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# The annual growth cycle of grapevines in Southern Finland

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## Summary

**The aim of this study was to investigate whether grape growing is possible in the southernmost areas of Finland, in the Helsinki-Vantaa area (Tuusula parish, lat. 60°24′10″N, long. 25°25′45″E). The annual growing cycle of grapevines, with some climate parameters, was monitored over ten years (2002-2011). The growth cycle of grapevines from bud break to harvest was 138 (± 9) days, the growing season 198(±18) days, the temperature sum 1608 (± 131) °C days (GDD, basic + 5 °C) and 794 (± 121) °C days (basic +10 °C), the number of sunshine hours 1447 (± 117) h, and the solar energy 2904 (± 127) MJ/m². Dependence was calculated between some essential growth factors by statistical analyses. According to the results it can be concluded that, under existing weather conditions, grape growing is possible in southernmost Finland, although it will be necessary to find or further develop varieties adapted to the northern cool climate and to identify regions with an optimal microclimate for growing grapes.**


K e y  w o r d s: Nordic grape growing, growing season, sunshine hours, temperature sum.

## Introduction

The northern limit for permanent growing of the European vine (*Vitis vinifera* L.) has extended to lat. 52°N within recent decades (Bauer 2008). The northernmost professional or pilot-type grape growing occurs nowadays in Poland (Szczecin, lat. 53°25´N), Denmark (Copenhagen area, lat. 55°33´N), Estonia (Räpina, lat. 58°05′N), Sweden (Stockholm area, lat. 59°10´), and Finland (Helsinki-Vantaa area, lat. 60°10´N). Plant breeding and global warming has made it possible to grow adapted grape varieties in Europe further north than lat. 52°N. Thus, grape growing is extending into many of those regions where it used to take place during the medieval warm climate period of the 1300s (Gladstones 2011).

The cool climate following the medieval warm period has hindered wine growing in Northern Europe, although efforts to grow grapes have persisted for hundreds of years (e.g. Justander 1786). During the last century the global temperature has risen by 0.6 to 1.0 °C (Briffa and Jones 1995, Intergovernmental Panel on Climate Change 2001 and 2007), and the growing seasons in European countries have been prolonged (Menzel *et al.* 2003, Menzel *et al.* 2008). Global warming has also been clearly detectable in the Baltic Sea and its surrounding countries (Zorida 2012), which has prolonged the growing seasons in these areas. As a consequence of this, vine growing conditions are becoming suitable for many hybrid and some *V. vinifera* L. grape varieties in Northern Europe. In Finland, the mean annual temperature has risen by approximately + 1 °C during the last 160 years (Tietäväinen *et al.* 2010). Concurrently, the duration and intensity of the thermal growing season has lengthened and, according to a "Central" scenario, will be lengthened by 4 weeks in Finland by the 2050s (Carter 1998). As a consequence of predicted global warming (Gubler *et al. 2006*), climatic change is expected to develop more and more favorably for northern wine growing in Europe.

In Finland and other parts of Northern Europe, grape growing is generally believed to be limited by shorter growing seasons and a cooler climate in comparison with conditions in Central Europe. However, long days and long sunshine hours during the growing season, which benefit vine growth and the ripening of berries, compensate for the slightly shorter growing season and slightly cooler climate of southern Fennoscandia during June, July, and August as compared with Central European wine growing areas. The aim of this study was to investigate and deduce whether grape growing is currently possible in southernmost Finland, based on ten years of monitoring.

## Material and Methods

The hybrid grape varieties 'Nordica' (*V. vinifera* x *V. labrusca*), 'Zilga' ('Dvietes 4-2-08') ('Smuglyanka' x 'Dvietes Zila') x 'Jubileinaja Novgoroda') and 'Rondo' (('Précoce de Maligre' x *V. amurensis* Rupr.) x 'St. Laurent'), previously grown in northern Europe, the Baltic countries, and the Netherlands, were monitored in this study during 2002–2011. These varieties were winter resistant black-grape hybrid varieties.

All vines (100 vine stocks) grown on their own roots were planted at a depth of 40-60 cm with a row spacing of 1.5-2.0 m and inter-plant spacing of 2.0 m. The soil was sandy clay with a high organic matter content of 6-8 % and a pH level ranging from 5.8 to 6.2 at a depth of 40 cm. The stocks grew unprotected in rows facing southwest and the offshoots were attached to wires at a height of 1.3 m, according to the single Guyot pruning system. In southernmost Finland (the Helsinki-Vantaa area), data on the annual mean temperature, the length of the growing season, the temperature sum of the growing season (GDD, + 5 °C basic temperature and + 10 °C basic temperature), the sun-

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shine hours, and the solar energy of the growing season for 2002-2011 were obtained from the Finnish Meteorological Institute (2012).

