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Changes in the grapevine's growth cycle in Southern Finland in the 2000s – comparison between two first decades

Karvonen Juha

Department of Agricultural Sciences, Faculty of Agriculture and Forestry, University of Helsinki, Finland; E-mail: juha.i.Karvonen@helsinki.fi

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ABSTRACT

The temperature of Southern Finland has risen faster than ever in the last few decades of a 172-year period. This has made it possible to grow hydride vine varieties and some *Vitis vinifera* varieties. This study evaluated the effects of climate change and growing conditions in the Helsinki region on the growth cycle of *Vitis vinifera* 'Rondo' for two consecutive decades (2000-2009) and (2010–2019). During 2010– 2019, the mean climate temperature had risen by 0.4 °C compared to the mean of 2000– 2009, grape harvesting had been sped up by 6 days and growth cycles had been reduced by 11 days. Changes were statistically significant ($p<0.05$). There was no significant difference between the mean of the growing seasons and the mean of the bud burst dates. Based on the study, it can be concluded that the appeared rise in annual air temperature significantly accelerated the growth cycle of Vitis 'Rondo' in the cool - cold growth zone of Southern Finland.

Keywords: *Vitis vinifera* 'Rondo', northern viticulture, climate change, growing season, grape harvest

1. INTRODUCTION

In recent decades, rising climate temperatures in the Northern hemisphere have advanced the spring and the start of plant growth (Post *et al.*, 2018). The average air temperature in Southern Finland has risen more than 2 °C between 1847 and 2013, which corresponds to an increase of 0.14 °C for each decade. Since 1960, the rise in air temperature has been faster than ever before and has occurred especially in November, December and January (Tietäväinen *et al.,* 2010). This has occurred as an earlier bud break and the start of flowering of the trees in the boreal zone. Between 1846 and 2005, they have occurred 3.3-11 days earlier per a hundred year (Linkosuo *et al.,* 2009). The global warming that has occurred and its predicted continuation will bring new plant and animal species and crops to the north. Of these, the grapevine has already gained a good foothold in Denmark (Hagerman, 2018) and Swedish Skåne and is conquering Southern Norway and Southern Finland.

Southern Finland, like all southern parts of Northern Europe, belongs to the cool-cold winegrowing area (Amerine & Winkler, 1944; Huglin & Schneider, 1998; Tornietto & Carbonneau, 2004). According to the Huglin indices, only two very early ripening *Vitis vinifera* varieties can be grown to harvest-ripe in these areas (Huglin & Schneider, 1998). Instead, there are dozens of suitable hybrid varieties and new hybrid varieties are breeding continuously (Rosenfeld, 2018). The number of suitable *Vitis vinifera* varieties has also increased; Pinot Noir, Leon Millot, Madelaine Royal, and Rondo have thrived in the 2010s at 61° latitudes, and Rondo has become the most commonly grown grapevine variety in Northern Europe. According to the Finnish Meteorological Institute, the temperature of the Finnish climate has risen by 0.2 °C every decade over the last 40 years (Mikkonen *et al.,* 2015), which, if continued, would increase the number of suitable *Vitis vinifera* varieties and would move grapevine cultivation farther north. The purpose of this study was to find out how much the air temperature of the Helsinki region (60°N, 24°E) has risen and how the grapevine growth cycle has changed since the beginning of 2000 for two consecutive decades.

2. MATERIAL AND METHODS

The study was conducted in a vineyard located in the Helsinki region (60°24'N, 25°01'E) in Southern Finland. It compared the annual averages of climate temperatures and the lengths of growing seasons over the past decade (2010–2019) with the first decade (2000–2009) of the 2000s. The average annual air temperatures and lengths of the growing seasons were based on the weather statistics of the Finnish Meteorological Institute. The bud burst and harvest-ripe berries of the monitored *Vitis vinifera* variety *Vitis* 'Rondo' were based on the Eichhorn-Lorenz phenological stages (Eichorn& Lorenz, 1977). The sugar concentration of the grapes at harvest measured by the Brix refractometer was 18%. The statistical treatment was compiled with a paired *t-test*, where $p<0.05$ was used to estimate statistical significance.

