University College of Southeast Norway
Faculty of Technology, Natural Science and Maritime Studies
Master Thesis
Study programme: Master of Environmental Science
Spring 2018

Nabin Bhandari

Apple tree phenology in relation to temperature in Sauherad (Norway)

University College of Southeast Norway/University of South-Eastern Norway

Faculty of Technology, Natural Science and Maritime Studies
Department of Nature, Health and Environment
PO Box 235
NO-3603 Kongsberg, Norway

http://www.usn.no

This thesis is worth 60 credits study points

Summary

Temperature plays a crucial role for the phenological development of plants and since past few decades Earth's temperature is increasing. Plants are responding to this rise in temperature, through variations in their phenology. The temperature related changes in phenology have been studied for various fruit trees, including apple. Therefore, our study presents the relationship of phenology of three apple cultivars i.e. Red Aroma, Summerred and Discovery with the temperature in Sauherad, Norway. Moreover, the study looks for variation in phenological development and temperature between two years i.e. 2015 and 2016.

This study makes use of multiple statistical tests (Spearman's rank correlation test, Wilcoxon signed ranks test and paired t-test). It shows that the phenological development of all the considered three apple cultivars have a strong positive correlation with cumulative growing degree days while moving from the green top stage to the fruit diameter (10 mm) stage in the year 2016. Phenological development of 2015 does not differ statistically from the phenological development of 2016 while looking at all cultivars together. However, in the individual case of Discovery, phenological development of the year 2015 varies from 2016. Another finding is the interannual variation of cumulative growing degree days during the period of January to mid-July. In the year 2015 cumulative growing degree days were reduced by 30.89 ^{0}C compared to the year 2016.

Apple cultivation is economically important in Norway and the findings of the study can be useful to the local apple farmers in Sauherad as well as researchers interested in this field.

Key words: Apple Cultivars, Climate Change, Cumulative Growing Degree Days, Phenological development

Acknowledgement

I am grateful towards my supervisors, associate professor Stefanie Reinhardt and professor Hans Renssen for continuous support, encouragement and suggestions that motivated me for my task. I would also like to thank, associate professor Andreas Zedrosser for helping me with the statistical part of the thesis.

My special thanks to Jonas Lystrup Andresen for helping me with my field work and Hanna Wistedt for providing me secondary data from 2015. Finally, I owe my deepest gratitude towards my family members and friends, for providing such a great environment during this study period.

Contents

1. INTRODUCTION

The surrounding environment is a key component for the growth of plants (Scott, 1969; Wilkinson, 2000; Yazdanpanah et al., 2010) and this applies to apple trees too. So, it's important to know about the environment while studying the development in apple trees. The environment comprises both biotic and abiotic factors and among these factors temperature plays a crucial role for the growth of plants (Bairam et al., 2012; Legave et al., 2008). Temperature is expected to increase remarkably in this 21st Century according to the Intergovernmental panel on climate change (IPCC) and the rise in temperature is considered as a major component contributing to climate change (CC). Plants show responses to CC in different forms, for example; shift in ecological range (Chen et al., 2011; Menéndez et al., 2006; Moritz et al., 2008; Parmesan & Yohe, 2003), or change in phenological development (Cleland et al., 2007; Forrest & Miller-Rushing, 2010; Walther et al., 2002; White et al., 1997). To observe the impacts of CC on phenological development, this study will continue to look at relationships of phenological development with temperature in 2016 in Sauherad as Hanna Wistedt did in 2015. Furthermore, the study will focus to know about the differences in phenological development and temperature within the years 2015 and 2016. A previous study conducted by Hanna Wistedt in 2015 shows a linear relationship between phenological development and temperature. Along with this, the study in 2015 concludes, there exist a difference in phenological development among three apple cultivars.

1.1 Climate change (CC)

Weather is the state of the atmosphere at a defined place and time (Poore, 1996), whereas climate is the average of weather conditions measured for a prolonged period (≥30 years) of time (DiMento & Doughman, 2014). In the present scenario, CC is being prominent with the increase in temperature and the global temperature went up by 0.6 ^{0}C in the 20th Century (IPCC, 2001). Furthermore, the global temperature is expected to rise in this 21st Century by 1 to 4 ^{0}C (IPCC, 2007b). A long-term change in climatic conditions as a result of natural variability or human activity is termed as CC (IPCC, 2007c). In the case of northern Europe, natural variability and regional fluctuation play a role to determine climatic conditions along with global warming (Førland & Alfnes, 2007). CC in Norway due to global warming can cause; an increase in temperature, precipitation, and growing season length (Gjershaug et al., 2009; Uleberg et al., 2014). Temperature in Norway have increased by ca. 1 ^{0}C in the 20th Century and the projected increase in temperature by the end of 21st century is ca. 4.5 ^{0}C (Hanssen-Bauer et al., 2017). Although, a temperature rise is observed throughout the year in Norway, the rise in temperature is more pronounced during summer and autumn than in winter (Hanssen-Bauer et al., 2017). In addition to this, Norway has a probability in the future to have short winters with mild temperatures (Førland & Alfnes, 2007; Gjershaug, 2009). Among the many municipalities in Norway, Sauherad municipality, situated in the south of the country, is also facing with the consequences of CC. Some of the expected changes in Sauherad due to CC are: a rise in annual precipitation by ca. 15% and in temperature by ca. 4 ^{0}C at the end of 21st Century, in combination with a reduced time of snow coverage (Klimaservicesenter, 2016).

1.2 Fruit tree phenology

Phenology is the study of life cycle events related to seasonal timing (Rathcke & Lacey, 1985). The life cycle events like development of flowers and onset of leaves in plants are induced by different environmental factors such as temperature rise, increased rainfall, elevated CO_2 and nitrogen deposition (Cleland et al., 2006; Talbert et al., 2013). Among the environmental factors, temperature plays an important role in the phenological development (Bairam et al., 2012; Legave et al., 2008) and it has dual role in fruit tree phenology, such as, low temperature is required to break bud endodormancy and relatively high temperature is essential for flowering (Chuine et al., 2016). Along with temperature, photoperiod (available amount of day light) plays an important role in the later stage of leaf fall. The impact of CC can also be seen in fruit production. Increasing temperature has caused various diseases in fruit trees (Devi, 2016) and has induced impacts on normal production of fruits, reducing the dormancy period of fruit trees (Hribar & Vidrih, 2015). Apple production is facing problems due to CC in the entire world. For instance, due to increase in temperature and decrease in winter rainfall, the apple production in northern India has decreased by 0.4 tons/hectare in the period of 1985-2009 (Sen et al., 2015), whereas certain areas of Japan will be unable to grow apples with the increase in temperature in near future, i.e. apple trees will shift their geographical range of growth (Morinaga, 2018). It's not all about the quantity of apple production, quality of apples is also decreased due to rise in temperature. The concentration of malic acid, which makes apples tasty, is slowly being diminished in some apple cultivars in response to an increase in temperature (Stromberg, 2013).

1.3 Apple cultivation in Norway

The apple is one of the oldest cultivated tree that is grown in temperate regions of the world with some extend in tropical regions too and has the highest economic value among fruits (Jackson, 2003). In Norway, the apple production has significant economic value (Thornews, 2013) and is commercially cultivated in the southern part of the country (Sletten et al., 2012). Beyond, the southern part of Norway, apples are being cultivated in some of the warm parts of the east and west, that have mean temperatures of 12.5-14 ^{0}C in the period of May to September (Røen, 1996). The annual increase in the land used for apple cultivation also shows the relevancy of apple fruit production in Norway. Apple cultivation land in Norway increased from 1,351 hectares to 1,429 hectares during the period of 2010 to 2016 (Statista, 2018b). In the coming decades, apple trees can possibly grow beyond the present distribution towards higher elevation and latitudes due to the rise in temperature (Sthapit et al., 2012), leading to further increase in the area of apple cultivation in Norway. An indication for this is the temporal advancement in flowering of apple trees that can be seen in southern Norway in response to an increase in temperature (Tjomsland, 2014), as a flowering advancement of nine days is seen in the period of 1986 to 2016 (Rivero et al., 2017).

In this situation, the major challenge for Norwegian farmers is to know the relationship between a rise in temperature and the phenological development of apple trees. Information gathered from various studies related to temperature rise and apple trees can help farmers to choose the right apple cultivar for their farm, i.e. that best suits the expected rise in temperature (Parkes, 2017).

1.4 Aim of the study

The entire globe is struggling with the impacts of CC and some of the impacts like the rise in annual temperature and precipitation can be seen in the southern part (Telemark county) of Norway too (Klimaservicesenter, 2016). In the same way, phenological development of apple trees in the southern part of Norway have also responded to the impacts of CC (Rivero et al., 2017). This situation makes phenological development in response to CC an interesting subject to. It is essential to study phenological development further (Jones & Thornton, 2003) because it provides relevant information about the existing ecological system and evolution pattern (Forrest & Miller-Rushing, 2010) as well as contributes to scientific studies in the field of biodiversity, agriculture, forestry and human health (Ruml & Vulić, 2005). The results from phenological studies are vital for research findings (Chapman et al., 2005) and plays an important role for the planning and organizing of agricultural activities, such as the optimal time for the plantation and use of fertilizers (Moola & Mallik, 1998; Ruml & Vulić, 2005). Most importantly, the planned agricultural activities based on phenological activities helps to gain maximum production (Sakamoto et al., 2005).

A study by Wistedt (2016) gives information about relationship between phenological development and temperature in Sauherad for the year 2015 only and it is hard to generalize result from only one year. So, this study intends to further investigate about the relationship between phenological development of apple trees and temperature in the year 2016 too. In addition to this, our study tries to look for the variation in phenological development as well as CGDD from the years 2015 and 2016. These findings will help local farmers to know about response of apple trees to change in temperature and can help other researchers that work in the relevant field. In general, the hypotheses of this study can be summarized in the following way;

H_1: There is a no relationship between phenological development and CGDD.

H_2: There is a no difference in phenological development of 2015 and 2016.

i.e. Phenological development of 2015 = Phenological development of 2016.

H_3: There is a no difference in CGDD of 2015 and 2016.

i.e. CGDD of 2015 = CGDD of 2016.

2. MATERIAL AND METHODS

2.1 Apple cultivars included in this study

The genus *Malus* includes a various number of species and subspecies. The domesticated apple *Malus domestica* Borkh is considered to be the result of interspecific hybridization (Kellerhals, 2009; Robinson et al., 2001). In contrast to traditional practice, these days apple trees are obtained mainly with grafting branches in-to shoots, giving a tree with characteristics of the parental cultivar to which the branch belongs (Seppä, 2014). Different cultivars are developed based on the environmental and biological requirements (Jackson, 2003). In Norway, the cultivars Aroma and Summerred are regarded as tasting the best by consumers (Redalen, 1987) and the consumers preference is based on flavor (Varming et al., 2014). This study includes three apple cultivars that are commonly cultivated in Telemark county: Red Aroma, Summerred and Discovery.

Red Aroma is the result of a cross between Ingrid Marie and Filippa varieties (Oulton, 2006), and originates from Sweden (Pippin, 2015a). Red Aroma is a delicious apple developed from cloning of Aroma, which is cultivated in Norway along with other Scandinavian countries. Red Aroma provides fruits in the months of September to October (Fruit, 2013). This apple tree gives a medium to large, sized fruit having a red color well spread on its cover (Planteskole, 2017).

Summerred originated from Canada in 1964 and the cultivar has medium sized fruits with sweet flavor (Nursery, 2017). This cultivar of apple grows well in regions with hot summers and is considered best for the area that lies in the north-west Pacific region (Gardener, 2017). The southern part of Norway has warm summers and this area is therefore suitable for the Summerred apple. Moreover, Summerred tree have a strong growth and spreads horizontally. Summerred fruits can be harvested in the month of August, i.e. earlier than Red Aroma (NSW, 2005).

Discovery is a cross of Worcester Pearmain and Beauty of Bath varieties that was raised in England around 1949 (Oulton, 2004). This cultivar of apple grows well in temperate climatic condition (Pippin, 2015b) and belongs to commonly cultivated cultivars in Norway too (Børve et al., 2015). In addition to this, Discovery gives fruit with a medium size that has a uniform flat-round shape (Focused, 2017). Discovery fruits are harvested in late August.

2.2 Study area

This study was conducted on the farms located at Liagrend, Nyhus and Årnes that lie within Sauherad municipality in Telemark county of Norway (Fig. 1, Fig. 2). Geologically, all three farms have same bedrock called Charnockite (NGU, 2018a) and the underlying bedrock is covered by a layer of Holocene marine sediments (NGU, 2018c).

Figure 1: Sauherad municipality in Telemark county of Norway (Google, 2018b).

Figure 2: Location of Liagrend, Nyhus and Årnes farm lands at Sauherad municipality (Google, 2018a).

Sauherad municipality, situated in the southern part of Norway, has relatively warm summers and cold winter with snowfall. Sauherad in the period of 1961 to 1990 had January with the lowest temperature (ca. -6 ^{0}C) and July with the highest temperature (ca. 16 ^{0}C). In the same way, rainfall varies from 40 mm to 90 mm round the year in the period of 1961-1990 (Fig. 3).

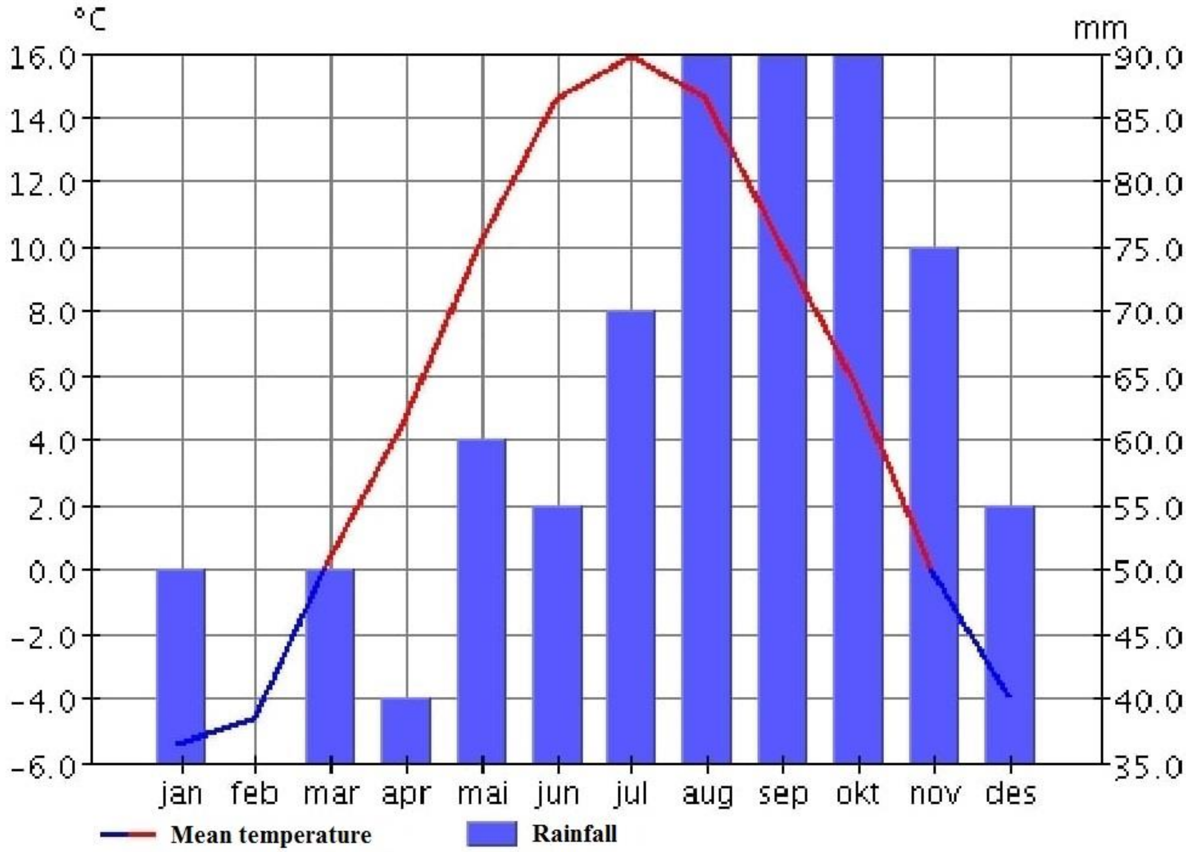


Figure 3: Average temperature and precipitation from 1961 to 1990 at Gvarv - Nes station in Sauherad municipality (eklima, 2018b).

The Liagrend farm is divided into two parts as a small road passes through it (Fig. 4). Among these two parts, one is relatively smaller in size with less slope terrain whereas the larger part of the farm consists of steeper slopes providing good drainage facility for trees. The distribution of the sampled trees is well illustrated in Fig. 4 and the Liagrend farm has all the three apple cultivars (i.e. Red Aroma, Summerred and Discovery) that were studied during this research period. Liagrend farm stretches from around 60 m above sea level to 115 m above sea level and while observing the distribution of apples in this farm, Red Aroma and Summerred are planted in the area with altitude 100 m above sea level and Discovery is planted below that altitude. The location of Discovery on this farm is at $59^0$22'31.11''N, $9^0$16'00.36''E and Red Aroma as well as Summerred are located at $59^0$22'31.76''N, $9^0$16'03.56''E.

Figure 4: Approximate area of Liagrend farm (big polygon on left hand side shows cultivation area of Discovery (line A-B) whereas Red Aroma (line C-D) and Summerred (line E-F) are cultivated in a small polygon on right hand side) (NGU, 2018b).

Nyhus farm is distinct from the other two farms as this farm is fragmented and consist of two areas lying apart from each other (Fig. 5). Among these two areas, one with Summerred is near by the road whereas the next area which is not exposed to the road has Red Aroma and Discovery. The area with Red Aroma and Discovery is more sloped terrain than the area with Summerred. The distribution of sampled trees in this farm can be seen in Fig. 5. Along with three apple cultivars that were studied, this farm grows other fruit trees too. The Nyhus farm extends from around 30 m above sea level to 90 m above sea level and within this farm, Summerred is cultivated at higher altitude whereas Red Aroma and Discovery are cultivated at lower altitude. The location of Discovery in this farm is at $59^0$22'45.83''N, $9^0$11'51.12''E, whereas Red Aroma is at $59^0$22'50.36''N, $9^0$1157.17E and Summerred is at $59^0$22'58.38''N, $9^0$12'33.07''E.