The stages of the annual growth cycle of grapevines were evaluated according to the following criteria (Eichhorn and Lorenz 1977, Coombe 1995): 1) bud break (Eichhorn-Lorenz no. 4): overwintered buds swelled; first leaf tissue visible, 2) flowering (Eichhorn-Lorenz no. 18): flowers formed on the inflorescence primordia after bud burst, 3) fruit setting and veraison, lasting from the end of flowering until veraison and the harvest stage (Eichhorn-Lorenz no. 35-38). In this study, in order to compare dates for the beginning of harvest in each year, harvesting started when the E-L no. was 38 and the Brix value reached a minimum of 16 °Brix. Thereafter the harvest was continued incrementally for 10-14 d, and at the very end of harvest, the highest Brix values were 20-22 °Brix.

The dependence and statistical significance between growth factors, such as annual mean temperature, length of growing season, GDDs, number of sunshine hours, and solar energy were reported using the Pearson correlation coefficient $R^2$. Its difference to zero was tested with test quantity t and calculated with the formula:

$$t = R\sqrt{\mathrm{n} - 2/1 - R^2}$$

when the degrees of freedom (*df*) were n - 2. The *P*-value corresponding to the observed test quantity was extracted from the *t* distribution.

## Results

Tab. 1 shows the annual growth cycle of grapevines during ten consecutive years. The start and end of various stages in the growth cycle varied between different years by about two weeks. Bud swelling and breaking began between May 1 and May 16, followed by bud burst shoots a few days later. During the ten-year period, the earliest date for the start of harvest was September 14, 2002, and the latest October 7, 2004. (Tab. 1)

The period from bud break until blooming was, on average, 51(± 7) d (range 39-67 d) *i.e.* about 1.5 months. This was the longest single stage of the growth cycle, though each stage of the growth cycle lasted approximately 1.5 months. The time period from blooming until start of harvest (16 °Brix) lasted three months. In Southern Finland, the growth phase of grapevines from the beginning of bud break until harvest and crop maturation lasted, on average, 138 (± 9) d (range 129-158 d), *i.e.* 4.5-5.5 months (Tab. 2).

The shortest growing season lasted 169 d (2009), and the longest 229 d (2008). The growing season averaged 198 (± 18) d (median 205 d) for ten years, *i.e.* nearly 6.5 months. The mean GDD (basic +5 °C) was 1608 (± 131) °C d and 794 (± 121) °C (basic +10 °C). In four years (2003, 2004, 2008, 2009) GDD (basic +5 °C) was 1424-1491 °C days, but during the last observation year (2011) it was 1829 °C d and 934 °C d (basic +10 °C). In 2002-2011 the mean number of sunshine hours over the whole growing season was 1447 (± 117) h and solar energy, on average, 2904 (± 127) MJ/m² (Tab. 3).

In the Helsinki-Vantaa area, a significant dependence was calculated between sunshine hours and solar radiation, sunshine hours and GDD (basic + 5 °C), and solar radiation and GDD (basic + 5C). There was no significant dependence between other external growth factors such as annual average temperature and growing season, and annual average temperature and GDD (Tab. 4).

## Discussion

It is widely believed that in Finland and elsewhere in Northern Europe, at lat. 55°-60°N, grape growing is limited by the persistent snow layer, shorter growing seasons, and

Table 1

Stages of annual growth cycle of grapevine in Helsinki-Vantaa area (Tuusula, 60°24’10´´N, 25°25’45´’E) during 2002-2011

| Year | Bud break[a] | Blooming[b] | Veraison[c] | Harvest[d] |
|---|---|---|---|---|
| 2002 | 1 May | 16 June – 28 June | 2 August | 14 September |
| 2003 | 16 May | 9 July – 23 July | 16 August | 22 September |
| 2004 | 2 May | 8 July – 26 July | 9 August | 7 October |
| 2005 | 6 May | 1 July – 15 July | 27 July | 30 September |
| 2006 | 12 May. | 30 June – 12 July | 7 August | 19 September |
| 2007 | 11 May | 2 July – 14 July | 22 August | 18 September |
| 2008 | 14 May | 1 July − 14 July | 9 August | 1 October |
| 2009 | 12 May | 20 June – 29 June | 6 August | 22 September |
| 2010 | 11 May | 29 June − 14 July | 10 August | 28 September |
| 2011 | 8 May | 25 June – 10 July | 6 August | 19 September |

[a]E-L no. 4 (Green tip; first leaf tissue visible) [b]E-L no. 18 (Inflorescence well developed, flower caps in place, but color fading from green); [c]E-L no. 35 (Berries begin to change color); [d]E-L no. 38 (Berries harvest ripe); E-L no. (Eichhorn-Lorenz number) for grapevine growth stages; Modified from Eichhorn-Lorenz (1977) by Coombe (1995).