3. RESULTS AND DISCUSSION

During the 160-year monitoring of the Finnish climate, the climate has warmed by 0.6 °C since the beginning of the 2000s compared with the 160-year average (Tietäväinen *et al.* 2010), which indicates an accelerated rising of the climate temperature. The study evaluated the first two decades of the millennium and found that the temperature in the Helsinki region increased by 0.4 °C during the latter 10-year period (2010-2019) compared to the previous 10-year period (2000-2009) (Table 1). Compared to the results of Tietäväinen *et al.,* (2010), this increase was more than twice higher per decade. It is also noteworthy that during 2010–2019, the average annual temperature of the climate exceeded seven times 7 °C and was close to 8 °C in 2015 (Table 1). The climate of Northern Europe is characterized by warm summer months with mild temperature fluctuations; winter months are cold with unstable temperatures with extreme fluctuations. Due to the cold winter months, the annual average air temperatures in the Helsinki region still remain below 9 °C, which is considered one of the preconditions for the success of *Vitis vinifera* (Bauer *et al.,* 2014).

Table 1 Comparison of annual average air temperatures between 2000—2009 and 2010—2019

Year	Annual average air temperature °C	Year	Annual average air temperature °C
2000	7.2	2010	5.0
2001	5.9	2011	7.2
2002	6.1	2012	7.0
2003	5.6	2013	7.0
2004	6.2	2014	7.3
2005	6.6	2015	7.8

2006	6.7	2016	6.6
2007	7.0	2017	6.6
2008	7.8	2018	7.3
2009	6.2	2019	7.0
X̄ ±SD	6.5 ± 0.7		6.9 ± 0.7
Median	6.4		7.0

Statistical difference between averages: t =1.06851, p> 0.05

In cool wine growing areas, an increase in temperature by 1 °C has been calculated to extend the growing season by 11 days (Finnish Meteorological Institute, 2018), but in warm and hot areas, a rise in climate temperature may lead to a shorter growing season (Wheeling, 2017). In this study, the average growing season during 2010-2019 was only 1 day longer than the average for 2010-2009. Based on the median value, the lengthening of the growing season was more distinct (Table 2). There were large fluctuations of almost two months in the lengths of growing seasons during both periods. Therefore, there cannot be statistically significant differences over these short 10-year time periods. In addition, it has been stated that, between the lengths of the growing seasons and changes in climate temperatures, the correlation is poor (Karvonen, 2014). Only a rise in temperature of 1 °C over the next decades might result a clear prolongation of the growing season.

Table 2 Comparison of lengths of growing seasons between two consecutive decades, average air temperature above 5 °C

Start and end dates of growing seasons	Year	Length of growing seasons, days	Year	Start and end dates of growing seasons	Length of growing seasons, days
21 Apr -20 Oct	2000	177	2010	10 Apr - 4 Nov	209
22 Apr -19 Oct	2001	175	2011	4 Apr - 8 Nov	208
10 Apr -2 Oct	2002	176	2012	21 Apr - 21Oct	185
16 Apr -14 Oct	2003	182	2013	23 Apr -13 Oct	176
15 Apr -27 Oct	2004	196	2014	17 Apr -14 Oct	182
13 Apr -15 Nov	2005	217	2015	8 Apr -5 Oct	191
22 Apr -27 Oct	2006	189	2016	6 Apr - 24 Oct	194
11 Apr -1 Nov	2007	205	2017	1 May -18 Oct	174
1 Apr -15 Nov	2008	229	2018	14 Apr -17 Nov	221
23 Apr -8 Oct	2009	169	2019	16 Apr - 28 Oct	195
	X̄ ± SD	192 ± 20			193 ± 15
	Median	186			191

Statistical difference between averages: t = 0.53453, p> 0.05

The budburst of the grapevine is depending on the geographical location and elevation of the vineyard, local microclimate and grape variety. In temperate zones of the Northern hemisphere, the vine buds break out between March and April (Bauer*et al.,* 2014). The budburst is also strongly dependent on the soil temperature (Tomasi *et al.,* 2007; Koch & Oehl, 2018). Therefore, in the cool and cold Northern wine growing areas the buds do not break out until the soil temperature is over 7 °C in the depth of 40 cm (Karvonen, 2014). The budburst at the end of May reduces also the risk of the late frost. In this study, the budburst of *Vitis vinifera* 'Rondo' was latest on 21 May. There were no significant differences between the average dates of budburst between the decades (2000–2009) and 2010–2019 (Table 3).