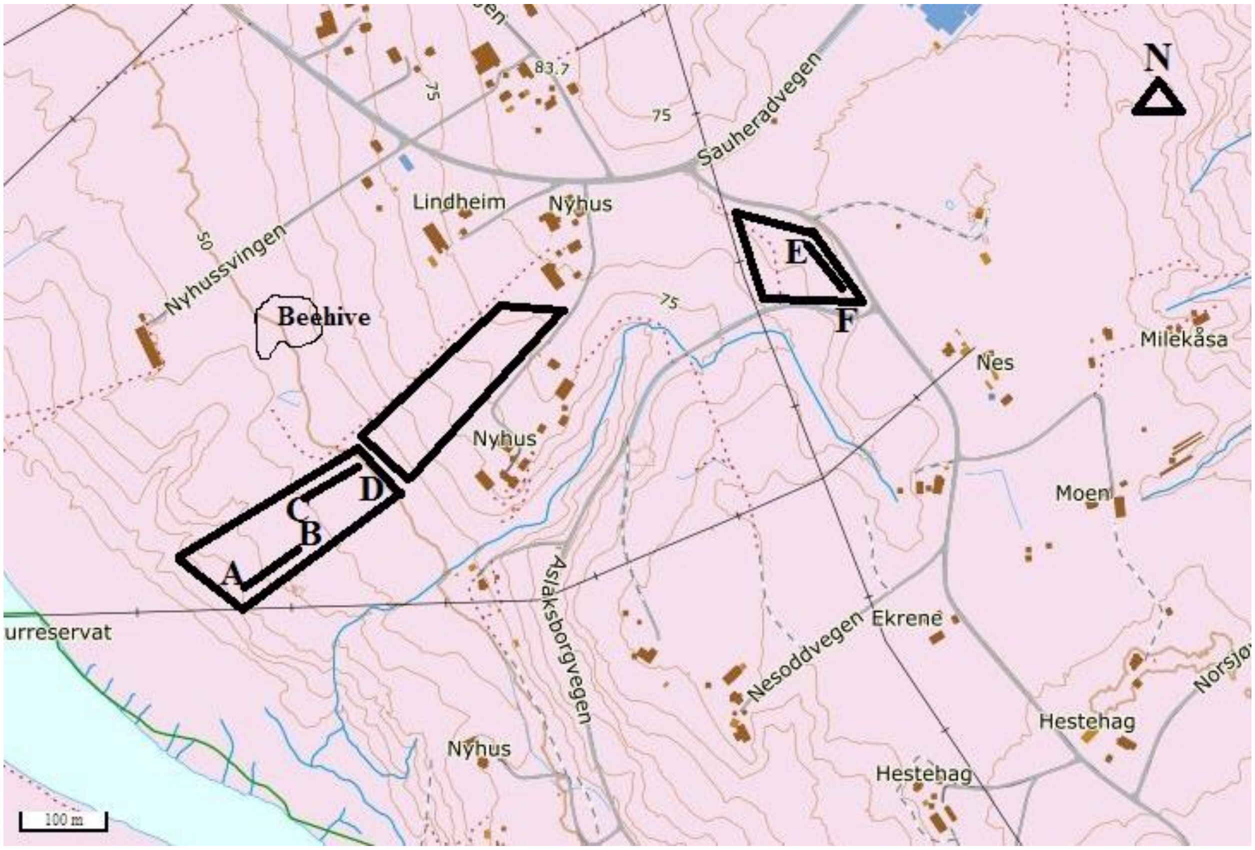


Figure 5: Approximate area of Nyhus farm (small polygon on the right hand side shows cultivation area of Summerred (line E-F) and Red Aroma (line C-D) and, Discovery (line A-B) are cultivated on elongated polygon on the left hand side) (NGU, 2018b).

Årnes farm is not fragmented like the previous two farms and this farm has relatively flat area to grow plants (Fig. 6). This makes the whole area uniformly exposed to sunlight and other environmental factors. The distribution of sampled trees in this farm can be seen in Fig. 6. Along with three apple cultivars that were studied during this research, Årnes grows some other types of fruit trees too. Årnes farm extends from around 30 m above sea level to 43 m above sea level but sampled trees lie close to 40 m above sea level. Discovery and Red Aroma in this farm are located at 59^{0}21'58.25''N, 9^{0}11'09.47''E, whereas Summerred is at 59^{0}21'58.54''N, 9^{0}11'06.12''E.

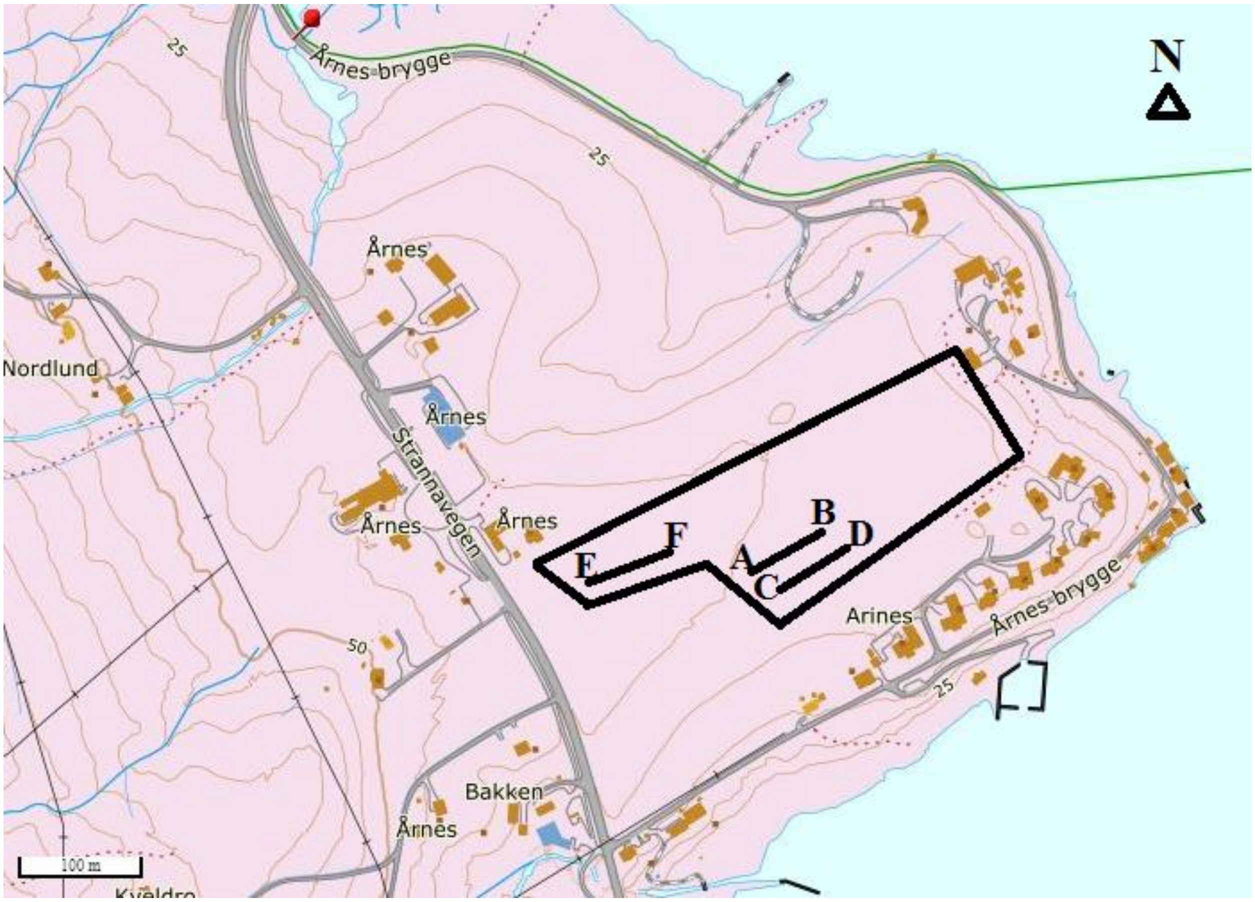


Figure 6: Approximate area of Årnes farm and distribution of apple cultivars i.e. Summerred (line E-F), Discovery (line A-B), Red Aroma (line C-D) (NGU, 2018b).

Considering the area of apple cultivation, Årnes is the largest and Nyhus is the smallest farm. Moreover, each farm has all three apple cultivars and tagging can be found in first, fourth as well as seventh number of sampled trees (Fig. 7).

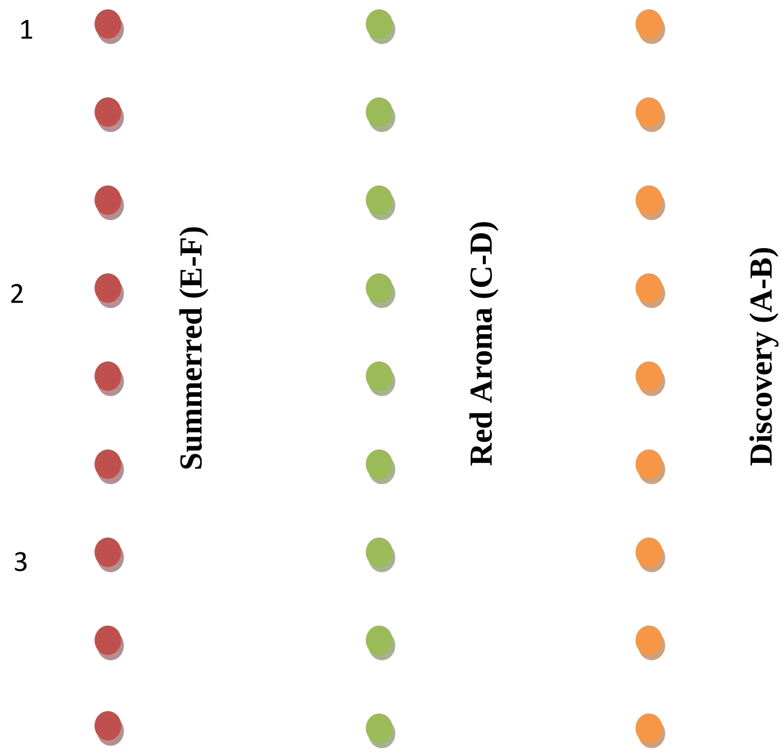


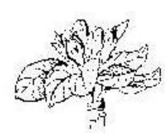
Figure 7: Distribution of apple cultivars in the field and (1,2,3) tagging used for first, fourth and seventh number of sampled trees.

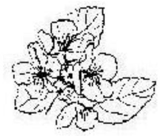
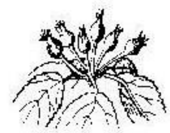
2.3 Data collection

2.3.1 Phenology observation

A standard diagram sheet (Kernobst-Phenology) (Höhn, April 2008) developed by Agroscope ACW was used in the process of phenological observation to make the collected data precise and consistent. In the field phenological stages such as green top, mouse ear, balloon stage, central bloom open, full bloom, pollination, fading and fruit diameter (10 mm) were observed and these stages are indicated in table 1 with an asterisk (*) sign. The description of these phenological stages in the standard diagram sheet is given in German language, which was translated to English using Google translator (Table 1). Although phenological observation was conducted from 15th of April to 3rd of June, in the month of May and June field work was carried out around three times a week as the majority of flower development stages occur in this period.

Table 1: Different stage of flower phenology (Höhn, April 2008).

Code	Stage	Description	
A/1	Winter bud	Bud is in rest and it is closed.	
B/2	Bud swelling	Bud starts to get swelling and bud scales get longer.	
C/3	Green top*	Bud starts to break-up and have some green leaves.	
C3/4	Mouse ear*	Green leaf tips move upward from bud shells by 10 mm and first leaflets spread.	
D/5	Green bud	Bud is still closed and single flowers start from each other to solve.	
E/6	Red bud	Petals start to stretch and become visible. The sepals are also slightly open.	
E2/7	Balloon stage*	Majority of the flowers look like balloon as bud gets swollen and is not covered.	
F/8	Central bloom open*	Flowering starts: about 10% of the flowers are open.	
F2/9	Full bloom*	At least 50% of the flowers are open and petals fall off start.	

G/10	Pollination*		
H/11	Fading*	At least 80% of the petals have fallen off.	
I/12	Fruit diameter (10 mm) *	Fruits develop to 10 mm diameter.	
After this stage, fruit matter starts to grow in diameter (>10 mm).			

Observation in the field

From each farm 27 apple trees were observed, including nine trees per apple cultivar i.e. Red Aroma, Summerred and Discovery. The sampled trees were predetermined based on a previous study (Wistedt, 2016). One-third of the sample trees were tagged with number (one, two and three) in the field, which allows an easy identification of individuals (Fig. 8).

Total number of samples (apple trees) studied from three farms = (Number of the farms) (Number of apple cultivars) (Number of trees representing each type of apple cultivars in one farm)

= (Three) (Three) (Nine)

= 81 apple trees

Figure 8: Tagging for sampled apple cultivars in the field.

2.3.2 Weather data

For this study, weather data was gained from the station, GVARV-NES (Station number : 32060) that lies at the altitude of 93 m above sea level and is the nearest station to all three farms (NMI, 2017). Weather data for GVARV-NES was provided by eklima.no. This weather data was used to calculate temperature at all three respective farms using a lapse rate of 100 m rise in altitude causing a fall in temperature with 0.65 ^{0}C (Britannica, 2016; Gratz, 2016; SMHI, 2012). Table 2 presents the temperature difference of each farm from GVARV-NES station and this table is used to calculate actual maximum and minimum temperature of a day at respective altitude at which apple cultivars are cultivated. For the phenological development in a tree, temperature above a certain threshold/base temperature is required. Different threshold temperatures are being considered in several studies (Cannell & Smith, 1986; Slafer & Savin, 1991; Valentini et al., 2001). Most of the studies in Norway use 5 ^{0}C as threshold temperature and the Norwegian meteorological institute also uses 5 ^{0}C to calculate growing degree days (GDD) (eklima, 2018a). Hence, this study uses 5 ^{0}C as threshold temperate. With the use of maximum and minimum temperature of a day and threshold temperature, GDD were calculated in the following way;

GDD = [Maximum temperature (TAX) + Minimum temperature (TAN)]/2 - threshold temperature (5 ^{0}C)

GDD are the temperatures above a threshold temperature within 24 hours (Herms, 2004) and different approaches can be used to calculate it. The way in which GDD are calculated in this study is termed as the average method (Herms, 2004). Calculation of GDD was followed by the calculation of cumulative growing degree days (CGDD). During the calculation of CGDD, only positive values of GDD were added from the successive Julian days, while the negative values of GDD were replaced by value zero. During the field work of this study, phenological stages observed were recorded with respect to Julian days. So, in the initial stage CGDD were calculated for each individual day in a year and then CGDD were attributed to each phenological stage based on the Julian day in which phenological stage was observed.

Although Wistedt (2016) used maximum temperature (TAX) and mean temperature (TAM), to find out the relationship of temperature with phenological development, this study uses CGDD instead of TAX and TAM. CGDD are more precise than Julian days to predict about the phenological development and can be used for the phenological study of plants (Miller et al., 2001).

Table 2: Calculation of temperature difference from the weather station (93 m) according to lapse rate.

Farm	Apple cultivar	Altitude (m)	Temperature difference according to lapse rate (0.65 ^{0}C/100 m)
Liagrend	Red Aroma	105	-0.08 ^{0}C
	Summerred	108	-0.10 ^{0}C
	Discovery	99	-0.04 ^{0}C
Nyhus	Red Aroma	53	+0.26 ^{0}C
	Summerred	87	+0.04 ^{0}C
	Discovery	37	+0.36 ^{0}C
Årnes	Red Aroma	40	+0.34 ^{0}C
	Summerred	40	+0.34 ^{0}C
	Discovery	39	+0.35 ^{0}C

2.4 Statistical analysis

Microsoft Excel 2007, Statistical Package for the Social Sciences (SPSS) and R were used for statistical analysis. These tools were employed to present data graphically as well as to conduct statistical tests. Spearman's rank correlation was used to know about the relationship between phenological development and CGDD. Wilcoxon signed ranks test was used to know about variation in phenological development of apple cultivars in 2015 and 2016 with respect to CGDD. In the same way, Wilcoxon signed ranks test was used to find variation in phenological development within apple cultivars and farms in 2016. CGDD and monthly mean temperature of two years i.e. 2015 and 2016 were compared with the help of a paired sample t-test. For all the statistical tests, a confidence interval of 95% was taken.

3. RESULTS

3.1 Phenological development in 2016

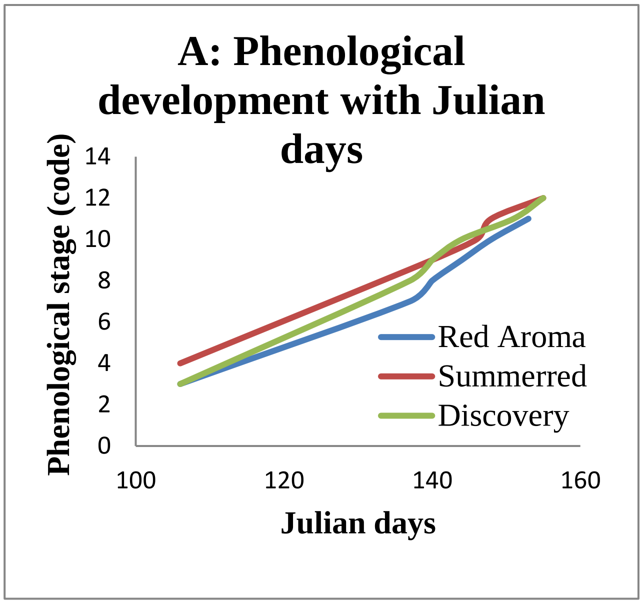
3.1.1 Liagrend

While observing the phenological development in apple cultivars at Liagrend, it is clear that different temperatures are required by cultivars to gain various phenological stages. Among three apple cultivars, Red Aroma and Discovery require almost the same CGDD to reach the green top stage whereas with the similar CGDD Summerred can reach the mouse ear stage. Moving from green top stage to fruit diameter (10 mm) stage, Discovery starts its initial development together with Red Aroma but later on, its phenological development is similar to Summerred (Table 3).

Table 3: Phenological development of apple cultivars at Liagrend with respective Julian days and Cumulative Growing Degree Days (CGDD).

Phenological stage	Red Aroma		Summerred		Discovery	
	Julian Days	CGDD (^{0}C)	Julian Days	CGDD (^{0}C)	Julian Days	CGDD (^{0}C)
Green top	106	44.84			106	45.92
Mouse ear			106	44.30		
Balloon stage	137	160.44				
Central bloom open	140	185.75			137	162.53
Full bloom	144	215.23	140	184.65	140	187.96
Pollination	148	259.06	146	233.10	144	217.6
Fading	153	320.11	148	257.80	151	293.07
Fruit diameter (10 mm)			155	346.90	155	351.11

Although phenological development (green top stage) of Red Aroma starts together with Discovery, later they never coincide. In contrast to that, the phenological development of Discovery and Summerred coincides several times while moving from the green top stage to the fruit diameter (10 mm) stage (Fig. 9).