Table 2

Lengths of stages of annual growth cycle of grapevine in Helsinki-Vantaa area (Tuusula 60°24´10’’N, 25°25’45’’E) during 2002-2011

| Year | Bud break to start of blooming (d) | Start of blooming to start of veraison (d) | Start of veraison to start of harvest (d) | Total growth cycle (d) |
|---|---|---|---|---|
| 2002 | 47 | 47 | 43 | 137 |
| 2003 | 54 | 38 | 37 | 129 |
| 2004 | 67 | 32 | 59 | 158 |
| 2005 | 56 | 26 | 65 | 147 |
| 2006 | 49 | 39 | 43 | 131 |
| 2007 | 52 | 51 | 27 | 130 |
| 2008 | 48 | 39 | 52 | 139 |
| 2009 | 39 | 57 | 37 | 133 |
| 2010 | 49 | 42 | 49 | 140 |
| 2011 | 48 | 42 | 44 | 134 |
| $\bar{X}$±SD | 51±7 | 41±8 | 47±10 | 138±9 |
| Median | 49 | 41 | 46 | 136 |

Table 3

Annual average temperatures, lengths of growing seasons, temperature sums of growing seasons, sunshine hours and solar radiation in Helsinki-Vantaa area during 2002-2011

| Year | AAT* °C | First and last d of GS[a] | GS[b] (d) | GDD[c] 5 °C (d) | GDD[c] 10 °C (d) | SH[d] during GS | SE[e] during GS |
|---|---|---|---|---|---|---|---|
| 2002 | 6.0 | Apr. 10 - Oct. 2 | 176 | 1669 | 940 | 1661 | 3168 |
| 2003 | 6.2 | Apr. 16 - Oct. 14 | 182 | 1489 | 723 | 1310 | 2721 |
| 2004 | 7.1 | Apr. 15 - Oct. 27 | 196 | 1424 | 634 | 1290 | 2729 |
| 2005 | 6.6 | Apr. 13 - Nov. 15 | 217 | 1607 | 750 | 1501 | 2949 |
| 2006 | 6.7 | Apr. 22 - Oct. 27 | 189 | 1763 | 915 | 1599 | 2991 |
| 2007 | 7.0 | Apr. 11 - Nov. 1 | 205 | 1592 | 766 | 1428 | 2914 |
| 2008 | 7.6 | Apr. 1 - Nov. 15 | 229 | 1474 | 619 | 1428 | 2902 |
| 2009 | 6.2 | Apr. 23 - Oct. 8 | 169 | 1491 | 719 | 1334 | 2798 |
| 2010 | 5.9 | Apr. 10 - Nov. 4 | 209 | 1711 | 939 | 1401 | 2978 |
| 2011 | 7.2 | Apr. 4 - Nov. 8 | 208 | 1829 | 934 | 1518 | 2888 |
| $\bar{X}$±SD | 6.7 ± 0.5 | | 198 ± 18 | 1608 ± 131 | 794 ± 121 | 1447 ± 117 | 2904 ± 127 |
| Median | 6.7 | | 205 | 1600 | 758 | 1428 | 2908 |

* Annual average temperature, [a]growing season, [b]length of growing season, [c]growing degree days (+ 5 °C d and + 10 °C d), [d]number of sunshine hours, [e]solar energy (MJ/m²).

cooler climate in comparison with conditions in Central Europe. However, over the last 20 years several grapevine varieties have been found suitable for growing in Northern Europe (Stock *et al.* 2005). In Denmark, 48 grapevine varieties have been approved for growing. Among the most popular are 'Ortega', 'Rondo', 'Leon Milot', 'Madelaine Angevine', 'Solaris', and 'Phoenix' (Bentzen and Smith 2009). The same varieties are also grown in Sweden and Finland.

