	0	3,92	644	0	3,38	704	0	3,10	1063	0	3,32	925	0	2,96	931	0	3,04	402	0	3,24	409	0	3,34	252	8	3,26	92	0	3,41							5766	5,77	8	3,30	6	961
	III	146	0	3,65	415	0	3,52	564	0	3,30	794	0	3,52	1086	0	3,20	904	0	3,46	386	0	3,16	557	53	3,78	194	0	3,34	83	0	3,32							5129	5,13	53	3,43	6	855
Glen Magna	I							60	0	4,62	850	0	4,24	1615	0	3,66	2224	0	3,78	1152	0	3,94	2067	247	3,88	1237	32	3,66	675	0	3,90	661	0	3,72	195	0	3,68	10736	10,74	279	3,91	6	1789
	II							93	0	4,65	515	0	4,06	818	0	4,04	1255	0	4,26	702	0	3,86	1111	95	4,22	608	14	3,38	324	0	3,26	442	0	3,28	113	0	3,23	5981	5,98	109	3,82	5	1196
	III							73	0	4,06	285	0	4,00	656	0	3,76	1110	0	3,82	665	0	3,44	1038	145	4,20	705	36	3,92	375	0	3,70	368	0	3,44	152	0	3,80	5427	5,43	181	3,81	6	905
Malling Hestia	I							39	0	3,25	23	0	2,88	181	0	3,12	190	0	3,28	180	0	3,08	283	40	3,22	281	11	3,22	232	0	3,08	409	0	3,56	203	0	3,46	2021	2,02	51	3,21	6	337
	II							96	0	3,69	247	0	3,50	512	0	3,42	515	0	3,58	242	0	3,42	536	55	3,54	478	10	3,02	392	0	2,62	629	0	2,92	344	0	2,86	3991	3,99	65	3,26	6	665
	III																																									4	
Octavia	I				72	0	4,50	184	0	4,38	747	0	4,06	1309	0	4,14	1445	0	4,30	875	0	3,96	1294	79	4,98	842	66	4,72	593	0	4,62	440	0	4,46	181	0	4,31	7982	7,98	145	4,40	6	1330
	II				40	0	4,00	272	0	4,26	572	0	4,14	901	0	4,24	918	0	3,76	654	0	3,94	1030	80	4,48	782	11	4,36	491	0	4,50	444	0	4,34	172	0	4,65	6276	6,28	91	4,24	6	1046
	III				60	0	4,00	133	0	3,80	283	0	3,74	373	0	3,68	540	14	3,78	439	0	4,40	442	40	3,98	236	0	3,93	173	0	4,12	160	0		96	0	4,65	2935	2,94	54	4,01	3	978
Tulameen	I							250	0	4,42	345	0	4,38	391	0	3,80	847	0	3,74	728	0	3,68	547	54	3,72	302	0	3,48	172	0	3,74	197	0	3,46	49	0	3,50	3828	3,83	54	3,79	6	638
	II							41	0	3,15	64	0	4,00	196	0	3,48	314	0	3,48	376	0	3,26	344	39	3,20	241	15	3,18	85	0	3,04	121	0	3,03	38	0	2,71	1820	1,82	54	3,25	6	303
	III							66	0	3,88	106	0	3,66	150	0	3,13	211	0	3,44	172	0	3,28	230	23	3,26	54	0	3,00	35	7	2,25	49	0	2,72	12	0	2,40	1085	1,09	30	3,10	6	181