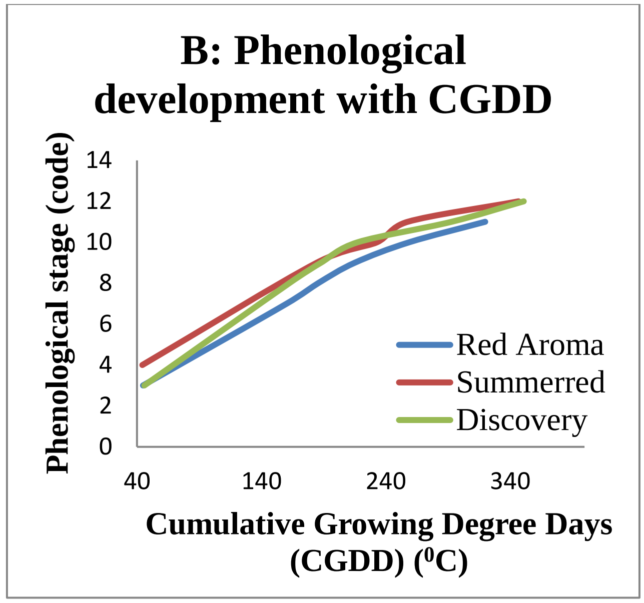


Figure 9: Phenological development of three apple cultivars at Liagrend (A), (B).

3.1.2 Nyhus

At Nyhus farm, phenological development of Summerred and Discovery is relatively similar when compared with Red Aroma (Table 4). As seen at Liagrend farm, Red Aroma requires more CGDD and uses more Julian days than Summerred and Discovery to reach all the phenological stages from green top stage to fruit diameter (10 mm) stage at this farm.

Table 4: Phenological development of apple cultivars at Nyhus with respective Julian days and Cumulative Growing Degree Days (CGDD).

Phenological stage	Red Aroma		Summerred		Discovery	
	Julian Days	CGDD (^{0}C)	Julian Days	CGDD (^{0}C)	Julian Days	CGDD (^{0}C)
Green top						
Mouse ear			106	48.08	106	56.78
Balloon stage	137	178.49				
Central bloom open	140	204.82			137	183.95
Full bloom	144	235.66	140	192.44	140	210.58
Pollination	148	280.85	144	222.40	144	241.82
Fading	155	372.47	148	266.71	148	287.41
Fruit diameter (10 mm)			155	356.79	155	379.73

While moving from green top stage to fruit diameter (10 mm), phenological development of Summerred sometimes overlaps with phenological development of Discovery, but the phenological development of Red Aroma never coincides with the phenological development of other two apple cultivars (Fig. 10).

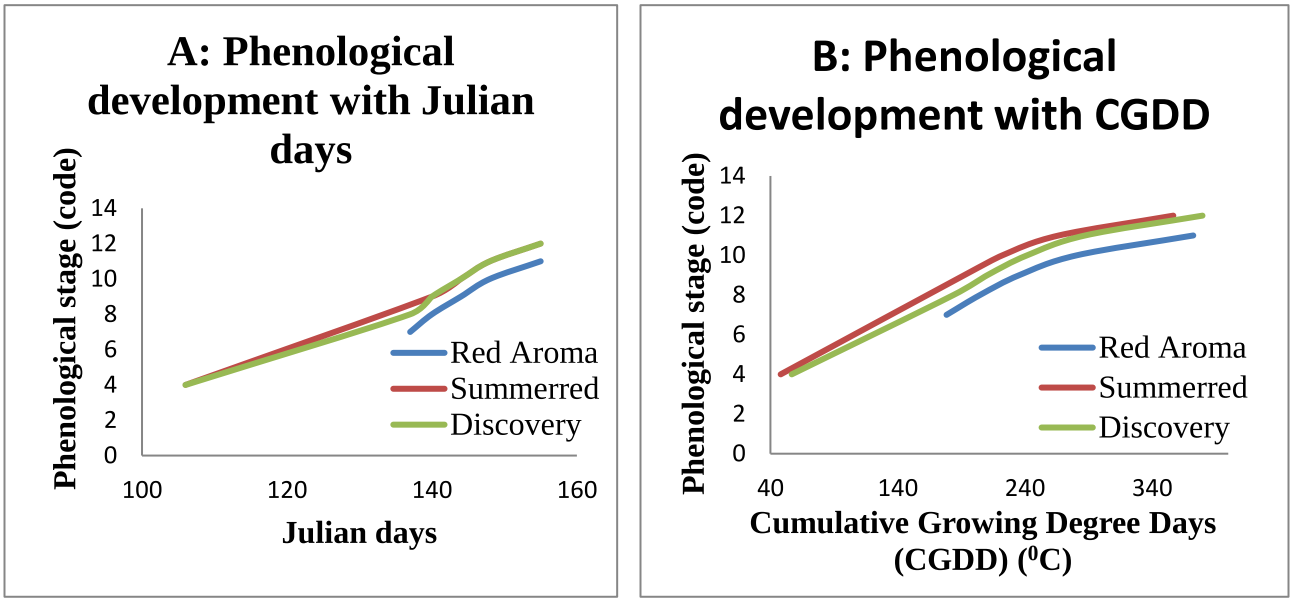


Figure 10: Phenological development of three apple cultivars at Nyhus (A), (B).

3.1.3 Årnes

All three apple cultivars at Årnes use CGDD and Julian days to reach a particular phenological stage. Looking at each case, Summerred and Discovery have significant similarities while developing from green top stage to fruit diameter (10 mm) stage in comparison to Red Aroma (Table 5).

Table 5: Phenological development of apple cultivars at Årnes with respective Julian days and Cumulative Growing Degree Days (CGDD).

Phenological stage	Red Aroma		Summerred		Discovery	
	Julian Days	CGDD (^{0}C)	Julian Days	CGDD (^{0}C)	Julian Days	CGDD (^{0}C)
Green top	106	56.22				
Mouse ear			106	56.22	106	56.50
Balloon stage	137	182.85				
Central bloom open	140	209.42			140	210.00
Full bloom	144	240.58	140	209.42	144	241.20
Pollination	148	286.09	146	260.51	146	261.15
Fading	155	378.27	151	318.71	151	319.40
Fruit diameter (10mm)			155	378.27	155	379.00

At Årnes, Summerred and Discovery start mouse ear stage together using almost same CGDD and same Julian days and this can be seen while reaching fruit diameter (10 mm) stage too although some inter-lying stage in between these two stages were attained in various days using different CGDD. In addition to this, phenological development process of Red Aroma coincides with development of Discovery at some point (Fig. 11), in contrast to the results at Nyhuus farm.

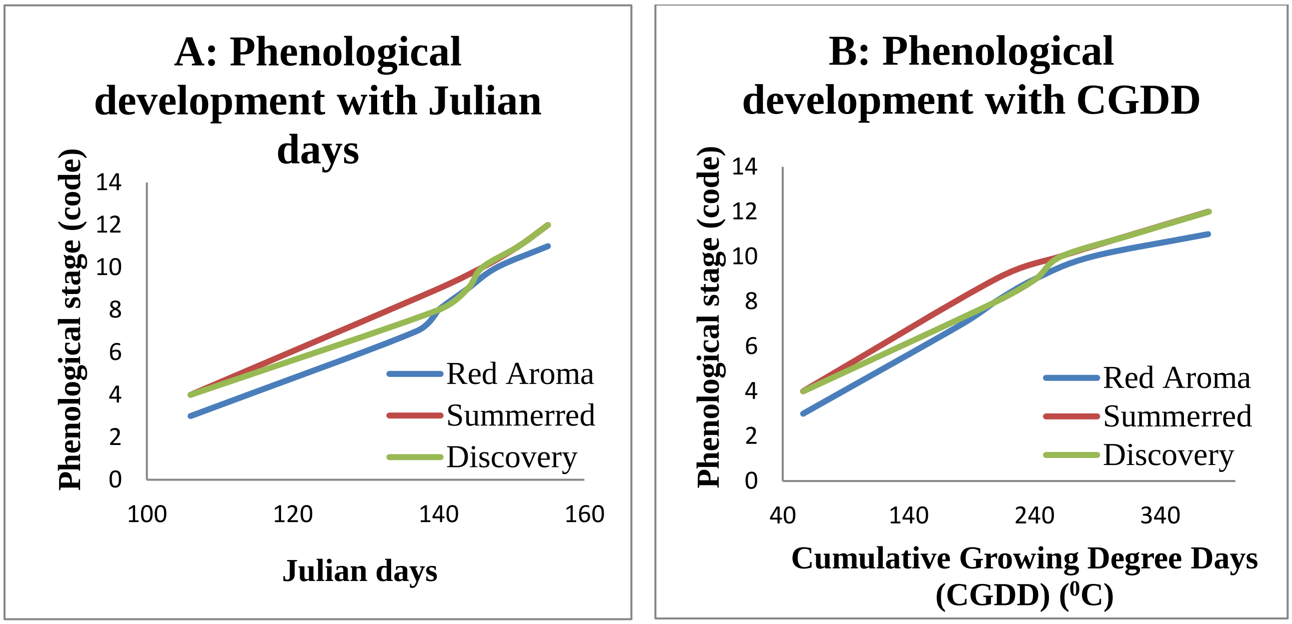


Figure 11: Phenological development of three apple cultivars at Årnes (A), (B).

3.1.4 Relationship between phenological development and CGDD

To know the relationship between phenological development and CGDD, Spearman's rank correlation test was conducted (Annex I) and the result from this test gives, a p-value of less than 0.05 in each individual case. This helps to conclude that, as expected, the phenological development of apple cultivars have a relationship with CGDD i.e. phenological development depends on CGDD. It looks natural that, with the increase in CGDD phenological development will be moving from lower stage to higher stage but the Spearman's rank correlation coefficient of positive one in each individual case provides basis to say certain degree rise in CGDD has an equivalent proportion of development in phenology too. Hence, we reject H_1 in this case i.e. phenological development has a strong positive relationship with CGDD.

3.1.5 Variation of phenological development within apple cultivars and farms

As discussed in 3.1.4, the phenological development of apple cultivars depends on temperature, but to know, if all the apple cultivars have the same trend of the phenological development, the Wilcoxon signed rank test was conducted (Annex IV). We find that, the phenological development of Red Aroma is statistically late by ca. 4 days from the Summerred and ca. 3.5 days from Discovery (Table 6). However, the phenological development of Summerred is not significantly different from the phenological development of Discovery. The p-value of more than 0.05 in the case of Summerred and Discovery helps to say, they do not have difference in phenological development (Annex IV).

Table 6: Mean Julian day of phenological development calculated for; (I) apple cultivars and (II) farms [using phenological stage from full bloom to fading].

			Mean Julian day
I	**Apple cultivars**	Red Aroma	148.78
		Summerred	144.78
		Discovery	145.33
II	**Farms**	Liagrend	146.00
		Nyhus	145.67
		Årnes	147.22

In addition to this, a Wilcoxon signed rank test was performed to know about the variation in phenological development within farms (Annex IV). The result for the farms shows that, phenological development at Årnes is late by ca. 1.55 days from the phenological development at Nyhus (Table 6). However, the timing of phenological development at Liagrend is not statistically different from the phenological development at Nyhus and Årnes (Annex IV).

3.2 Phenological development in 2015 compared to 2016

Another aim of this study is to find variation in year to year phenological development. To gain this objective, phenological data from 2015 and 2016 were used, but the phenological data from 2015 includes the phenological stage from green top to fruit diameter (30 mm), whereas phenological data from 2016 includes phenological stage from green top to fruit diameter (10 mm).

3.2.1 Liagrend

At the Liagrend farm, the phenological development of apple cultivars in one year differs from the next year, but at some point, phenological development of one-year overlaps with the phenological development of the next year. In the case of Red Aroma in 2016, phenological development looks to be forward at green top stage and fruit diameter (10 mm) stage but during the phenological development in between these two stages, phenological development in 2015 moves ahead with less Julian days. Phenological development of Summerred is a bit similar to Discovery at this farm. In both the apple cultivars, the phenological development in 2016 is slower at initial phase of development but later on phenological development in 2016 moves ahead of 2015 (Fig. 12).

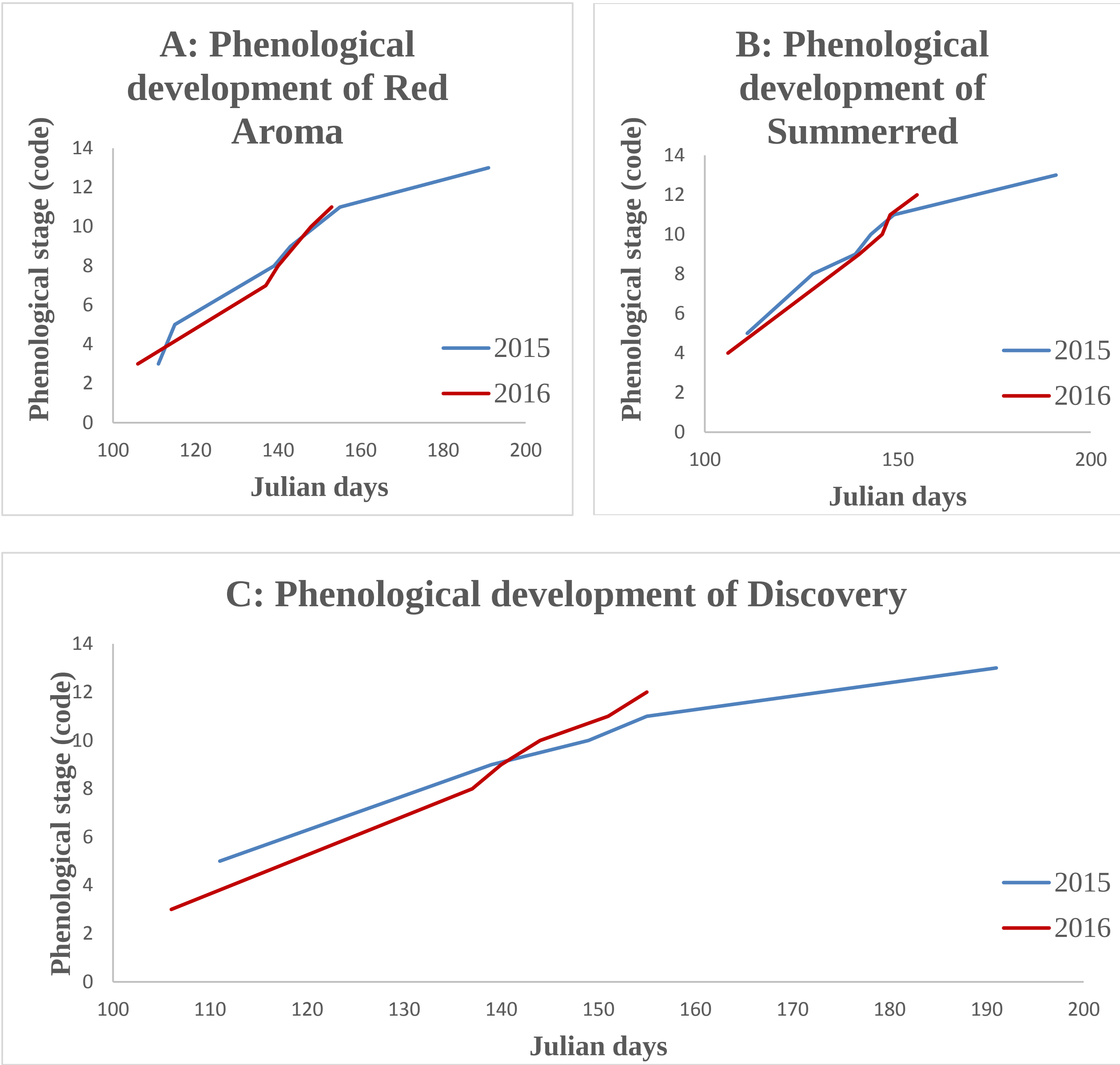


Figure 12: Phenological development of three apple cultivars at Liagrend in 2015 and 2016 with Julian day (A), (B), (C).

3.2.2 Nyhus

Red Aroma at this farm in 2016 reached the fruit diameter (10 mm) stage earlier than in 2015, although the phenological development in 2016 is late before this stage in 2015. Furthermore, the phenological development of Summerred and Discovery at this farm is different from the previous farm as most of the time phenological development in 2015 overlaps with the phenological development in 2016 (Fig. 13). One thing is similar in all the apple cultivars at this farm i.e. phenological development in 2016 is late at the initial stage but later on, it moves ahead of the phenological development in 2015.

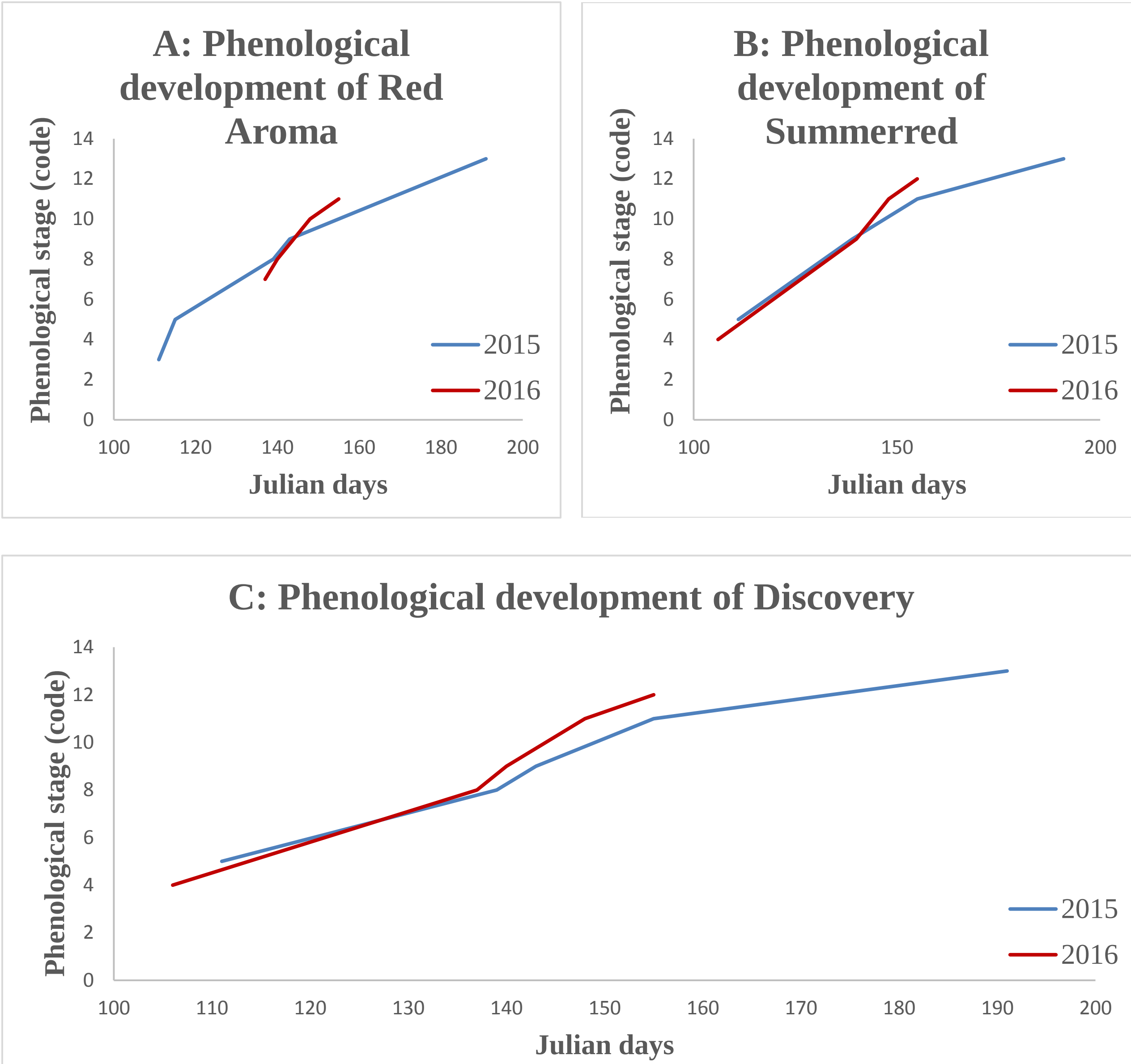


Figure 13: Phenological development of three apple cultivars at Nyhus in 2015 and 2016 with Julian day (A), (B), (C).

