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TRENDS IN CLIMATICALLY RELEVANT TEMPERATURE INDICES FOR GRAPEVINE GROWING IN THE REGION OF SREMSKI KARLOVCI, SERBIA

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Abstract

The study aimed to evaluate the structure, variability and trends of climate parameters important for grapevine growing in Sremski Karlovci for the period 1981–2007. A number of average and extreme temperature indices were calculated for annual, growing season and different growth intervals of grapevine. Results showed significant trends in: annual mean, maximum and minimum temperatures (0.06, 0.06 and 0.05°C/year, respectively); growing season mean, maximum and minimum temperatures (0.04, 0.05 and 0.05°C/year, respectively); growing degree days (10.7°C/year); annual number of days with minimum temperature higher than 90th percentile (1.0 days/year); annual number of days with maximum temperature higher than 90th percentile (0.9 days/year); the number of days with maximum temperatures above 30°C (0.7 days/year) and the number of days with maximum temperatures above 35°C (0.2 days/year); the number of tropical nights (0.6 days/year); the number of days with minimum temperatures below –2.5°C (–0.5 days/year). The most pronounced changes in climatic variables examined were recorded during the period from flowering to veraison.

Key words: grapevine, temperature indices, trends, Sremski Karlovci, Serbia

Introduction

Climate is one of the most important factors controlling grape and wine production from selection of a suitable grapevine varieties to the type and quality of wines produced (Gladstones, 1992). Recent climate change has been found to affect viticulture and wine industry across the world. Climate change is not uniform and the impact on viticulture depends on the region and the ways in which the climate change (Jones and Davis, 2000; Jones at al., 2005; Laget et al., 2008; Nemani et al., 2001; Petrie and Sadras, 2008; Ramos et al., 2008).

Out of all the climatic factors, temperature appears to be the most important, influencing the growth and development of the vine, the metabolism of acids and accumulation of sugars, the formation of different compounds that give the aroma, colour and flavour in grapes. During the winter, the completion of chilling requirements in regular and sufficient way is necessary for setting the latent buds effectively. During the spring, grapevines need sustained daily mean temperatures above 10°C to initiate growth. Growing season length and temperatures have a major influence on grape ripening and fruit quality. Jones et al. (2005) showed that average growing season temperature plays an important role for quality vintages and that increases in temperature may result in decreased quality for those varieties that are cultivated close to their optimum climatic conditions.

One of the most significant signals of the global and regional climate changes, in addition to the changes in the average temperature conditions, is the change in the extreme temperature indices. Temperature extremes during berry growth may cause premature veraison, abscission of the berries and less flavor development (Mullins et al. 1992). So-called “negative” temperatures for vine

(maximum daily temperature above 35^{o}C) may cause partial or total inhibition of plant function, especially when associated with drought. Frost occurrence and timing affect viticulture in many ways and may present a limiting climatic factor for vine growing. Low frost risk in spring and fall, and a long frost-free period are favourable for grapevine. During the spring, temperatures below −2.5°C can adversely affect the growth and reduce bud fruitfulness, leading to lower yields and quality of grapes, while fall frosts may injure maturing canes and berries. In the winter, extreme low temperatures may cause freezing injuries to grapevines. The minimum temperature that vine may resist in the winter varies from −5 to −20◦C (Winkler et al., 1974), depending on cultivar, location, characteristics of the low-temperature episode and viticultural practices.
The aim of the study was to determine recent-past trends in biophysically meaningful variables for viticulture in order to study the impacts of climatic changes and variability on grape growing in the region of Sremski Karlovci.

Materials and methods

The study was done for Sremski Karlovci situated on Mt. Fruška Gora's slopes in the Srem viticultural region. Air temperature data were from climatological station maintained by the Republic Hydrometeorological Service of Serbia from 1981 until 2007. The station was located at 45°10' N and 20°10' E, 110 at an eleveation of 110 m in the ampelographic collection of the Novi Sad Faculty of Agriculture, where phenological observations of a great number of grapevine cultivars have been conducting since 1986.

To analyze the climate structure in these regions, daily maximum and minimum temperatures were used to derive a number of climatically important parameters for grape growing (Table 1). Besides average values, extreme temperature indices were calculated. They were based on fixed thresholds that have biological meaning for grapevine, station-related thresholds (percentile-based indicators) and variability extremes, which give the relationship between maximum and minimum temperatures (i.e. diurnal temperature range). In addition, various periods were considered: annual, growing season and different growth intervals of grapevine.
The trends in temperature indices are determined by the slope from a linear regression fit.

Results and discussion

Basic descriptive statistics, the slope of linear regressions and corresponding correlation coefficients (R) f or the selected temperature indices are given in Table1.