Table 3 Number of days before bud break after 30 April (E-L No 5)

Year	Number of days	Year	Number of days
2000	11	2010	11
2001	12	2011	8
2002	1	2012	9
2003	16	2013	14
2004	2	2014	13
2005	6	2015	15

2006	12	2016	11
2007	11	2017	21
2008	14	2018	11
2009	12	2019	8
$\bar{X}$ ±SD	10 ± 5		12 ± 4
Median	12		11

Statistical difference between averages: t = 0.53453, p> 0.05

At the start of the grape harvest and growth cycle of grapes, there have always been big interannual variations, even in the same locality. Garnier *et al.* (2011) investigated the beginning date of harvest from 1525 to 1847 in Besancon (France), and during that period, the interannual beginning of the harvest had fluctuated 66 days as a consequence of wars and years with an exceptional climate. After that, climate warming has promoted the grapes to harvest. During the last 40-year period (1975–2014), the grape harvest of *Vitis vinifera* varieties had advanced in South-western Germany by 26–27 days 17 (Koch & Oehl, 2018). In the conducted study containing two consecutive decades, the onset of the grape harvest was reduced by 6 days, indicating a statistically significant earlier harvest (p <0.05). The biggest difference between the years was 21 days. In 2018 and 2019, grapes were harvested ripe already in the first week of September. From the results, it can be concluded that the grape harvest moved almost one week earlier as a consequence of climate warming in the cool climate of the Helsinki region (Table 4).

Table 4 Number of days before start of harvest after 31 August (E-L No 38)

Year	Number of days	Year	Number of days
2000	27	2010	28
2001	31 (1 Oct)	2011	19
2002	14	2012	30
2003	22	2013	14
2004	36 (6 Oct)	2014	19
2005	30	2015	28
2006	19	2016	9
2007	18	2017	28
2008	31(1 Oct)	2018	8
2009	22	2019	7
$\bar{X}$ ±SD	25 ± 7		19 ± 9
Median	24.5		19

Statistical difference between averages: t = 4.74345, p< 0.05

In Northern European cool climates, the growth cycle of the grapevine from the flowering to the harvest has been reported to last 100 days 19 (Nordmark, 2017). However, it is influenced by the local climate, the temperature sum of growing season and the selection of grape variety (Huglin & Schneider, 1998). According to Table 5, the growth cycle of the *Vitis vinifera* cultivar *Vitis* 'Rondo' from bud burst (E-L 5) to harvest (E-L 38 and Brix18%) had declined during the second decade by an average of 11 days and a median of about 13 days. The difference is statistically significant (p<0.05) and is related to the significant earlier start of harvesting, which might have been promoted by the climate warming by 0.4 °C during the 10-year period. Due to the shortened growth cycle, it can be concluded that the period from the flowering to the harvest has been shortened to less than 100 days (Nordmark, 2017).

Table 5 Comparison between the lengths of grapevine growth cycles from bud burst to harvest over two decades.

Year	Length of growth cycles days	Year	Length of growth cycles days
2000	144	2010	140
2001	142	2011	134
2002	139	2012	142
2003	127	2013	116
2004	157	2014	126

2005	147	2015	133
2006	130	2016	117
2007	130	2017	128
2008	140	2018	116
2009	133	2019	120
$\bar{X}$ ±SD	139 ± 9		128 ± 9
Median	140		127

Statistical difference between averages: $t = 8.19916$, $p < 0.05$

4. CONCLUSION

The study viewed climate change and its impact on grapevine growth conditions in the Helsinki region during the first two decades of the millennium. It observed an increase of 0.4 °C in the latter 10-year period compared to the previous 10-year period. Compared to the decades of the previous 20th century, this increase was more than twice higher during each of them. Between 2010 and 2019, the mean annual climate temperature exceeded seven times 7 °C, and in 2015, it was close to 8 ° C. The budburst was latest on May 21. The growth cycle of *Vitis vinifera* variety Vitis 'Rondo', from bud break (E-L 5) to harvest (E-L 38 and Brix18%), was shortened by 11 days on average and by median 13 days over the second decade (2010–2019) compared to 2000–2019. The difference is statistically significant ($p<0.05$). The average beginning of harvest was shortened by 6 days, indicating a significant earlier harvest ($p<0.05$). The biggest difference in harvest days between the years was 21 days. The mean length of the growing seasons in 2010–2019 was only 1 day longer than the mean in 2000–2009. The median was slightly longer. Even during these short two decades, little upward trending climate warming significantly accelerated the growth cycle of *Vitis vinifera* 'Rondo' in the Helsinki region.

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