3.2.3 Årnes

Phenological development of Red Aroma at Årnes is almost similar to the phenological development of Red Aroma at Liagrend. In addition to this, phenological development of Summerred in 2016 at this farm reached the fruit diameter (10 mm) stage earlier than in 2015, whereas the phenological stages before fruit diameter (10 mm) stage in 2016 are late in compared to 2015. Phenological development of Discovery in 2015 does not completely overlap with the phenological development in 2016, although phenological development of Discovery in both the years 2015 and 2016 seems to move almost together before the full bloom stage. After full bloom stage, the phenological development in 2016 moves faster than in 2015 (Fig. 14).

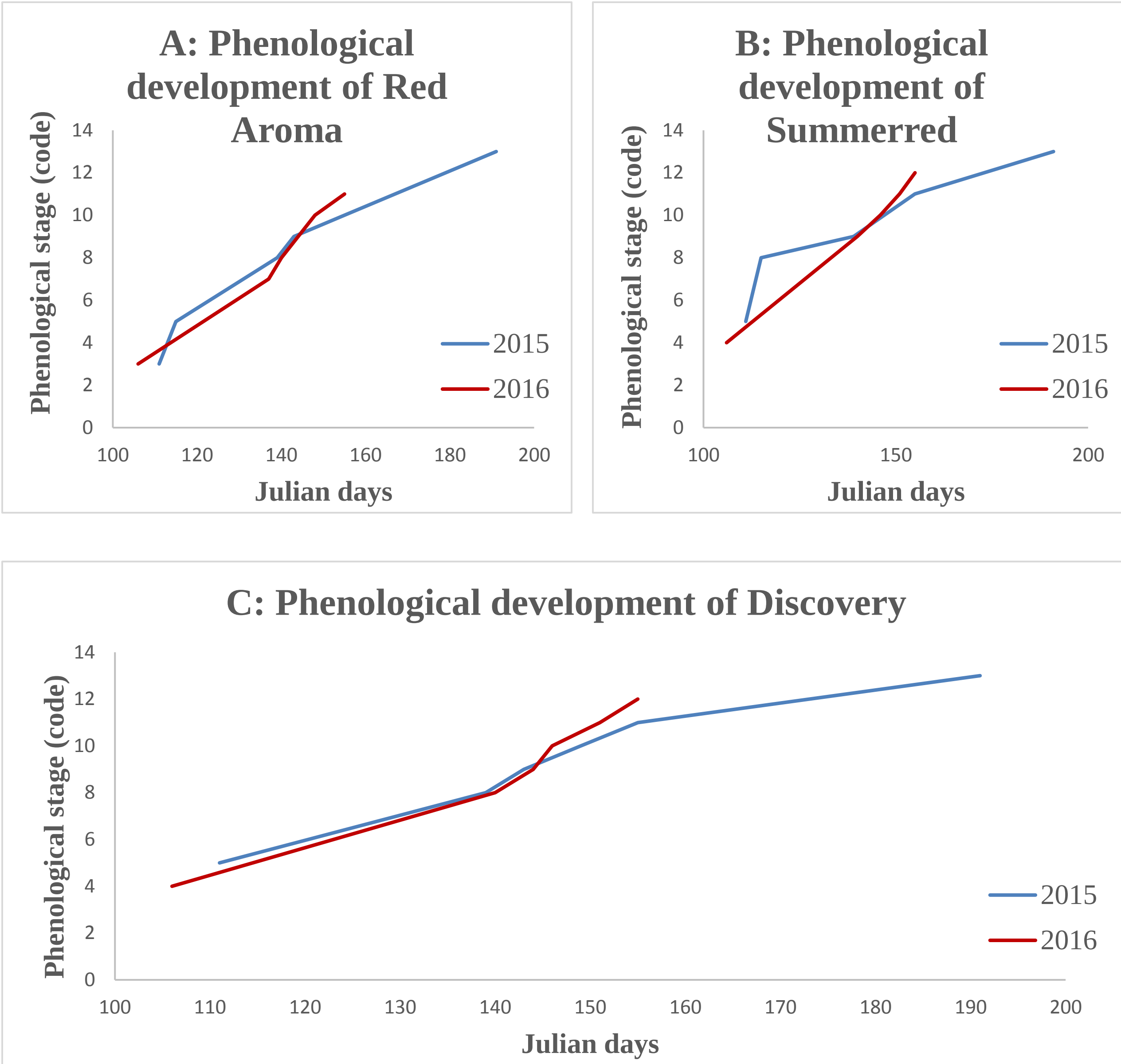


Figure 14: Phenological development of three apple cultivars at Årnes in 2015 and 2016 with Julian day (A), (B), (C).

3.2.4 Variation of phenological development in 2015 compared to 2016

To know the variation of phenological development in 2015 with respect to 2016, a Wilcoxon signed rank test was carried out (Annex V). The result of the statistical test gives a p-value of less than 0.05 only for variation in Discovery but the p-values for other two apple cultivars as well as farms are greater than 0.05. In this situation it can be said that, phenological development of Discovery in 2015 varies from phenological development of Discovery in 2016, whereas the phenological development in the other two apple cultivars and farms do not differ statistically. The phenological development of Discovery in 2016 differs from the phenological development of Discovery in 2015 by ca. 3.23 days (Table 7).

Table 7: Mean Julian day of phenological development calculated for; (I) apple cultivars and (II) Farms in the year 2015 and 2016 [using phenological stage from full bloom to fading].

			Mean Julian day	
			2015	**2016**
I	Apple cultivars	Red Aroma	149.00	146.83
		Summerred	145.57	144.71
		Discovery	148.56	145.33
II	Farms	Liagrend	146.50	146.25
		Nyhus	148.43	145.57
		Årnes	148.43	146.86

Calculated values in Table 7 for mean Julian days are different from the values in Table 6 and it has the reason behind it;

While making calculation in Table 7, only the data were taken for phenological stage that were observed in both the years 2015 and 2016, (i.e. if a particular phenological stage is observed in only one year instead of both, that phenological stage was not used for calculation).

3.3 Study of CGDD and monthly mean temperature in the year 2015 and 2016

3.3.1 Variation of CGDD in the year 2015 with 2016

Beyond the phenological development, this study tries to investigate the variation in CGDD of two consecutive years i.e. 2015 and 2016. For the study of CGDD during phenological development in apple cultivars, the temperature from January first (Julian day = 1) to July 10 (Julian day = 191) was used.

At all three farms, CGDD move in a mixed way before Julian day 130 (approximately) i.e. sometimes CGDD in 2015 is greater than 2016 in the certain period of Julian days and vice versa but after Julian day 130 (approximately), CGDD of 2016 starts to be greater than CGDD of 2015. Along with this, CGDD of 2016 remains greater than CGDD of 2015 at all three farms while reaching to Julian day 191 (Fig. 15). In a similar way as in Fig. 15, at all three farms for each apple cultivars, CGDD moves in a same way with some degree of difference based on Table 2.

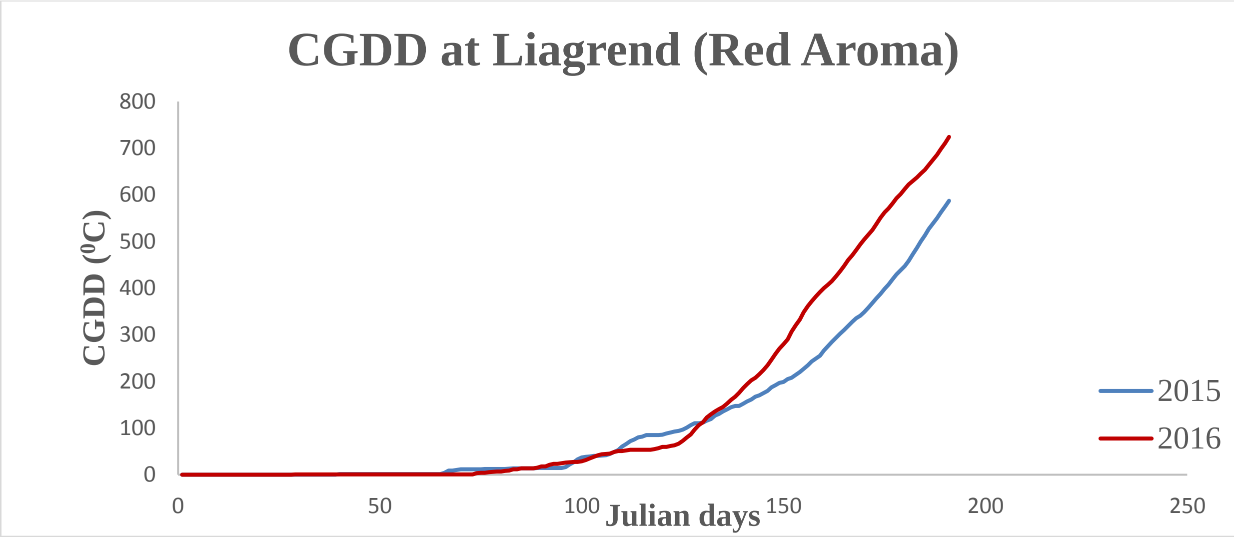


Figure 15: Cumulative growing degree days (CGDD) with Julian day at Liagrend (Red Aroma).

To find out, if some variation exists in between CGDD of two consecutive years, a paired sample t-test was used (Appendix VI) and the result of the test gives, p-values of less than 0.05. This helps to conclude that, CGDD of 2015 are different from CGDD of 2016. Hence, H_3 is rejected i.e. CGDD of the year 2015 is different from the year 2016. On average, CGDD in 2015 are less by 30.89 ^{0}C than CGDD in 2016 while moving from Julian day 1 to Julian day 191 (Table 8).

Table 8: Mean CGDD at three farms (from Julian day 1 to Julian day 191) for different apple cultivars (Red Aroma, Summerred and Discovery) in the year 2015 and 2016.

Farm	**Apple cultivar**	**Mean CGDD**	
		2015	2016
Liagrend	Red Aroma	110.92	141.85
	Summerred	110.31	141.22
	Discovery	112.15	143.10
Nyhus	Red Aroma	121.73	152.65
	Summerred	114.61	145.64
	Discovery	125.07	155.89
Årnes	Red Aroma	124.41	155.25
	Summerred	124.41	155.25
	Discovery	124.74	155.57
Average		118.71	149.60

3.3.2 Variation of monthly mean temperature in the year 2015 and 2016

In addition to CGDD, a comparative study was made to know about the variation in monthly mean temperature from the years 2015 and 2016 at GVARV-NES station. Monthly mean temperatures in 2016 had greater fluctuations than the monthly mean temperatures in 2015 (Fig. 16). In 2015, January have monthly mean temperature of ca. 0 ^{0}C and this continues to rise till

July, but after July monthly mean temperature starts to fall and in December, it reaches to 1.4 ^{0}C (Annex X). In contrast to 2015, 2016 has January with monthly mean temperature of -5.2 ^{0}C that continuously grows till June and after July, monthly mean temperature starts to decline and reaches to ca. 0 ^{0}C in December (Annex X). While observing monthly mean temperature collectively from both the years 2015 and 2016, temperature from mid-April to July (i.e. spring) is higher in 2016 than 2015. This high monthly mean temperature during the spring in 2016 compared to 2015 is reflected through CGDD values from Julian day 130 onwards (Fig. 15). Along with this, monthly mean temperature of 2015 and 2016 was compared with the average monthly mean temperature (approximate) from the period of 1961-1990.

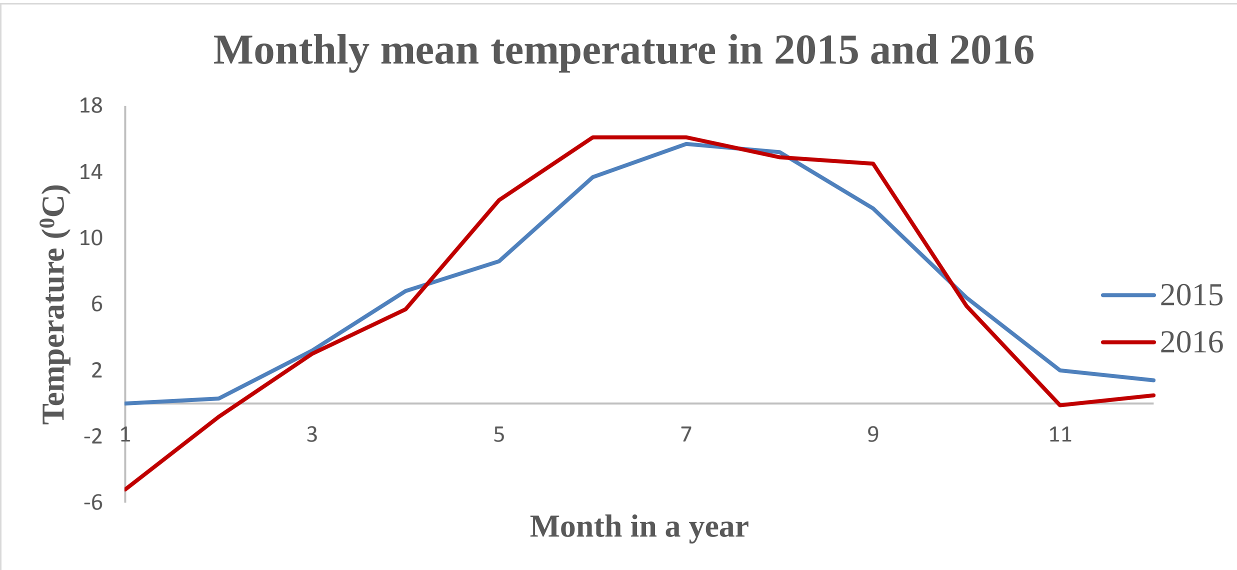


Figure 16: Variation of monthly mean temperature in 2015 and 2016.

To know the variation in monthly mean temperature paired sample t-test was conducted. Paired sample t-test gives a p-value of 0.793 while looking for the variation of phenological development in 2015 and 2016. The p-value of 0.793 is greater than 0.05 and helps to conclude, monthly mean temperature of 2015 is not statistically different from the monthly mean temperature of 2016. Along with this, paired t-test gives a p-values of 0.134 and 0.031 respectively for the year 2016 and 2015, while studying variation with monthly mean temperature from the period of 1961-1990. These p-values are also greater than 0.05 and helps to conclude, monthly mean temperatures of 2015 and 2016 are not statistically different from monthly mean temperature from the period of 1961-1990.

4. DISCUSSION

4.1 Phenological development in relation to CGDD (temperature) in 2016

Temperature controls the growth of plants and plays an important role for their phenological development (Medel et al., 2012; Saxe et al., 2001). Nordli et al. (2008) mentions that particularly the early phenological development in plants is strongly correlated with temperature. Instead of using temperature, we used CGDD to study the relationship between phenological development and temperature. CGDD or heat sum is the sum of average daily temperature above a certain threshold temperature (Ghelardini et al., 2006; Hunter & Lechowicz, 1992). The dependency of phenological development on temperature can be seen in this study too, i.e. CGDD has a strong positive correlation with the phenological development in the stage green top to the fruit diameter (10 mm) stage (Annex I). In a similar way, Wistedt (2016) in Sauherad using the same apple trees i.e. sample tress, as in our study finds a linear relationship between temperature and phenological development while phenological development proceeds from green top stage to fruit diameter (>20 mm). In addition to this, our study shows that, plants need a specific CGDD to reach a particular phenological stage. Miller et al. (2001) also mention that plants require a certain temperature to move from one phenological stage to the next phenological stage. This makes CGDD useful to know about phenological development and Miller et al. (2001) mention CGDD is more helpful than Julian days to predict about phenological development.

Although, CGDD plays an important role in the phenological development of all considered three apple cultivars, the trend of phenological growth in these three apple cultivars are not similar in our study. Red Aroma is comparatively late in phenological development with respect to Summerred and Discovery at all three farms in 2016, i.e. Summerred and Discovery can gain a phenological stage of a higher level than Red Aroma utilizing the same CGDD (Table 6). Wistedt (2016) also shows phenological development of Red Aroma is late compared to Summerred and Discovery in Sauherad in 2015. Along with this, a study by Casique (2015) at Ås in Norway, classifies Red Aroma, Discovery and Summerred as late flowering, mid-season flowering and early flowering respectively. Concluding all the studies together, it can be said that Red Aroma is late in phenological development compared to Summerred and Discovery. However, our study does not show significant difference in phenological development of Summerred compared to Discovery. Our study shows that, in the year 2016 phenological development of Red Aroma is late by ca. 4 and 3.5 days compared to Summerred and Discovery, respectively (Table 6). Beyond the CGDD, Julian days have also a strong positive relationship with phenological development (Annex II). The reason behind this strong positive relationship between CGDD and phenological development as well as Julian days and phenological development is a strong positive relationship between Julian days and CGDD (Annex III).

Our study shows that the, phenological development of apple cultivars at Årnes farm located at low altitude is statistically late by ca. 1.55 days relative to the Nyhus farm located relatively at higher altitude in the year 2016. This contrasts with, a study by Nordli et al. (2008) that shows for the period of 1965-2005, the deciduous trees with same genotype planted in different part of Norway, plants at lower altitude have earlier phenological development. Altitude is not only a sole reason to decide phenological development, as shown by Oteros et al. (2013), who found that local olive phenology in Spain depends on orientation of farm, precipitation and air temperature. So, the reason behind late phenological development at Årnes can be various environmental factors beyond altitude. However, the phenological development of apple cultivars at Liagrend is not significantly different from Nyhus and Årnes (Annex IV).