Growing season temperature for the period 1981–2007 averaged 17.8°C, while mean annual temperature for the same period was 12.3°C. During this 27–year period, annual mean temperature increased significantly by 0.06°C/year, maximum temperature by 0.06°C/year and minimum temperature by 0.05°C/year. Growing season mean, maximum and minimum temperatures showed significant trends of 0.04, 0.05 and 0.05°C/year, respectively (Fig. 1). Since the maximum and minimum temperatures changed nearly at the same rate, diurnal temperature range exhibit no significant trends during any period studied. Significant changes (10.7°C/year) in heat unit accumulations during the growing season (calculated as growing

Table 1. Descriptive and trend statistics for temperature based indices for the region of Sremski Karlovci over the period 1981–2007. **Bold** indicates significant trends at the 0.05 (*), 0.01 (**) and 0.001 (***) levels

Index	Mean	SD	Max	Min	Trend (yr^{-1})	R	p-value
ANNUAL							
Average daily temperature (°C)	12.3	0.87	14.2	11.0	**0.05**	0.50	0.004**
Average maximum daily temperature (°C)	16.8	1.05	19.2	15.0	**0.06**	0.43	0.012*
Average minimum daily temperature (°C)	7.7	0.59	9.3	6.5	**0.05**	0.55	0.001***
Number of days with Tmin > 90th percentile	33.2	12.20	59.0	15.0	**1.05**	0.68	<0.001***
Number of days with Tmax > 90th percentile	36.4	15.13	75.0	17.0	**0.87**	0.45	0.009**
Number of days with Tmin < 10th percentile	36.1	11.21	59.0	19.0	-0.22	-0.16	0.219
Number of days with Tmax < 10th percentile	35.8	10.51	56.0	17.0	-0.15	-0.11	0.285
Number of days with Tmax > 25°C	88.3	16.2	123	60	0.52	0.26	0.099
Number of days with Tmax > 30°C	55.4	13.1	63	11	**0.74**	0.45	0.010**
Number of days with Tmax > 35°C	2.7	3.9	15	0	**0.20**	0.41	0.018*
Number of days with Tmin > 20°C	9.7	7.3	25.0	1.0	**0.56**	0.60	<0.001***
Number of days with Tmin < 0°C	66.7	14.8	92.0	34.0	-0.44	-0.24	0.120
Number of days with Tmin < -2.5°C	38.4	11.3	61.0	20.0	**-0.48**	-0.34	0.048*
Number of days with Tmin < -10°C	4.4	4.7	19.0	0.0	-0.10	-0.17	0.204
GROWING SEASON (April – October)							
Average daily temperature (°C)	17.8	0.8	19.6	16.3	**0.04**	0.40	0.021*
Average maximum daily temperature (°C)	23.3	1.1	25.9	21.4	**0.05**	0.40	0.022*
Average minimum daily temperature (°C)	12.8	0.7	14.2	11.5	**0.05**	0.59	0.022*
Diurnal temperature range (°C)	10.5	0.7	11.7	9.4	0.00	0.02	0.468
Growing Degree Days (°C)	1775.9	164.3	2156.8	1529.5	**10.72**	0.52	0.003**
1 JANUARY – BEGINNING OF BUDBURST (January – March)							
Average daily temperature (°C)	3.8	2.3	8.3	-0.5	0.07	0.25	0.100
Average maximum daily temperature (°C)	7.6	2.5	12.4	3.0	0.08	0.27	0.088
Average minimum daily temperature (°C)	0.1	2.1	4.3	-4.0	0.06	0.24	0.119
Number of days with Tmin < 0°C	42.4	16.0	67.0	9.0	-0.35	-0.18	0.200
Number of days with Tmin < -2.5°C	26.8	13.3	54.0	0.0	-0.48	-0.29	0.078
Number of days with Tmin < -10°C	3.3	4.9	19.0	0.0	-0.12	-0.19	0.176
BEGINNING OF BUDBURST – BEGINNING OF FLOWERING (April – May)							
Average daily temperature (°C)	15.0	1.4	17.7	11.6	**0.06**	0.36	0.031*
Average maximum daily temperature (°C)	20.1	1.7	23.5	16.0	**0.07**	0.34	0.042*
Average minimum daily temperature (°C)	9.8	1.1	11.9	7.3	**0.05**	0.39	0.024*
Number of days with Tmin < 0°C	0.7	1.2	5.0	0.0	0.00	0.01	0.472
BEGINNING OF FLOWERING – BEGINNING OF VERAISON (June – July)							
Average daily temperature (°C)	21.4	1.2	24.1	19.1	**0.10**	0.66	<0.001***
Average maximum daily temperature (°C)	26.8	1.5	30.5	24.4	**0.11**	0.60	<0.001***
Average minimum daily temperature (°C)	15.9	1.1	18.2	13.6	**0.09**	0.68	<0.001***
Number of days with Tmax > 25°C	39.0	7.2	55.0	26.0	**0.46**	0.51	0.003**
Number of days with Tmax > 30°C	15.4	7.5	31.0	4.0	**0.57**	0.61	<0.001***
Number of days with Tmax > 35°C	1.2	2.4	11.0	0.0	**0.16**	0.52	0.003**
Number of days with Tmin > 20°C	5.7	4.4	14.0	1.0	**0.40**	0.72	<0.001***
Diurnal temperature range (°C)	10.9	0.8	12.9	9.4	0.02	0.19	0.169
BEGINNING OF VERAISON – HARVEST							
Average daily temperature (°C)	20.2	1.1	22.9	17.5	0.01	0.08	0.347
Average maximum daily temperature (°C)	25.6	1.5	29.3	21.5	-0.01	-0.05	0.407
Average minimum daily temperature (°C)	14.8	0.9	16.9	13.4	0.03	0.28	0.081
Number of days with Tmax > 25°C	34.2	7.4	51.0	20.0	-0.14	-0.15	0.222
Number of days with Tmax > 30°C	11.5	7.3	27.0	1.0	0.03	0.03	0.432
Number of days with Tmax > 35°C	1.5	2.4	10.0	0.0	0.04	0.15	0.229
Number of days with Tmin > 20°C	3.8	4.2	16.0	0.0	0.16	0.31	0.060
Diurnal temperature range (°C)	10.8	1.1	12.8	8.1	-0.04	-0.30	0.067