In this study monitored hybrid grape varieties 'Nordica', 'Zilga' and 'Rondo' have proved to be winter resistant and abundant harvest giving cultivars at the latitude of 59-60 degrees in Sweden and Finland (Flen, Stockholm, Turku, Helsinki) over the last 10-20 years. 'Zilga', bred in Latvia and flourishing in cool climates, is the variety most certain to produce a crop above the latitude of 55 degrees. It has been grown on open land even up to the latitude of 63 degrees in Finland (Karvonen 2010).

In northern Europe the onset of grapevine growth is delayed because of late snow cover, which may persist until mid-April. Consequently, bleeding begins at this latitude only in late April or early May, when the snow cover melts completely and surface soil frost no longer represents a threat. It should be realized, however, that the thick snow layer protects grapevines against heavy winter frost (Karvonen 2008) and, in turn, the long days during the growing season, which benefit vine growth and the ripening of berries, compensate for the slightly shorter growing season in southern regions of the Nordic Countries.

Snow is exploited in viticulture in different parts of the world. In Canada, the growth period lasts for six months and, in winter, temperatures can fall to -30 °C, the ground freezes, and several feet of snow cover the ground (Bells 2013). In Siberia, the snow cover is raised to 1.5 m by installing a snow fence in the middle of the vineyard to

Table 4

Correlation coefficients and significances between growth factors during growing seasons in Helsinki-Vantaa area during 2002-2011

| Growth factors | *n** | Growth factors | *R* | *R²* | *t* | *P* |
|---|---|---|---|---|---|---|
| Sunshine hours | 10 | solar radiation | 0.89 | 0.80 | 5.6288 | <0.001 |
| Sunshine hours | 10 | GDD** | 0.72 | 0.52 | 2.9394 | <0.02 |
| Solar radiation | 10 | GDD** | 0.61 | 0.37 | 2.1737 | <0.02 |
| Annual average temperature | 10 | length of growing season | 0.37 | 0.14 | 1.1285 | <0.1 |
| Annual average temperature | 10 | GDD** | 0.37 | 0.14 | 1.1285 | <0.1 |
| Length of growing season | 10 | annual growth cycle | 0.30 | 0.09 | 0.3145 | >0.2 |
| Length of growing season | 10 | GDD** | 0.10 | 0.01 | 0.2843 | >0.2 |

* The sample size, statistically significant $P \leq 0.05$. ** Growing degree d (+5 °C).

accumulate snow on both sides (Yaschenko 2006). In the Helsinki-Vantaa area, there is no need to cover the vines in snow and soil, as the temperature in Southern Finland does not drop to -40 °C as it does in Canada or Siberia.

On the basis of the records presented in Tab. 1 and 2, and according to many previous climate change studies (Menzel *et al.* 2003, Menzel *et al.* 2008, Tietäväinen *et al.* 2011), this study also set out to determine whether current growth conditions in southernmost Finland have changed or are changing so as to allow the outdoor cultivation of grapes. Tab. 3 shows how the mean temperatures of single years in the Helsinki-Vantaa area (Tuusula) were, in each of the ten years monitored, 0.3-1.0 °C higher than the mean (5.6 °C) for the annual temperatures monitored in 1971-2000 by the Finnish Meteorological Institute (2004).

The grapevine rarely begins to bloom in Southern Finland in mid-June. In general, blooming starts in late June and continues for about two weeks (Tab. 1 and 2). In Central Europe, the blooming usually starts in late May, or in early June, and sometimes occurs as late as early July (Johnson 1994). In Southern Finland, the veraison begins in mid-August and grapes are harvested after mid-September.

During the period from blooming to harvest, the GDD and number of sunshine hours are crucial for growth and ripening. According to Bauer (2008) *V. vinifera* L. requires at least 180 d of vegetative growing season. In northern parts of Scandinavia, the thermal growing season is shorter than 180 d, but in Denmark and at the southern boundary of the hemiboreal growth zone (Peel *et al. 2007*), in Southern Finland and Southern Sweden and in the Baltic countries, it is from 180 to 200 d (Rötzer and Chmielewski 2001), which is sufficient for growing *V. vinifera* L. (Bauer 2008).