4.2 Variation in phenological development, CGDD and monthly mean temperature

Our study shows that phenological development in 2015 does not differ statistically from the phenological development in 2016 while looking at the holistic development of all three apple cultivars in Sauherad. However, Wolfe et al. (2005) claim that phenological development has been shifting in the recent time period. Though, in the individual case, phenological development of Discovery in 2015 is late by ca. 3.23 days compared to the year 2016, while remaining the same in Red Aroma and Summerred. Our study has data from only two years and it is difficult to analyze precisely the variation in phenological development using data from very short period of time. So, our study is unable to build concretely an idea about variation in phenological development. Along with this, Nordli et al. (2008) says that, it is easy to observe variations of phenological development in long time series data i.e. it is good to have data from multiple years to get a clue regarding differences in phenological development.

In addition to variation in phenological development, our study tries to look for differences in CGDD in between the year 2015 and 2016. The result of the study shows that, the CGDD of 2015 differs from the CGDD of 2016 (Annex VI). While looking at the CGDD from Julian day 1 to Julian day 191, Julian day in 2016 has 30.89 ^{0}C more in average than compared to Julian day in 2015 (Table 8). At the same time, monthly mean temperatures from mid-April to July in 2016 are greater than in 2015 (Fig. 16). However, looking at the entire year, the monthly mean temperatures remain the same in both the year 2015 and 2016 (p-value > 0.05). In the same way Karmeshu (2012) in USA also shows that the, temperature of one year may not significantly differ from another year due to internal variability in the climate system. So, it is not always obvious that temperature in one year varies from the next year.

Although, this study shows similar temperatures in two consecutive years 2015 and 2016, a decadal change in temperature can be seen. The IPCC (2007a) shows that, global temperature has been rising in recent decades and these temperatures have increased by 0.55 ^{0}C after 1970. Along with the IPCC, some other studies also support the idea of an increase in global temperature (Fig. 17) and in the similar way increasing trend of temperature can be seen in whole Europe during the late 20th and early21st century compared to the temperature of past 1500 years of time (Luterbacher et al., 2004). The trend of increasing temperature can be seen in Norway too. Based on the global future projections for the increase in temperature made by the

IPCC, Hanssen-Bauer et al. (2017) also makes a projection for temperature rise in Norway and different counties within Norway. Fig. 18 shows the increasing trend of temperature in Telemark county, since 1900 to 2015 and along with this, it presents a projection of temperature in the near future also. All these scenarios make clear that, temperature is following an increasing trend.

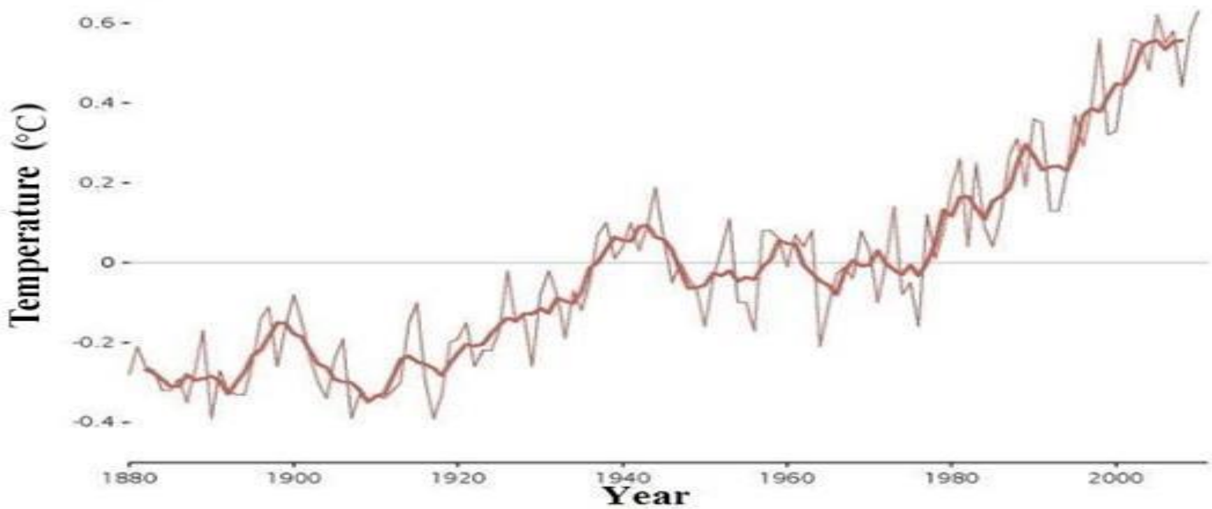


Figure 17: Temperature change in the recent decades globally, thin line in the figure represents annual data and thick line represents the line for mean from five years data (Source: (NASA, 2011)).

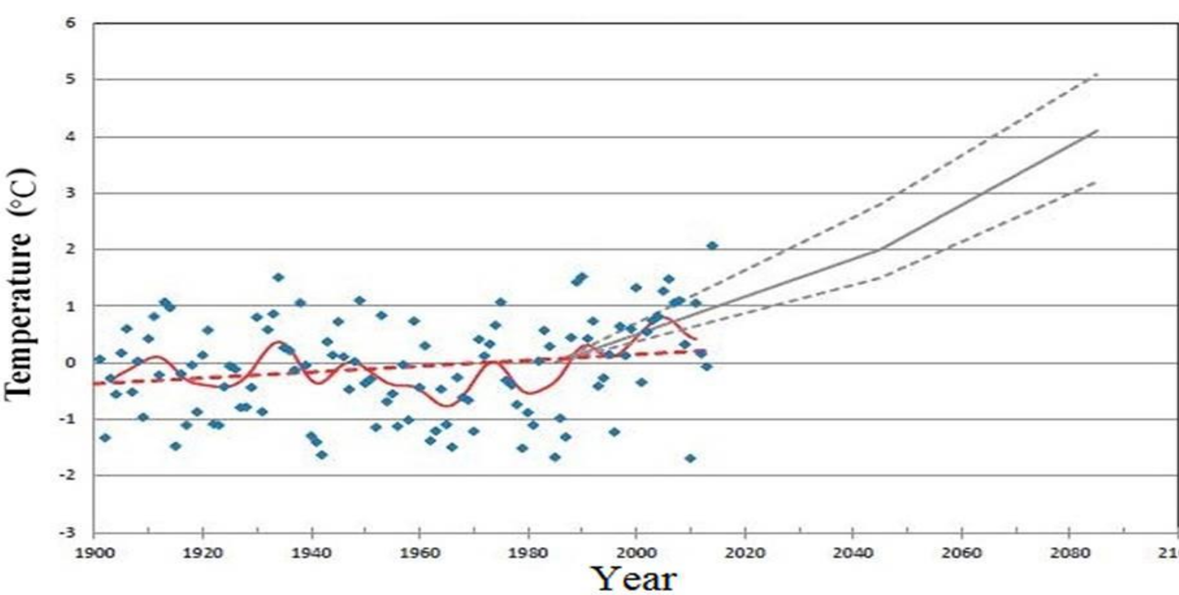


Figure 18: Deviation of annual temperature from 1900 to around 2015 and future projection of rise in temperature at Telemark county (Source: (Klimaservicesenter, 2016)).

4.3 Phenological development of apple and CC

CC causes variation in phenological development (Cleland et al., 2007) and sometimes global CC can bring devastating situations in agricultural sector through great economic loss to farmers (Garbrecht & Schneider, 2005). A study by Darbyshire et al. (2017) consisting of 14 different sites shows apple has different flowering times based on winter and spring temperature. However, phenological development depends on apple cultivars too (Petri et al., 2012). Still, apple phenology differs from one place to next on the entire globe. Phenological development is shifting earlier in many parts of the world. In a similar way, earlier shifts of phenological development can be seen in Europe too (Eccel et al., 2009; Guedon & Legave, 2008).

Along with phenological development, CC plays an important role for the productivity of apples. Many countries with a temperate climate for apple farming are facing problems with the increase in temperature as it causes reduced time for chilling as well as unusual water availability. Chilling is a time duration below certain temperature required by apple trees to come out of dormancy and it plays an important role for bud break (Gardea et al., 2000; Young, 1992). These effects of CC have caused a decrease in apple production in countries like, India (Singh et al., 2016), Pakistan (Asghar et al., 2012) and United States of America (Wang et al., 2017). Regarding Europe, increases in temperature has some positive impacts along with negative (Olesen et al., 2011) and basically in northern Europe apple cultivation land gets expanded (Olesen & Bindi, 2002) but some of the countries like Bulgaria, Romania, Serbia and few more countries get adversely affected by CC (Olesen et al., 2011). Although, Europe has some positive impacts of CC, its overall consequences has negative impacts in Europe (Olesen et al., 2011).

Poland produces the largest amount of apples within Europe (Lemanowicz & Krukowski, 2009), and a study by Wypych et al. (2017) in Poland predicts that inconsistency in temperature increases frequency of spring frost in apple. Along with Poland, apple cultivation in other European countries are also tackling with impacts of CC and it is one of the important issues in Europe. Moreover, Olesen et al. (2011) shows that farmers in Europe have started to use suitable cultivars and bring change in cultivation time to cope with effects of CC. According to Rai et al. (2015) and Manandhar et al. (2014), apple is shifting its range of distribution towards higher elevation and altitude in response to rising temperatures. Shifting of the range that creates a favorable environment for apple growth will certainly increase the area suitable for apple cultivation in Norway. The area of apple cultivation in Norway have increased in the present decade (Statista, 2018a) and this evidence also supports the idea of an increase in the area for apple cultivation.

4.4 Apple phenology in Sauherad

The result of this study shows that phenological development in Sauherad in both the years 2015 and 2016 are not statistically different from each other when considering all data from the three cultivars together. However, in the individual cases the phenological development of Discovery has shifted earlier by ca. 3.23 days in the year 2016 compared to 2015 (Table 7). In addition to this, CGDD of the year 2015 statistically varies from CGDD of 2016 in Sauherad at all three farms for each apple cultivar (Table 8). When considering the situation of CGDD and phenological development together, we see that although CGDD varies, the phenological development remains the same. Based on this result, our study concludes that various environmental factors such as, soil, precipitation and altitude along with the temperature play a role to alter phenological development in Sauherad. In the similar way, Cole and Sheldon (2017) also mention that different environmental factors like soil type and altitude play an important role to determine phenological development of deciduous trees beyond the temperature.

However, earlier shift of phenological development in the year 2016 compared to 2015 exists at Sauherad for Discovery and this shift in phenological development shows that Discovery responds in a different way to the environmental factors than Red Aroma and Summerred. A study by Massonnet et al. (2007) shows that apple cultivars can respond to a particular environmental component in diverse ways and their research finds two different apple cultivars use water in different quantity due to difference in stomatal structure. As apple cultivars respond in different ways to environmental factors, there exists a probability to have differences in phenological development among apple cultivars too. In our case, Discovery may have responded to environmental factors in a different way than Red Aroma and Summerred. So, Red Aroma and Summerred do not have difference in phenological development between the years 2015 and 2016 but Discovery have difference in phenological development between the years 2015 and 2016.

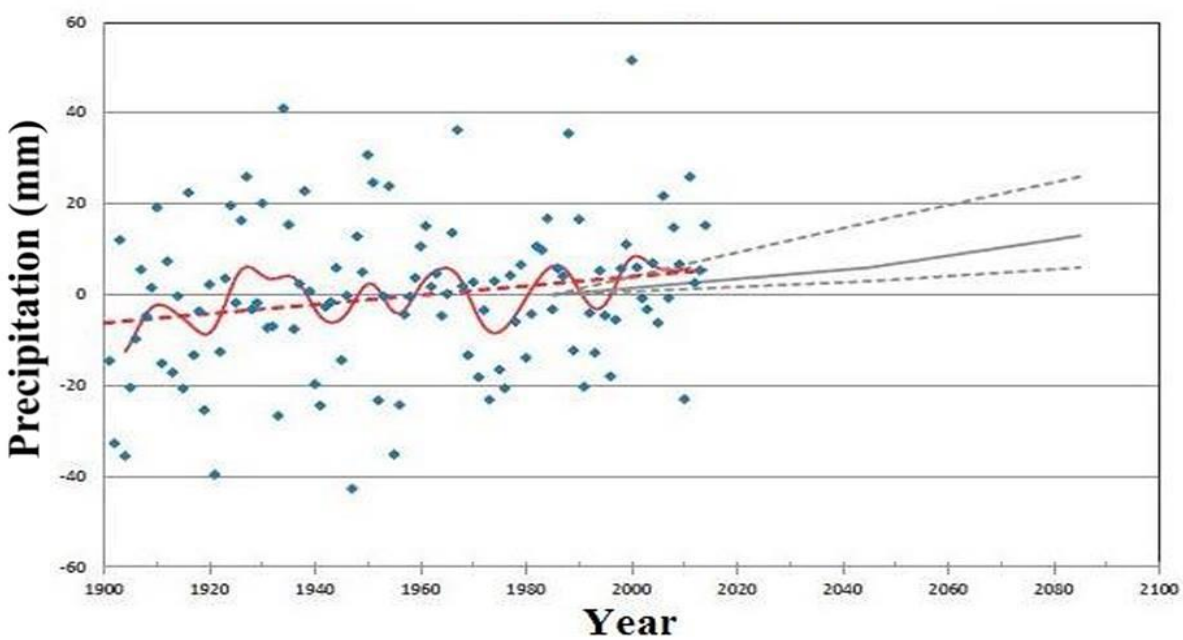


Figure 19: Deviation of annual precipitation (%) from 1900 to around 2015 and future projection of rise in precipitation at Telemark county (Source: (Klimaservicesenter, 2016)).

Environmental factors are changing at a global level as well as a local level. In the case of Sauherad municipality (Telemark county) also several environmental factors are changing. According to Klimaservicesenter (2016), at the end of 21st century environmental factors in Telemark county will have several changes such as; rise in annual temperature by ca. 4 ^{0}C, increase in growing season length by 1-3 months, along with the rise in precipitation by ca. 15 % and change in the duration of snow cover. As annual temperature is going to rise in Sauherad area, it can have negative consequences for apple cultivars that require a long chilling period and possibly apple cultivars growing well at present may not be useful after few decades. In addition to this, Fig. 18 and Fig. 19 help to visualize the situation of temperature and rainfall in coming years. All these facts show that, environmental parameters will be continuously changing in coming year. So, the phenological development of apples is expected to have some fluctuations in the near future in Sauherad in response to environmental factors. Moreover, a study by Rivero et al. (2017) shows that apple phenology has shifted earlier in southern part of Norway in response to temperature.

5. CONCLUSIONS

This study deals with the phenological development of three apple cultivars (Red Aroma, Summerred and Discovery) and CGDD in Sauherad municipality in southern part of Norway and adds knowledge about year to year phenological development in relation to temperature.

This study shows that, CGDD plays an important role for the phenological development of all three apple cultivars at three different farms (Liagrend, Nyhus and Årnes) in the year 2016. However, the study shows that phenological development of Red Aroma is late compared to Summerred and Discovery by ca. 4 and 3.5 days respectively. Along with the variation in phenological development of apple cultivars, phenological development varies among farms also. Årnes farm is late by ca. 1.55 days in phenological development compared to Nyhus. Though, phenological development at Liagrend farm is not statistically different from Nyhus and Årnes farm.

The next finding of this research confirms that phenological development of Discovery in 2015 differs from 2016, but in the case of the other two apple cultivars and three farms, phenological development in 2015 does not differ statistically from 2016. Based in this study, phenological development of Discovery in 2015 is ca. 3.23 days late than phenological development of Discovery in 2016.

Another important query of this research is to know about changes in CGDD and monthly mean temperature. This study suggests CGDD of 2015 differs from the CGDD of 2016 in the period of Julian day 1 to Julian day 191 (i.e. mid July), whereas on an annual basis, the monthly mean temperature of 2015 do not differ statistically from the monthly mean temperature of 2016. In this situation, it is really hard to say something about the trend of CC in Sauherad, only observing temperature from two consecutive years. At the same time, variations in CGDD provides some clue about changes in temperature and this process on the long-term can bring change in climate.

This study shows that, phenological development of Red Aroma is statistically different from Summerred and Discovery in the year 2016, but further research should be carried out to know about differences between phenological development of Summerred and Discovery too. In addition to this, our study finds that apple cultivars at Liagrend and Nyhus are later in phenological development than apple cultivars at Årnes. This suggests it is important to look at apple production based on the difference in the phenological development at different farms. The detailed information about phenological development of apple cultivars and its production in Sauherad will help farmers in the near future to design their farms for the maximum production of apples. Along with this, to draw conclusions about temperature change, we should try our best to use temperature data from as many years (≥ 30 years) as IPCC recommends. Therefore, a long-term monitoring of apple tree phenological development and CGDD in Sauherad is recommended.

REFERENCES

Asghar, A., Ali, S. M., & Yasmin, A. (2012). Effect of climate change on apple (Malus domestica var. ambri) production: A case study in Kotli Satian, Rawalpindi, Pakistan. *Pakistan Journal of Botany, 44*(6), 1913-1918.

Bairam, E., Sahli, A., & Sahli, H. (2012). Analysing global climatic change and its impact on fruit tree phenology using ClimaTree tool: Example of Anna apple tree under Tunisian conditions. In (pp. 38-42).

Børve, J., Talgø, V., & Stensvand, A. (2015). Apple canker caused by Neonectria ditissima in Norway. *IOBC-WPRS Bulletin, 110*, 105-106.

Britannica, E. (2016). Lapse rate. *Encyclopædia Britannica*.

Cannell, M., & Smith, R. (1986). Climatic warming, spring budburst and forest damage on trees. *Journal of Applied Ecology*, 177-191.

Casique, R. R. (2015). *Phenology and effect of climate on apple cultivars (Malus domestica Borkh.) in Norway.* Norwegian University of Life Sciences, Ås, Retrieved from https://scholar.google.no/scholar?hl=no&as_sdt=0%2C5&q=Phenology+and+effect+of+climate+on+apple+cultivars+%28Malus+domestica+Borkh.%29+in+Norway&btnG=

Chapman, C. A., Chapman, L. J., Struhsaker, T. T., Zanne, A. E., Clark, C. J., & Poulsen, J. R. (2005). A long-term evaluation of fruiting phenology: importance of climate change. *Journal of Tropical ecology, 21*(01), 31-45.

Chen, I.-C., Hill, J. K., Ohlemüller, R., Roy, D. B., & Thomas, C. D. (2011). Rapid range shifts of species associated with high levels of climate warming. *Science, 333*(6045), 1024-1026.

Chuine, I., Bonhomme, M., Legave, J. M., García De Cortázar-Atauri, I., Charrier, G., Lacointe, A., & Améglio, T. (2016). Can phenological models predict tree phenology accurately in the future? The unrevealed hurdle of endodormancy break. *Global Change Biology, 22*(10), 3444-3460. doi:10.1111/gcb.13383

Cleland, E. E., Chiariello, N. R., Loarie, S. R., Mooney, H. A., & Field, C. B. (2006). Diverse responses of phenology to global changes in a grassland ecosystem. *Proceedings of the National Academy of Sciences, 103*(37), 13740-13744.

Cleland, E. E., Chuine, I., Menzel, A., Mooney, H. A., & Schwartz, M. D. (2007). Shifting plant phenology in response to global change. *Trends in Ecology & Evolution, 22*(7), 357-365.

Cole, E. F., & Sheldon, B. C. (2017). The shifting phenological landscape: Within-and between-species variation in leaf emergence in a mixed-deciduous woodland. *Ecology and Evolution, 7*(4), 1135-1147.

Darbyshire, R., Farrera, I., Martinez-Lüscher, J., Leite, G. B., Mathieu, V., El Yaacoubi, A., & Legave, J.-M. (2017). A global evaluation of apple flowering phenology models for climate adaptation. *Agricultural and Forest Meteorology, 240-241*, 67-77.

Devi, C. A. (2016). *Impacts of climate change on important fruit crops of Rosaceae family.* IGKV, Retrieved from https://www.slideshare.net/ChongthamAllaylayDev/impacts-of-climate-change-on-important-fruit-crops-of-rosaceae-family

DiMento, J. F. C., & Doughman, P. (2014). *Climate Change : What It Means for Us, Our Children, and Our Grandchildren* (2nd ed. ed.). Cambridge: The MIT Press.

Eccel, E., Rea, R., Caffarra, A., & Crisci, A. (2009). Risk of spring frost to apple production under future climate scenarios: the role of phenological acclimation. *International Journal of Biometeorology, 53*(3), 273-286.

eklima. (2018a). Free access to weather- and climate data from Norwegian Meteorological Institute from historical data to real time observations. *Growth Degree Days.* Retrieved from http://sharki.oslo.dnmi.no/eklimapub/servlet/ReportInfo?action=paradesc&p=VEKST&la=en&co=US

eklima. (2018b). Free access to weather- and climate data from Norwegian Meteorological Institute from historical data to real time observations. *monthly normal values.* Retrieved from http://sharki.oslo.dnmi.no/pls/portal/BATCH_ORDER.PORTLET_UTIL.Download_Image_BLob?p_BatchId=916103&p_IntervalId=1756178&p_Index=1

Focused, G. (Producer). (2017, 2017.10.31). DISCOVERY APPLE TREE. Retrieved from https://www.gardenfocused.co.uk/fruitarticles/apples/variety-discovery.php

Førland, E. J., & Alfnes, E. (2007). *Climate change and natural disasters in Norway : an assessment of possible future changes*. In Met.no report (online), Vol. no. 06/2007.

Forrest, J., & Miller-Rushing, A. J. (2010). Toward a synthetic understanding of the role of phenology in ecology and evolution. In: The Royal Society.

Fruit, L. O. (Producer). (2013, 2017.10.30). Red Aroma. Retrieved from http://www.laerkehoejfrugt.dk/frugt/aebler/rod-aroma/

Garbrecht, J. D., & Schneider, J. M. (2005). *Variations of annual precipitation and air temperature in Oklahoma, Kannas and Texas 1985-2003*. Retrieved from https://www.ars.usda.gov/ARSUserFiles/30700510/CliVar_Inter.pdf

Gardea, A. A., Carvajal-Millán, E., Orozco, J. A., Guerrero, V. M., & Llamas, J. (2000). Effect of chilling on calorimetric responses of dormant vegetative apple buds. *Thermochimica Acta, 349*(1), 89-94.

Gardener, B. (Producer). (2017, 2017.10.31). Malus Domestica (Summerred Apple). Retrieved from https://www.backyardgardener.com/plantname/malus-domestica-summerred-apple/

Ghelardini, L., Falusi, M., & Santini, A. (2006). Variation in timing of bud-burst of Ulmus minor clones from different geographical origins. *Canadian journal of forest research, 36*(8), 1982-1991.

Gjershaug, J. O. (2009). *Alien species and climate change in Norway : an assessment of the risk of spread due to global warming*. In NINA rapport (online), Vol. 468.

Gjershaug, J. O., Rusch, G., Öberg, S., & Qvenild, M. (2009). Alien species and climate change in Norway: An assessment of the risk of spread due to global warming.

Google. (2018a). Sauherad. Retrieved from https://www.google.no/maps/place/Sauherad/@59.4404221,9.0284913,10z/data=!3m1!4b1!4m5!3m4!1s0x4647344041712267:0x4e4ee63d69733e2f!8m2!3d59.4401979!4d9.3107279

Google. (2018b). Sauherad kommune, Holmenvegen. Retrieved from https://www.google.no/maps/place/Sauherad+kommune/@64.5366248,3.5291392,5z/data=!4m5!3m4!1s0x464749d69b73842b:0x83a9c3c7f617f598!8m2!3d59.38637!4d9.1761116

Gratz, J. (2016, 8 August). Does Elevation Affect Temperature. *ON THE SNOW*.

Guedon, Y., & Legave, J. M. (2008). Analyzing the time-course variation of apple and pear tree dates of flowering stages in the global warming context.(Report). *ecological modelling, 219*(1 2), 189.

Hanssen-Bauer, I., Førland, E. J., Haddeland, I., Hisdal, H., Mayer, S., Nesje, A., . . . Ådlandsvik, B. (2017). *Climate in Norway 2100*. Retrieved from Norway: http://www.miljodirektoratet.no/Documents/publikasjoner/M741/M741.pdf

Herms, D. A. (2004). Using degree-days and plant phenology to predict pest activity. *IPM (integrated pest management) of midwest landscapes*, 49-59.

Höhn, H. (April 2008). Kernobst - Phänologie. Retrieved from http://www.agrometeo.ch/phenologie/stadesarbosa.pdf

Hribar, J., & Vidrih, R. (2015). *Impacts of climate change on fruit physiology and quality.* Paper presented at the Proceedings. 50th Croatian and 10th International Symposium on Agriculture. Opatija. Croatia.

Hunter, A. F., & Lechowicz, M. J. (1992). Predicting the timing of budburst in temperate trees. *Journal of Applied Ecology*, 597-604.

IPCC. (2001). *Working Group I: The Scientific Basis*. Retrieved from http://www.ipcc.ch/ipccreports/tar/wg1/index.php?idp=5
IPCC. (2007a). Climate change 2007: The physical science basis. *Agenda, 6*(07), 333.
IPCC. (2007b). *Projections of Future Changes in Climate*. Retrieved from https://www.ipcc.ch/publications_and_data/ar4/wg1/en/spmsspm-projections-of.html
IPCC. (2007c). *Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Retrieved from
Jackson, J. E. (2003). *The biology of apples and pears*: Cambridge University Press.
Jones, P. G., & Thornton, P. K. (2003). The potential impacts of climate change on maize production in Africa and Latin America in 2055. *Global environmental change, 13*(1), 51-59.
Karmeshu, N. (2012). *Trend detection in annual temperature & precipitation using the Mann Kendall test–a case study to assess climate change on select states in the northeastern United States.*
Kellerhals, M. (2009). Introduction to apple (Malus× domestica). In *Genetics and Genomics of Rosaceae* (pp. 73-84): Springer.
Klimaservicesenter, N. (2016). *Klimaprofil Telemark*. Retrieved from Norway: https://www.fylkesmannen.no/Documents/Dokument%20FMTE/Milj%C3%B8%20og%20klima/Klima/Klimaprofil%20Telemark.pdf
Legave, J., Christen, D., Giovannini, D., & Oger, R. (2008). *Global warming in Europe and its impacts on floral bud phenology in fruit species.* Paper presented at the Workshop on Berry Production in Changing Climate Conditions and Cultivation Systems. COST-Action 863: Euroberry Research: from 838.
Lemanowicz, M., & Krukowski, A. (2009). *Quantitative description of the fruit industry and fruit supply chains in Poland.* Paper presented at the 113th EAAE Seminar "A resilient European food industry and food chain in a challenging world", Greece.
Luterbacher, J., Dietrich, D., Xoplaki, E., Grosjean, M., & Wanner, H. (2004). European seasonal and annual temperature variability, trends, and extremes since 1500. *Science (New York, N.Y.), 303*(5663), 1499.
Manandhar, S., Pandey, V. P., & Kazama, F. (2014). Assessing suitability of apple cultivation under climate change in mountainous regions of western Nepal. *Assessing suitability of apple cultivation under climate change in mountainous regions of western Nepal, 14*(2), 743-756.
Massonnet, C., Costes, E., Rambal, S., Dreyer, E., & Regnard, J. L. (2007). Stomatal Regulation of Photosynthesis in Apple Leaves: Evidence for Different Water-use Strategies between Two Cultivars. *Annals of Botany, 100*(6), 1347-1356.
Medel, G., Medel, F., Huber, A., & McConchie, C. (2012). *Phenological Development and Growing Degree Days in Gevuina avellana Mol.* Paper presented at the VIII International Congress on Hazelnut 1052.
Menéndez, R., Megías, A. G., Hill, J. K., Braschler, B., Willis, S. G., Collingham, Y., . . . Thomas, C. D. (2006). Species richness changes lag behind climate change. *Proceedings of the Royal Society of London B: Biological Sciences, 273*(1593), 1465-1470.
Miller, P., Lanier, W., & Brandt, S. (2001). Using growing degree days to predict plant stages. *Ag/Extension Communications Coordinator, Communications Services, Montana State University-Bozeman, Bozeman, MO*. Retrieved from http://store.msuextension.org/publications/agandnaturalresources/mt200103ag.pdf
Moola, F., & Mallik, A. (1998). Phenology of Vaccinium spp. in a black spruce (Picea mariana) plantation in northwestern Ontario: possible implications for the timing of forest herbicide treatments. *Canadian journal of forest research, 28*(10), 1579-1585.

Morinaga, K. (2018). Food and Fertilizer Technology Center. *Impact of Climate Change on Horticulture Industry and Technological Countermeasures in Japan.* Retrieved from http://www.fftc.agnet.org/library.php?func=view&id=20120104150721

Moritz, C., Patton, J. L., Conroy, C. J., Parra, J. L., White, G. C., & Beissinger, S. R. (2008). Impact of a century of climate change on small-mammal communities in Yosemite National Park, USA. *Science, 322*(5899), 261-264.

NASA. (2011). Despite Subtle Differences, Global Temperature Records in Close Agreement. Retrieved from https://www.nasa.gov/topics/earth/features/2010-climate-records.html

NGU. (2018a). Berggrunn N250 (M 1 : 250 000). Retrieved from http://geo.ngu.no/kart/minkommune/?kommunenr=822

NGU. (2018b). Berggrunn Nasjonal berggrunnsdatabase. Retrieved from http://geo.ngu.no/kart/berggrunn/?lang=Norsk&Box=-214586:6452754:1270610:7939800&map=Berggrunn%2EN250%2Emed%2Elineamenter

NGU. (2018c). løsmasser. Retrieved from http://geo.ngu.no/kart/minkommune/?kommunenr=822

NMI. (2017). Air temperature, cloud cover and precipitation. Retrieved from http://sharki.oslo.dnmi.no/pls/portal/BATCH_ORDER.PORTLET_UTIL.Download_BLob?p_BatchId=874206&p_IntervalId=1684474

Nordli, Ø., Wielgolaski, F.-E., Bakken, A. K., Hjeltnes, S. H., Måge, F., Sivle, A., & Skre, O. (2008). Regional trends for bud burst and flowering of woody plants in Norway as related to climate change. *International Journal of Biometeorology, 52*(7), 625-639.

NSW. (2005, May 2005). Apple varieties. *Agfact H4.1.12* Second. Retrieved from https://www.dpi.nsw.gov.au/agriculture/horticulture/pomes/apples/varieties

Nursery, K. (2017). Summerred Apple. Retrieved from https://www.keepers-nursery.co.uk/fruit-trees/apple/early-season-eating-apple/summerred

Olesen, J. E., & Bindi, M. (2002). Consequences of climate change for European agricultural productivity, land use and policy. *European Journal of Agronomy, 16*(4), 239-262.

Olesen, J. E., Trnka, M., Kersebaum, K. C., Skjelvåg, A. O., Seguin, B., Peltonen-Sainio, P., . . . Micale, F. (2011). Impacts and adaptation of European crop production systems to climate change. *European Journal of Agronomy, 34*(2), 96-112.

Oteros, J., García-Mozo, H., Vázquez, L., Mestre, A., Domínguez-Vilches, E., & Galán, C. (2013). Modelling olive phenological response to weather and topography. *Agriculture, Ecosystems and Environment, 179*, 62-68. doi:10.1016/j.agee.2013.07.008

Oulton, R. (2004). Discovery Apples. [2007.05.14]. Retrieved from http://www.cooksinfo.com/discovery-apples

Oulton, R. (2006). Aroma Apples. [2009.06.30]. Retrieved from http://www.cooksinfo.com/aroma-apples

Parkes, H. (2017). Effects of climate change on apple and pear production. *Climate change, Dormancy, flowering and pollination.* Retrieved from http://apal.org.au/effects-climate-change-apple-pear-production/

Parmesan, C., & Yohe, G. (2003). A globally coherent fingerprint of climate change impacts across natural systems. *Nature, 421*(6918), 37-42.

Petri, J. L., Hawerroth, F. J., Leite, G. B., Couto, M., & Francescatto, P. (2012). *Apple phenology in subtropical climate conditions*: INTECH Open Access Publisher.

Pippin, O. (Producer). (2015a). Aroma apple. Retrieved from https://www.orangepippin.com/apples/aroma

Pippin, O. (Producer). (2015b, 2017.10.31). Discovery apple. Retrieved from https://www.orangepippin.com/apples/discovery

Planteskole, J. (Producer). (2017, 2017.10.30). DWARF TREE 'RED AROMA'. Retrieved from https://jespersplanteskole.dk/dvaergtrae-aeble-rod-aroma

Poore, M. (1996). *Weather and climate*: TMW Media Group.

Rai, R., Joshi, S., Roy, S., Singh, O., Samir, M., & Ch, A. (2015). Implications of changing climate on productivity of temperate fruit crops with special reference to apple. *Journal of Horticulture*.

Rathcke, B., & Lacey, E. P. (1985). Phenological Patterns of Terrestrial Plants. *Annual Review of Ecology and Systematics, 16*, 179-214.

Redalen, G. (1987). Quality assessment of apple cultivars and selections. *Fruit Breeding 224*, 441-448.

Rivero, R., Sønsteby, A., Heide, O. M., Måge, F., & Remberg, S. F. (2017). Flowering phenology and the interrelations between phenological stages in apple trees (Malus domestica Borkh.) as influenced by the Nordic climate. *Acta Agriculturae Scandinavica, Section B — Soil & Plant Science, 67*(4), 292-302. doi:10.1080/09064710.2016.1267256

Robinson, J. P., Harris, S. A., & Juniper, B. (2001). Taxonomy of the genus Malus Mill.(Rosaceae) with emphasis on the cultivated apple, Malus domestica Borkh. *Plant Systematics and Evolution, 226*(1-2), 35-58.

Røen, D. (1996). *Apple breeding in Norway.* Paper presented at the Eucarpia Symposium on Fruit Breeding and Genetics 484.

Ruml, M., & Vulić, T. (2005). Importance of phenological observations and predictions in agriculture. *Journal of Agricultural Sciences, Belgrade, 50*(2), 217-225.

Sakamoto, T., Yokozawa, M., Toritani, H., Shibayama, M., Ishitsuka, N., & Ohno, H. (2005). A crop phenology detection method using time-series MODIS data. *Remote Sensing of Environment, 96*(3-4), 366-374.

Saxe, H., Cannell, M. G., Johnsen, Ø., Ryan, M. G., & Vourlitis, G. (2001). Tree and forest functioning in response to global warming. *New Phytologist, 149*(3), 369-399.

Scott, D. (1969). *Determining the type of relationship between plants and environmental factors.* Paper presented at the Proceedings (New Zealand Ecological Society).

Sen, V., Rana, R. S., & Chauhan, R. (2015). Impact of climate variability on apple production and diversity in Kullu valley, Himachal Pradesh. *Indian Journal of Horticulture, 72*(1), 14-20.

Seppä, L. (2014). *Domestic apple cultivars: Sensory descriptions and consumer responses.* (Doctoral dissertation), University of Helsinki, Retrieved from https://helda.helsinki.fi/handle/10138/44689

Singh, N., Sharma, D., & Chand, H. (2016). Impact of Climate Change on Apple Production in India: A Review. *Current World Environment, 11*(1), 251.

Slafer, G., & Savin, R. (1991). Developmental base temperature in different phenological phases of wheat (Triticum aestivum). *Journal of Experimental Botany, 42*(8), 1077-1082.

Sletten, A., Hofsvang, T., Rafoss, T., & Sundheim, L. (2012). Pest risk assessment for apple proliferation phytoplasma (“Candidatus Phytoplasma mali”). *Norwegian Scientific Committee for Food Safety (VKM), 11*, 905-907.

SMHI. (2012, November 29). SMHI. *Temperature.* Retrieved from http://www.smhi.se/kunskapsbanken/meteorologi/temperatur-1.3843

Statista. (2018a). Agricultural area used for apple production in Norway from 2010 to 2016 (in hectares). Retrieved from https://www.statista.com/statistics/713391/agricultural-area-used-for-apple-production-in-norway/

Statista. (2018b). Agriculture. *Agricultural area used for apple production in Norway from 2010 to 2016 (in hectares).* Retrieved from https://www.statista.com/statistics/713391/agricultural-area-used-for-apple-production-in-norway/

Sthapit, B., Rao, V. R., & Sthapit, S. (2012). Tropical fruit tree species and climate change. *Bioversity International, New Delhi*, 15-26.

Stromberg, J. (2013). Climate Change Is Altering the Taste and Texture of Fuji Apples. *Japanese scientists determined that warmer temperatures have gradually made the fruits mealier and less flavorful.* Retrieved from https://www.smithsonianmag.com/science-nature/climate-change-is-altering-the-taste-and-texture-of-fuji-apples-44558/

Talbert, C., Kern, T. J., Morisette, J., Brown, D., & James, K. (2013). *MODIS phenology image service ArcMap toolbox* (2331-1258). Retrieved from

Thornews. (2013). ThorNews supplier of norwegian culture. *Norwegian Apple Day – October 17th.* Retrieved from https://thornews.com/2013/10/17/norwegian-apple-day-october-17th/

Tjomsland, A. (2014). Climate change could lead to more Norwegian fruit. Retrieved from http://sciencenordic.com/climate-change-could-lead-more-norwegian-fruit

Uleberg, E., Hanssen-Bauer, I., Oort, B., & Dalmannsdottir, S. (2014). Impact of climate change on agriculture in Northern Norway and potential strategies for adaptation. *An Interdisciplinary, International Journal Devoted to the Description, Causes and Implications of Climatic Change, 122*(1), 27-39. doi:10.1007/s10584-013-0983-1

Valentini, N., Me, G., Ferrero, R., & Spanna, F. (2001). Use of bioclimatic indexes to characterize phenological phases of apple varieties in Northern Italy. *International Journal of Biometeorology, 45*(4), 191-195.