Currently, at the northern boundary of the hemiboreal growth zone, in Tuusula, the mean thermal growing season has been over 180 d in most years, so grape growing with suitable varieties could be successful there. Tab. 3 shows that the mean length of the thermal growing season for this decade was 198 (± 18) d. Every year GDD (basic +5 °C) was more than 1400 °C d and the mean for ten years was 1600 °C d, and the GDD (basic +10 °C) was on average 794 °C d. These circumstances are satisfactory for such *V. vinifera* L. varieties as 'Müller-Thurgau' (Löhnertz 2006, lectures, FH Eisenstadt). The annual mean temperatures at the growing site ranged from 5.9 to 7.6 °C around a mean for the entire period of 6.7 °C (Tab. 3). It remained significantly lower than the annual mean temperatures of several of the northernmost vine growing regions of Central Europe. Thus, mean annual temperatures have remained, on a year-by-year basis, lower than the 9 °C that Bauer (2008) considered the annual mean temperature for successful grape growing.

However, the annual mean temperatures can differ considerably from the long-term annual mean values presented in Tab. 3. In Fennoscandia, and in the Baltic countries, the northern winter reduces the annual mean temperature compared with Central Europe, but weather conditions such as sunshine hours and GDD (basic + 5 °C and + 10 °C) during the growing seasons are sufficiently warm for grape growing. For comparison, and to make a notable contrast, in the Yellow River valley in Inner Mongolia, 64 t of grapes are grown under climate conditions where the annual mean temperature is 6 °C and the frost-free period 127-180 d (Xiaoyan *et al.* 2012).

In most of Germany, the Czech Republic, Poland, southern Fennoscandia, and the Baltic countries the growing season begins about April 15-25 and ends on October 25-30 (Rötzer and Chmielewski 2001). The growing season in the Helsinki-Vantaa area may begin and end at about the same time (Finnish Meteorological Institute 2012). As shown in Tab. 2, over a period of eight years the growing season began in the Helsinki-Vantaa area (Tuusula) on April 15-25, with one year (2004) being earlier and one year (2003) later than the dates reported by Rötzer and Chmielewski (2001).

Vine growth and grape ripening depend, not only on the length of the growing season, but also on the length of the day, the amount of sunlight, and the intensity of solar radiation. In the Helsinki-Vantaa area the day is 3-3.5 h longer in May, June and July than in Bordeaux, and 2-2.5 h longer than in northern viticultural areas in Europe (e.g. Saale-Unstrut region, Germany, 51°N), but in August the difference narrows to 1.0-1.5 h. In South-Scandinavian areas, including the most southern Finland, the day length differences in May, June and July are only 0.5-1.5 hours (Gaisma 2012). In Northern Europe, the longer days of the growing season and the abundant sunshine can compensate for the shorter growing season compared to Central Europe. The total solar radiation energy of the growing season, 2904 (± 127) MJ/m² in the Helsinki-Vantaa area, was 8 % lower than in Klosterneuburg (Austria) and 18 % lower than in Bordeaux, in Central European wine growing areas, and compared to the Saale-Unstrut area it was 5 % lower. The solar radiation energy of the growing seasons varies in South-Scandinavia 2900-3200 MJ/m², that is at the same level or 100-200 MJ/m² lower than the solar radiation energy in northern traditional viticultural areas in Europe (Gaisma 2012, Finnish Meteorological Institute 2012).

The impact of single climate parameters on the phenological development of grapevines is difficult to evaluate. Only in years 2004, 2005 and 2008, when GDD (basic + 10 °C) has been exceptionally low, the total growth cycles have been longer than usual, too (Tab. 1, 2 and 3). On the other hand, compared to southernmost Sweden and Denmark and northern traditional viticultural areas in Europe such as Saale-Unstrut in Germany and Velke Zernoseky in the Czech Republic, bud break (E-L number 4) and blooming (E-L number 18) start in Tuusula 2-3 weeks later, but harvest (E-L number 38) may start simultaneously or even earlier. However, there are significant differences between individual years.

In statistical analyses, dependence was observed between sunshine hours and solar radiation, sunshine hours and GDDs, and solar radiation and GDDs, but correlations and dependencies were not evident between annual mean temperature and length of growing season, and annual mean temperature and GDDs, and between other external growth factors (Tab. 4). Other authors (Bootsma 1994, Briffa *et al.* 2009) recently reached a similar conclusion. They observed that during the current growing season there is so much variation that many compensation mechanisms operate to ensure a harvest.

## Conclusions

The growing of *Vitis vinifera* L. varieties and their hybrids up to reaching a harvest is nowadays possible in southernmost Finland, in the Helsinki-Vantaa region (Tuusula) at latitude of 60 °N. However, the varieties must have good winter resistance, the growing place must be as warm as possible, and the local microclimate must be optimal. Predicted global warming will further ameliorate conditions for grape growing and expand the growing conditions farther north.

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