Varming, C., Amigo, J. M., Petersen, M. A., & Toldam-Andersen, T. (2014). *Aroma Analysis and Data Handling in the Evaluation of Niche Apple Juices from 160 Local Danish Apple Cultivars-Chapter 53*: Elsevier Inc.

Walther, G.-R., Post, E., Convey, P., Menzel, A., Parmesan, C., Beebee, T. J. C., . . . Bairlein, F. (2002). Ecological responses to recent climate change. *Nature, 416*(6879), 389-395.

Wang, S. L., Ball, E., Nehring, R., Williams, R., & Chau, T. (2017). Impacts of Climate Change and Extreme Weather on US Agricultural Productivity: Evidence and Projection. In *Understanding Productivity Growth in Agriculture*: University of Chicago Press.

White, M. A., Thornton, P. E., & Running, S. W. (1997). A continental phenology model for monitoring vegetation responses to interannual climatic variability. *Global Biogeochemical Cycles, 11*(2), 217-234.

Wilkinson, E. (2000). *Plant-environment interactions*. In Books in soils, plants, and the environment ;, Vol. v. 77. R. E. Wilkinson (Ed.).

Wistedt, H. E. (2016). *Tre äpplesorters fenologiska utveckling undersökt i relation till temperaturen, uttryckt i daggrader, under växtsäsongen 2015.* (Bachelor i økologi og naturforvaltning), Høgskolen i Sørøst-Norge,

Wolfe, D. W., Schwartz, M. D., Lakso, A. N., Otsuki, Y., Pool, R. M., & Shaulis, N. J. (2005). Climate change and shifts in spring phenology of three horticultural woody perennials in northeastern USA. *International Journal of Biometeorology, 49*(5), 303-309.

Wypych, A., Sulikowska, A., Ustrnul, Z., & Czekierda, D. (2017). Variability of growing degree days in Poland in response to ongoing climate changes in Europe. *International Journal of Biometeorology, 61*(1), 49-59.

Yazdanpanah, H., Ohadi, D., & Soleimani, M. (2010). Forecasting different phenological phases of apple using artificial neural network. *Journal of Research in Agricultural Science, 6*(2), 97-106.

Young, E. (1992). Timing of high temperature influences chilling negation in dormant apple trees. *Journal of the American Society for Horticultural Science, 117*(2), 271-273.

LIST OF FIGURES AND TABLES

ANNEXES

Annex I Spearman's rank correlation coefficient and p-value for the relationship between phenological development and CGDD.

Farm	Apple cultivar	Spearman's rank correlation coefficient	P-value
Liagrend	Red Aroma	1	0.003
	Summerred	1	0.017
	Discovery	1	0.017
Nyhus	Red Aroma	1	0.017
	Summerred	1	0.017
	Discovery	1	0.003
Årnes	Red Aroma	1	0.003
	Summerred	1	0.017
	Discovery	1	0.003

Annex II Spearman's rank correlation coefficient and p-value for the relationship between Julian day and phenological development.

Farm	Apple cultivar	Spearman's rank correlation coefficient	P-value
Liagrend	Red Aroma	1	0.003
	Summerred	1	0.017
	Discovery	1	0.003
Nyhus	Red Aroma	1	0.017
	Summerred	1	0.017
	Discovery	1	0.003
Årnes	Red Aroma	1	0.003
	Summerred	1	0.017
	Discovery	1	0.003

Annex III Spearman's rank correlation coefficient and p-value for the relationship between CGDD and Julian day.

Farm	Apple cultivar	Spearman's rank correlation coefficient	P-value
Liagrend	Red Aroma	1	0.003
	Summerred	1	0.017
	Discovery	1	0.003
Nyhus	Red Aroma	1	0.017
	Summerred	1	0.017
	Discovery	1	0.017
Årnes	Red Aroma	1	0.003
	Summerred	1	0.017
	Discovery	1	0.003

Annex IV P-value to know variation of phenological development in 2016 within (I) three apple cultivars and (II)three farms.

I		II	
Apple cultivar	P-value	Farm	P-value
Red Aroma-Summerred	0.007	Liagrend-Nyhus	0.414
Summerred-Discovery	0.285	Nyhus-Årnes	0.066
Discovery-Red Aroma	0.010	Årnes-Liagrend	0.041

Annex V P-value to know variation of phenological development in the year 2015 with respect to 2016 at (II) three farms along with three (I) different apple cultivars.

I		II	
Apple cultivar	P-value	Farm	P-value
Red Aroma	0.339	Liagrend	0.723
Summerred	0.796	Nyhus	0.114
Discovery	0.020	Årnes	0.340

Annex VI P-value to know about variation of CGDD in the year 2015 with respect to 2016 (from the Julian day 1 to Julian day 191).

Farm	Apple cultivar	P-value
Liagrend	Red Aroma	0.000
	Summerred	0.000
	Discovery	0.000
Nyhus	Red Aroma	0.000
	Summerred	0.000
	Discovery	0.000

Årnes	Red Aroma	0.000
	Summerred	0.000
	Discovery	0.000

Annex VII CGDD at Liagrend in the year 2016 and 2015 for three apple cultivars.

Julian day	Red Aroma (CGDD)		Summerred (CGDD)		Discovery (CGDD)	
	2016	2015	2016	2015	2016	2015
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	0
16	0	0	0	0	0	0
17	0	0	0	0	0	0
18	0	0	0	0	0	0
19	0	0	0	0	0	0
20	0	0	0	0	0	0
21	0	0	0	0	0	0
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0
25	0	0	0	0	0	0
26	0	0	0	0	0	0
27	0	0	0	0	0	0
28	0	0	0	0	0	0
29	0.32	0	0.3	0	0.36	0
30	0.32	0	0.3	0	0.36	0
31	0.32	0	0.3	0	0.36	0
32	0.32	0	0.3	0	0.36	0
33	0.32	0	0.3	0	0.36	0

34	0.32	0	0.3	0	0.36	0
35	0.32	0	0.3	0	0.36	0
36	0.32	0	0.3	0	0.36	0
37	0.32	0	0.3	0	0.36	0
38	0.32	0	0.3	0	0.36	0
39	0.32	0	0.3	0	0.36	0
40	0.32	1.02	0.3	1	0.36	1.06
41	0.32	1.02	0.3	1	0.36	1.06
42	0.32	1.02	0.3	1	0.36	1.06
43	0.32	1.02	0.3	1	0.36	1.06
44	0.32	1.02	0.3	1	0.36	1.06
45	0.32	1.02	0.3	1	0.36	1.06
46	0.32	1.02	0.3	1	0.36	1.06
47	0.32	1.02	0.3	1	0.36	1.06
48	0.32	1.02	0.3	1	0.36	1.06
49	0.32	1.02	0.3	1	0.36	1.06
50	0.32	1.02	0.3	1	0.36	1.06
51	0.32	1.02	0.3	1	0.36	1.06
52	0.32	1.02	0.3	1	0.36	1.06
53	0.32	1.02	0.3	1	0.36	1.06
54	0.32	1.02	0.3	1	0.36	1.06
55	0.32	1.02	0.3	1	0.36	1.06
56	0.32	1.02	0.3	1	0.36	1.06
57	0.32	1.02	0.3	1	0.36	1.06
58	0.32	1.02	0.3	1	0.36	1.06
59	0.32	1.02	0.3	1	0.36	1.06
60	0.32	1.02	0.3	1	0.36	1.06
61	0.32	1.02	0.3	1	0.36	1.06
62	0.32	1.02	0.3	1	0.36	1.06
63	0.32	1.02	0.3	1	0.36	1.06
64	0.32	1.02	0.3	1	0.36	1.06
65	0.32	1.02	0.3	1	0.36	1.06
66	0.32	4.29	0.3	4.25	0.36	4.37
67	0.32	8.76	0.3	8.7	0.36	8.88
68	0.32	8.76	0.3	8.7	0.36	8.88
69	0.32	10.18	0.3	10.1	0.36	10.34
70	0.32	11.35	0.3	11.25	0.36	11.55
71	0.32	11.35	0.3	11.25	0.36	11.55
72	0.32	11.35	0.3	11.25	0.36	11.55
73	0.32	11.35	0.3	11.25	0.36	11.55
74	3.44	11.35	3.4	11.25	3.52	11.55
75	3.71	11.57	3.65	11.45	3.83	11.81
76	3.71	12.14	3.65	12	3.83	12.42

77	5.43	12.21	5.35	12.05	5.59	12.53
78	6.05	12.21	5.95	12.05	6.25	12.53
79	7.02	12.21	6.9	12.05	7.26	12.53
80	7.02	12.21	6.9	12.05	7.26	12.53
81	8.29	12.21	8.15	12.05	8.57	12.53
82	8.66	13.28	8.5	13.1	8.98	13.64
83	11.43	13.7	11.25	13.5	11.79	14.1
84	11.43	13.7	11.25	13.5	11.79	14.1
85	13.9	13.7	13.7	13.5	14.3	14.1
86	13.9	13.7	13.7	13.5	14.3	14.1
87	13.9	13.7	13.7	13.5	14.3	14.1
88	13.9	13.77	13.7	13.55	14.3	14.21
89	15.32	14.39	15.1	14.15	15.76	14.87
90	17.69	14.39	17.45	14.15	18.17	14.87
91	18.06	14.39	17.8	14.15	18.58	14.87
92	21.28	14.39	21	14.15	21.84	14.87
93	23.1	14.39	22.8	14.15	23.7	14.87
94	23.32	14.39	23	14.15	23.96	14.87
95	24.64	14.39	24.3	14.15	25.32	14.87
96	26.16	16.66	25.8	16.4	26.88	17.18
97	26.98	21.78	26.6	21.5	27.74	22.34
98	27.15	26.4	26.75	26.1	27.95	27
99	27.15	33.12	26.75	32.8	27.95	33.76
100	28.62	36.99	28.2	36.65	29.46	37.67
101	31.54	38.16	31.1	37.8	32.42	38.88
102	35.01	39.33	34.55	38.95	35.93	40.09
103	38.28	40.45	37.8	40.05	39.24	41.25
104	41.65	40.45	41.15	40.05	42.65	41.25
105	44.17	41.27	43.65	40.85	45.21	42.11
106	44.84	41.69	44.3	41.25	45.92	42.57
107	45.41	44.51	44.85	44.05	46.53	45.43
108	48.73	48.38	48.15	47.9	49.89	49.34
109	50.6	52.45	50	51.95	51.8	53.45
110	50.6	60.27	50	59.75	51.81	61.31
111	51.77	65.44	51.15	64.9	53.02	66.52
112	53.29	71.66	52.65	71.1	54.58	72.78
113	53.41	75.18	52.75	74.6	54.74	76.34
114	53.41	80.25	52.75	79.65	54.74	81.45
115	53.41	81.47	52.75	80.85	54.74	82.71
116	53.41	84.89	52.75	84.25	54.74	86.17
117	53.41	84.89	52.75	84.25	54.74	86.17
118	54.83	84.96	54.15	84.3	56.2	86.28
119	56.9	84.96	56.2	84.3	58.31	86.28

120	59.67	85.58	58.95	84.9	61.12	86.94
121	59.67	88.65	58.95	87.95	61.12	90.05
122	61.39	90.37	60.65	89.65	62.88	91.81
123	62.91	92.44	62.15	91.7	64.44	93.92
124	66.48	94.16	65.7	93.4	68.05	95.68
125	72.5	96.73	71.7	95.95	74.11	98.29
126	79.22	101	78.4	100.2	80.87	102.6
127	86.39	106.07	85.55	105.25	88.08	107.71
128	96.96	110.44	96.1	109.6	98.69	112.12
129	106.13	110.56	105.25	109.7	107.9	112.28
130	112.35	111.88	111.45	111	114.16	113.64
131	122.52	115.6	121.6	114.7	124.37	117.4
132	129.79	119.42	128.85	118.5	131.68	121.26
133	135.81	126.79	134.85	125.85	137.74	128.67
134	140.88	130.56	139.9	129.6	142.85	132.48
135	145.4	135.83	144.4	134.85	147.41	137.79
136	152.02	140.1	151	139.1	154.07	142.1
137	160.44	144.72	159.4	143.7	162.53	146.76
138	167.01	147.54	165.95	146.5	169.14	149.62
139	175.73	147.71	174.65	146.65	177.9	149.83
140	185.75	152.28	184.65	151.2	187.96	154.44
141	194.27	157.25	193.15	156.15	196.52	159.45
142	202.39	161.12	201.25	160	204.68	163.36
143	207.56	167.09	206.4	165.95	209.89	169.37
144	215.23	169.91	214.05	168.75	217.6	172.23
145	224.5	174.53	223.3	173.35	226.91	176.89
146	234.32	180	233.1	178.8	236.77	182.4
147	246.19	187.52	244.95	186.3	248.68	189.96
148	259.06	192.19	257.8	190.95	261.59	194.67
149	270.08	196.91	268.8	195.65	272.65	199.43
150	279.85	198.93	278.55	197.65	282.46	201.49
151	290.42	205	289.1	203.7	293.07	207.6
152	306.44	208.07	305.1	206.75	309.13	210.71
153	320.11	213.69	318.75	212.35	322.84	216.37
154	332.68	219.96	331.3	218.6	335.45	222.68
155	348.3	227.33	346.9	225.95	351.11	230.09
156	361.52	234.35	360.1	232.95	364.37	237.15
157	371.49	242.97	370.05	241.55	374.38	245.81
158	381.76	249.14	380.3	247.7	384.69	252.02
159	391.53	255.41	390.05	253.95	394.5	258.33
160	400	265.78	398.5	264.3	403.01	268.74
161	407.22	275.75	405.7	274.25	410.27	278.75
162	414.89	284.47	413.35	282.95	417.98	287.51

163	425.41	293.64	423.85	292.1	428.54	296.72
164	436.03	302.46	434.45	300.9	439.2	305.58
165	447.3	309.88	445.7	308.3	450.51	313.04
166	459.92	318.7	458.3	317.1	463.17	321.9
167	470.74	328.07	469.1	326.45	474.03	331.31
168	481.31	335.29	479.65	333.65	484.64	338.57
169	493.68	340.61	492	338.95	497.05	343.93
170	503.9	348.33	502.2	346.65	507.31	351.69
171	514.32	357.75	512.6	356.05	517.77	361.15
172	524.79	368.32	523.05	366.6	528.28	371.76
173	537.36	377.74	535.6	376	540.89	381.22
174	550.88	387.76	549.1	386	554.45	391.28
175	562.5	398.28	560.7	396.5	566.11	401.84
176	570.52	407.75	568.7	405.95	574.17	411.35
177	581.69	419.27	579.85	417.45	585.38	422.91
178	592.96	429.69	591.1	427.85	596.69	433.37
179	601.28	438.06	599.4	436.2	605.05	441.78
180	612.35	447.38	610.45	445.5	616.16	451.14
181	622.17	457.9	620.25	456	626.02	461.7
182	629.99	472.62	628.05	470.7	633.88	476.46
183	637.21	486.44	635.25	484.5	641.14	490.32
184	645.33	499.81	643.35	497.85	649.3	503.73
185	653.65	513.08	651.65	511.1	657.66	517.04
186	664.32	526.65	662.3	524.65	668.37	530.65
187	674.84	538.22	672.8	536.2	678.93	542.26
188	685.86	550.39	683.8	548.35	689.99	554.47
189	698.53	562.46	696.45	560.4	702.7	566.58
190	710.75	575.08	708.65	573	714.96	579.24
191	724.22	587.2	722.1	585.1	728.47	591.4

Annex VIII CGDD at Nyhus in the year 2016 and 2015 for three apple cultivars.

Julian day	Red Aroma (CGDD)		Summerred (CGDD)		Discovery (CGDD)	
	2016	2015	2016	2015	2016	2015
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0

5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	0
16	0	0	0	0	0	0
17	0	0	0	0	0	0
18	0	0	0	0	0	0
19	0	0	0	0	0	0
20	0	0	0	0	0	0
21	0	0	0	0	0	0
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0
25	0	0	0	0	0	0
26	0	0	0	0	0	0
27	0	0	0	0	0	0
28	0	0	0	0	0	0
29	0.66	0	0.44	0	0.76	0
30	0.66	0	0.44	0	0.76	0
31	0.66	0	0.44	0	0.76	0
32	0.66	0	0.44	0	0.76	0
33	0.66	0	0.44	0	0.76	0
34	0.66	0	0.44	0	0.76	0
35	0.66	0	0.44	0	0.76	0
36	0.66	0	0.44	0	0.76	0
37	0.66	0	0.44	0	0.76	0
38	0.66	0	0.44	0	0.76	0
39	0.66	0	0.44	0	0.76	0
40	0.66	1.36	0.44	1.14	0.76	1.46
41	0.66	1.36	0.44	1.14	0.76	1.46
42	0.66	1.36	0.44	1.14	0.76	1.46
43	0.66	1.36	0.44	1.14	0.76	1.46
44	0.66	1.36	0.44	1.14	0.76	1.46
45	0.66	1.36	0.44	1.14	0.76	1.46
46	0.66	1.36	0.44	1.14	0.76	1.46
47	0.66	1.36	0.44	1.14	0.76	1.46

48	0.66	1.36	0.44	1.14	0.76	1.46
49	0.66	1.52	0.44	1.14	0.76	1.72
50	0.66	1.63	0.44	1.14	0.76	1.93
51	0.66	1.63	0.44	1.14	0.76	1.93
52	0.66	1.63	0.44	1.14	0.76	1.93
53	0.66	1.63	0.44	1.14	0.76	1.93
54	0.66	1.63	0.44	1.14	0.76	1.93
55	0.66	1.63	0.44	1.14	0.76	1.93
56	0.66	1.63	0.44	1.14	0.76	1.93
57	0.66	1.63	0.44	1.14	0.76	1.93
58	0.66	1.63	0.44	1.14	0.76	1.93
59	0.66	1.63	0.44	1.14	0.76	1.93
60	0.66	1.63	0.44	1.14	0.76	1.93
61	0.66	1.63	0.44	1.14	0.76	1.93
62	0.66	1.63	0.44	1.14	0.76	1.93
63	0.66	1.63	0.44	1.14	0.76	1.93
64	0.66	1.63	0.44	1.14	0.76	1.93
65	0.66	1.63	0.44	1.14	0.76	1.93
66	0.66	5.24	0.44	4.53	0.76	5.64
67	0.66	10.05	0.44	9.12	0.76	10.55
68	0.66	10.05	0.44	9.12	0.76	10.55
69	0.66	11.81	0.44	10.66	0.76	12.41
70	0.66	13.32	0.44	11.95	0.76	14.02
71	0.66	13.32	0.44	11.95	0.76	14.02
72	0.66	13.32	0.44	11.95	0.76	14.02
73	0.66	13.32	0.44	11.95	0.76	14.02
74	4.12	13.32	3.68	11.95	4.32	14.02
75	4.73	13.88	4.07	12.29	5.03	14.68
76	4.73	14.79	4.07	12.98	5.03	15.69
77	6.79	15.2	5.91	13.17	7.19	16.2
78	7.75	15.2	6.65	13.17	8.25	16.2
79	9.06	15.2	7.74	13.17	9.66	16.2
80	9.06	15.2	7.74	13.17	9.66	16.2
81	10.67	15.2	9.13	13.17	11.37	16.2
82	11.38	16.61	9.62	14.36	12.18	17.71
83	14.49	17.37	12.51	14.9	15.39	18.57
84	14.49	17.37	12.51	14.9	15.39	18.57
85	17.3	17.37	15.1	14.9	18.3	18.57
86	17.3	17.37	15.1	14.9	18.36	18.57
87	17.3	17.37	15.1	14.9	18.36	18.57
88	17.3	17.78	15.1	15.09	18.36	19.08
89	19.06	18.74	16.64	15.83	20.22	20.14
90	21.77	18.74	19.13	15.83	23.03	20.14

91	22.48	18.74	19.62	15.83	23.84	20.14
92	26.04	18.75	22.96	15.83	27.5	20.25
93	28.2	18.75	24.9	15.83	29.76	20.25
94	28.76	18.75	25.24	15.83	30.42	20.25
95	30.42	18.75	26.68	15.83	32.18	20.25
96	32.28	21.36	28.32	18.22	34.14	22.96
97	33.44	26.82	29.26	23.46	35.4	28.52
98	33.95	31.78	29.55	28.2	36.01	33.58
99	33.95	38.84	29.55	35.04	36.01	40.74
100	35.76	43.05	31.14	39.03	37.92	45.05
101	39.02	44.56	34.18	40.32	41.28	46.66
102	42.83	46.07	37.77	41.61	45.19	48.27
103	46.44	47.53	41.16	42.85	48.9	49.83
104	50.15	47.74	44.65	42.85	52.71	50.14
105	53.01	48.9	47.29	43.79	55.67	51.4
106	54.02	49.66	48.08	44.33	56.78	52.26
107	54.93	52.82	48.77	47.27	57.79	55.52
108	58.59	57.03	52.21	51.26	61.55	59.83
109	60.8	61.44	54.2	55.45	63.86	64.34
110	61.11	69.6	54.29	63.39	64.27	72.6
111	62.62	75.11	55.58	68.68	65.88	78.21
112	64.48	81.67	57.22	75.02	67.84	84.87
113	64.94	85.53	57.46	78.66	68.4	88.83
114	64.94	90.94	57.46	83.85	68.4	94.34
115	64.94	92.5	57.46	85.19	68.4	96
116	65	96.26	57.46	88.73	68.56	99.86
117	65	96.52	57.46	88.77	68.56	100.22
118	66.76	96.93	59	88.96	70.42	100.73
119	69.17	96.93	61.19	88.96	72.93	100.73
120	72.28	97.89	64.08	89.7	76.14	101.79
121	72.28	101.3	64.08	92.89	76.14	105.3
122	74.34	103.36	65.92	94.73	78.3	107.46
123	76.2	105.77	67.56	96.92	80.26	109.97
124	80.11	107.83	71.25	98.76	84.27	112.13
125	86.47	110.74	77.39	101.45	90.73	115.14
126	93.53	115.35	84.23	105.84	97.89	119.85
127	101.04	120.76	91.52	111.03	105.5	125.36
128	111.95	125.47	102.21	115.52	116.51	130.17
129	121.46	125.93	111.5	115.76	126.12	130.73
130	128.02	127.59	117.84	117.2	132.78	132.49
131	138.53	131.65	128.13	121.04	143.39	136.65
132	146.14	135.81	135.52	124.98	151.1	140.91
133	152.5	143.52	141.66	132.47	157.56	148.72

134	157.91	147.63	146.85	136.36	163.07	152.93
135	162.77	153.24	151.49	141.75	168.03	158.64
136	169.73	157.85	158.23	146.14	175.09	163.35
137	178.49	162.81	166.77	150.88	183.95	168.41
138	185.4	165.97	173.46	153.82	190.96	171.67
139	194.46	166.48	182.3	154.11	200.12	172.28
140	204.82	171.39	192.44	158.8	210.58	177.29
141	213.68	176.7	201.08	163.89	219.54	182.7
142	222.14	180.91	209.32	167.88	228.1	187.01
143	227.65	187.22	214.61	173.97	233.71	193.42
144	235.66	190.38	222.4	176.91	241.82	196.68
145	245.27	195.34	231.79	181.65	251.53	201.74
146	255.43	201.15	241.73	187.24	261.79	207.65
147	267.64	209.01	253.72	194.88	274.1	215.61
148	280.85	214.02	266.71	199.67	287.41	220.72
149	292.21	219.08	277.85	204.51	298.87	225.88
150	302.32	221.44	287.74	206.65	309.08	228.34
151	313.23	227.85	298.43	212.84	320.09	234.85
152	329.59	231.26	314.57	216.03	336.55	238.36
153	343.6	237.22	328.36	221.77	350.66	244.42
154	356.51	243.83	341.05	228.16	363.67	251.13
155	372.47	251.54	356.79	235.65	379.73	258.94
156	386.03	258.9	370.13	242.79	393.39	266.4
157	396.34	267.86	380.22	251.53	403.8	275.46
158	406.95	274.37	390.61	257.82	414.51	282.07
159	417.06	280.98	400.5	264.21	424.72	288.78
160	425.87	291.69	409.09	274.7	433.63	299.59
161	433.43	302	416.43	284.79	441.29	310
162	441.44	311.06	424.22	293.63	449.4	319.16
163	452.3	320.57	434.86	302.92	460.36	328.77
164	463.26	329.73	445.6	311.86	471.42	338.03
165	474.87	337.49	456.99	319.4	483.13	345.89
166	487.83	346.65	469.73	328.34	496.19	355.15
167	498.99	356.36	480.67	337.83	507.45	364.96
168	509.9	363.92	491.36	345.17	518.46	372.62
169	522.61	369.58	503.85	350.61	531.27	378.38
170	533.17	377.64	514.19	358.45	541.93	386.54
171	543.93	387.4	524.73	367.99	552.79	396.4
172	554.74	398.31	535.32	378.68	563.7	407.41
173	567.65	408.07	548.01	388.22	576.71	417.27
174	581.51	418.43	561.65	398.36	590.67	427.73
175	593.47	429.29	573.39	409	602.73	438.69
176	601.83	439.1	581.53	418.59	611.19	448.6

177	613.34	450.96	592.82	430.23	622.8	460.56
178	624.95	461.72	604.21	440.77	634.51	471.42
179	633.61	470.43	612.65	449.26	643.27	480.23
180	645.02	480.09	623.84	458.7	654.78	489.99
181	655.18	490.95	633.78	469.34	665.04	500.95
182	663.34	506.01	641.72	484.18	673.3	516.11
183	670.9	520.17	649.06	498.12	680.96	530.37
184	679.36	533.88	657.3	511.61	689.52	544.18
185	688.02	547.49	665.74	525	698.28	557.89
186	699.03	561.4	676.53	538.69	709.39	571.9
187	709.89	573.31	687.17	550.38	720.35	583.91
188	721.25	585.82	698.31	562.67	731.81	596.52
189	734.26	598.23	711.1	574.86	744.92	609.03
190	746.82	611.19	723.44	587.6	757.58	622.09
191	760.63	623.65	737.03	599.84	771.49	634.65

Annex IX CGDD at Årnes in the year 2016 and 2015 for three apple cultivars.

Julian day	Red Aroma (CGDD)		Summerred (CGDD)		Discovery (CGDD)	
	2016	2015	2016	2015	2016	2015
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	0
16	0	0	0	0	0	0
17	0	0	0	0	0	0
18	0	0	0	0	0	0
19	0	0	0	0	0	0
20	0	0	0	0	0	0
21	0	0	0	0	0	0

22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0
25	0	0	0	0	0	0
26	0	0	0	0	0	0
27	0	0	0	0	0	0
28	0	0	0	0	0	0
29	0.74	0	0.74	0	0.75	0
30	0.74	0	0.74	0	0.75	0
31	0.74	0	0.74	0	0.75	0
32	0.74	0	0.74	0	0.75	0
33	0.74	0	0.74	0	0.75	0
34	0.74	0	0.74	0	0.75	0
35	0.74	0	0.74	0	0.75	0
36	0.74	0	0.74	0	0.75	0
37	0.74	0	0.74	0	0.75	0
38	0.74	0	0.74	0	0.75	0
39	0.74	0	0.74	0	0.75	0
40	0.74	1.44	0.74	1.44	0.75	1.45
41	0.74	1.44	0.74	1.44	0.75	1.45
42	0.74	1.44	0.74	1.44	0.75	1.45
43	0.74	1.44	0.74	1.44	0.75	1.45
44	0.74	1.44	0.74	1.44	0.75	1.45
45	0.74	1.44	0.74	1.44	0.75	1.45
46	0.74	1.44	0.74	1.44	0.75	1.45
47	0.74	1.44	0.74	1.44	0.75	1.45
48	0.74	1.44	0.74	1.44	0.75	1.45
49	0.74	1.68	0.74	1.68	0.75	1.7
50	0.74	1.87	0.74	1.87	0.75	1.9
51	0.74	1.87	0.74	1.87	0.75	1.9
52	0.74	1.87	0.74	1.87	0.75	1.9
53	0.74	1.87	0.74	1.87	0.75	1.9
54	0.74	1.87	0.74	1.87	0.75	1.9
55	0.74	1.87	0.74	1.87	0.75	1.9
56	0.74	1.87	0.74	1.87	0.75	1.9
57	0.74	1.87	0.74	1.87	0.75	1.9
58	0.74	1.87	0.74	1.87	0.75	1.9
59	0.74	1.87	0.74	1.87	0.75	1.9
60	0.74	1.87	0.74	1.87	0.75	1.9
61	0.74	1.87	0.74	1.87	0.75	1.9
62	0.74	1.87	0.74	1.87	0.75	1.9
63	0.74	1.87	0.74	1.87	0.75	1.9
64	0.74	1.87	0.74	1.87	0.75	1.9

65	0.74	1.87	0.74	1.87	0.75	1.9
66	0.74	5.56	0.74	5.56	0.75	5.6
67	0.74	10.45	0.74	10.45	0.75	10.5
68	0.74	10.45	0.74	10.45	0.75	10.5
69	0.74	12.29	0.74	12.29	0.75	12.35
70	0.74	13.88	0.74	13.88	0.75	13.95
71	0.74	13.88	0.74	13.88	0.75	13.95
72	0.74	13.88	0.74	13.88	0.75	13.95
73	0.74	13.88	0.74	13.88	0.75	13.95
74	4.28	13.88	4.28	13.88	4.3	13.95
75	4.97	14.52	4.97	14.52	5	14.6
76	4.97	15.51	4.97	15.51	5	15.6
77	7.11	16	7.11	16	7.15	16.1
78	8.15	16	8.15	16	8.2	16.1
79	9.54	16	9.54	16	9.6	16.1
80	9.54	16	9.54	16	9.6	16.1
81	11.23	16	11.23	16	11.3	16.1
82	12.02	17.49	12.02	17.49	12.1	17.6
83	15.21	18.33	15.21	18.33	15.3	18.45
84	15.21	18.33	15.21	18.33	15.3	18.45
85	18.1	18.33	18.1	18.33	18.2	18.45
86	18.14	18.33	18.14	18.33	18.25	18.45
87	18.14	18.33	18.14	18.33	18.25	18.45
88	18.14	18.82	18.14	18.82	18.25	18.95
89	19.98	19.86	19.98	19.86	20.1	20
90	22.77	19.86	22.77	19.86	22.9	20
91	23.56	19.86	23.56	19.86	23.7	20
92	27.2	19.95	27.2	19.95	27.35	20.1
93	29.44	19.95	29.44	19.95	29.6	20.1
94	30.08	19.95	30.08	19.95	30.25	20.1
95	31.82	19.95	31.82	19.95	32	20.1
96	33.76	22.64	33.76	22.64	33.95	22.8
97	35	28.18	35	28.18	35.2	28.35
98	35.59	33.22	35.59	33.22	35.8	33.4
99	35.59	40.36	35.59	40.36	35.8	40.55
100	37.48	44.65	37.48	44.65	37.7	44.85
101	40.82	46.24	40.82	46.24	41.05	46.45
102	44.71	47.83	44.71	47.83	44.95	48.05
103	48.4	49.37	48.4	49.37	48.65	49.6
104	52.19	49.66	52.19	49.66	52.45	49.9
105	55.13	50.9	55.13	50.9	55.4	51.15
106	56.22	51.74	56.22	51.74	56.5	52
107	57.21	54.98	57.21	54.98	57.5	55.25

108	60.95	59.27	60.95	59.27	61.25	59.55
109	63.24	63.76	63.24	63.76	63.55	64.05
110	63.63	72	63.63	72	63.95	72.3
111	65.22	77.59	65.22	77.59	65.55	77.9
112	67.16	84.23	67.16	84.23	67.5	84.55
113	67.7	88.17	67.7	88.17	68.05	88.5
114	67.7	93.66	67.7	93.66	68.05	94
115	67.7	95.3	67.7	95.3	68.05	95.65
116	67.84	99.14	67.84	99.14	68.2	99.5
117	67.84	99.48	67.84	99.48	68.2	99.85
118	69.68	99.97	69.68	99.97	70.05	100.35
119	72.17	99.97	72.17	99.97	72.55	100.35
120	75.36	101.01	75.36	101.01	75.75	101.4
121	75.36	104.5	75.36	104.5	75.75	104.9
122	77.5	106.64	77.5	106.64	77.9	107.05
123	79.44	109.13	79.44	109.13	79.85	109.55
124	83.43	111.27	83.43	111.27	83.85	111.7
125	89.87	114.26	89.87	114.26	90.3	114.7
126	97.01	118.95	97.01	118.95	97.45	119.4
127	104.6	124.44	104.6	124.44	105.05	124.9
128	115.59	129.23	115.59	129.23	116.05	129.7
129	125.18	129.77	125.18	129.77	125.65	130.25
130	131.82	131.51	131.82	131.51	132.3	132
131	142.41	135.65	142.41	135.65	142.9	136.15
132	150.1	139.89	150.1	139.89	150.6	140.4
133	156.54	147.68	156.54	147.68	157.05	148.2
134	162.03	151.87	162.03	151.87	162.55	152.4
135	166.97	157.56	166.97	157.56	167.5	158.1
136	174.01	162.25	174.01	162.25	174.55	162.8
137	182.85	167.29	182.85	167.29	183.4	167.85
138	189.84	170.53	189.84	170.53	190.4	171.1
139	198.98	171.12	198.98	171.12	199.55	171.7
140	209.42	176.11	209.42	176.11	210	176.7
141	218.36	181.5	218.36	181.5	218.95	182.1
142	226.9	185.79	226.9	185.79	227.5	186.4
143	232.49	192.18	232.49	192.18	233.1	192.8
144	240.58	195.42	240.58	195.42	241.2	196.05
145	250.27	200.46	250.27	200.46	250.9	201.1
146	260.51	206.35	260.51	206.35	261.15	207
147	272.8	214.29	272.8	214.29	273.45	214.95
148	286.09	219.38	286.09	219.38	286.75	220.05
149	297.53	224.52	297.53	224.52	298.2	225.2
150	307.72	226.96	307.72	226.96	308.4	227.65

151	318.71	233.45	318.71	233.45	319.4	234.15
152	335.15	236.94	335.15	236.94	335.85	237.65
153	349.24	242.98	349.24	242.98	349.95	243.7
154	362.23	249.67	362.23	249.67	362.95	250.4
155	378.27	257.46	378.27	257.46	379	258.2
156	391.91	264.9	391.91	264.9	392.65	265.65
157	402.3	273.94	402.3	273.94	403.05	274.7
158	412.99	280.53	412.99	280.53	413.75	281.3
159	423.18	287.22	423.18	287.22	423.95	288
160	432.07	298.01	432.07	298.01	432.85	298.8
161	439.71	308.4	439.71	308.4	440.5	309.2
162	447.8	317.54	447.8	317.54	448.6	318.35
163	458.74	327.13	458.74	327.13	459.55	327.95
164	469.78	336.37	469.78	336.37	470.6	337.2
165	481.47	344.21	481.47	344.21	482.3	345.05
166	494.51	353.45	494.51	353.45	495.35	354.3
167	505.75	363.24	505.75	363.24	506.6	364.1
168	516.74	370.88	516.74	370.88	517.6	371.75
169	529.53	376.62	529.53	376.62	530.4	377.5
170	540.17	384.76	540.17	384.76	541.05	385.65
171	551.01	394.6	551.01	394.6	551.9	395.5
172	561.9	405.59	561.9	405.59	562.8	406.5
173	574.89	415.43	574.89	415.43	575.8	416.35
174	588.83	425.87	588.83	425.87	589.75	426.8
175	600.87	436.81	600.87	436.81	601.8	437.75
176	609.31	446.7	609.31	446.7	610.25	447.65
177	620.9	458.64	620.9	458.64	621.85	459.6
178	632.59	469.48	632.59	469.48	633.55	470.45
179	641.33	478.27	641.33	478.27	642.3	479.25
180	652.82	488.01	652.82	488.01	653.8	489
181	663.06	498.95	663.06	498.95	664.05	499.95
182	671.3	514.09	671.3	514.09	672.3	515.1
183	678.94	528.33	678.94	528.33	679.95	529.35
184	687.48	542.12	687.48	542.12	688.5	543.15
185	696.22	555.81	696.22	555.81	697.25	556.85
186	707.31	569.8	707.31	569.8	708.35	570.85
187	718.25	581.79	718.25	581.79	719.3	582.85
188	729.69	594.38	729.69	594.38	730.75	595.45
189	742.78	606.87	742.78	606.87	743.85	607.95
190	755.42	619.91	755.42	619.91	756.5	621
191	769.31	632.45	769.31	632.45	770.4	633.55

Annex X Monthly mean temperature at GVARV-NES station in the year 2016 and 2015 along with the period of 1961-90. (Source: eklima.no)

Month in year	Monthly mean temperature		
	2016	2015	1961-90
1	-5.2	0	-0.56
2	-0.8	0.3	-0.41
3	3.0	3.2	0.01
4	5.7	6.8	4.2
5	12.3	8.6	10.1
6	16.1	13.7	14.4
7	16.1	15.7	16
8	14.9	15.2	14.4
9	14.5	11.8	10
10	5.9	6.4	5
11	-0.1	2	0
12	0.5	1.4	-4