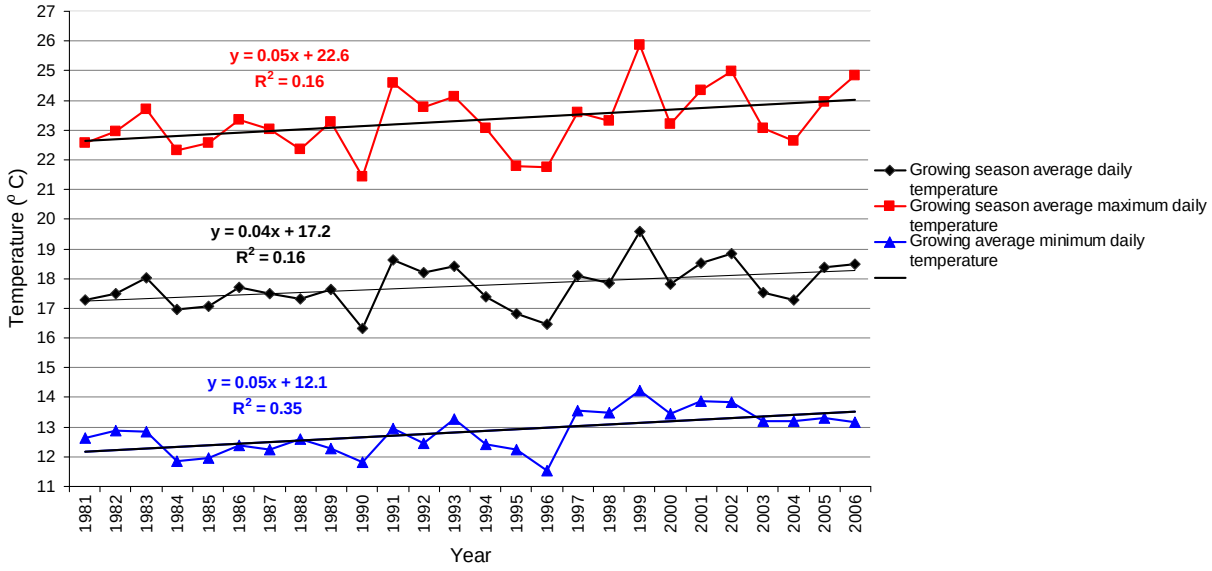

Figure 1. Time series and linear trends for growing season average, maximum and minim daily temperatures from 1981 to 2007 for Sremski Karlovci, Serbia

degree-days using a base of 10°C with no upper cut-off) were detected. Results showed a positive trend in the annual series of most indices related to high temperature. Trends of extreme indices based on percentiles, warm days (Tmax > 90th percentile) and warm nights (Tmin > 90th percentile) were significant. The annual number of tropical days (Tmax > 30 °C) has increased at a faster rate than that of the annual number of summer days (Tmax > 25 °C). The trend of number of days with so-called “negative” temperatures for vine (Tmax > 35°C) also showed significant positive trends, as well as the number of tropical nights (Tmin > 20°C). Examining annual and seasonal frequencies of days with low temperatures, a decline in the number of days with minimum temperatures below 0, – 2.5, –10°C was found. The trend was negative, but not significant, except for the annual number of days with Tmin <–2.5°C.

For the period from beginning of flowering to beginning of veraison, the strongest and most significant trends were detected for all selected indices. Conversely, the same indices did not show significant trends during ripening. This is a consequence of fact that September temperatures showed even negative trend over the study period, while June and July temperatures showed the significant positive trends (data not shown).

Conclusion

Analysis of temperature based indices for Sremski Karlovci, revealed a general warming in this viticultural region over the period from 1981 to 2007. It was found that the daily maximum temperature is getting more extreme, whereas the minimum temperature is getting less extreme. The strongest increase was detected for hot related extremes such as summer days and tropical nights. The nature and trends of climate variables and bioclimatic indices important for grapevine growing suggest that grapevine is and will be grown in warmer conditions than before. Consequently, vine phenology has already been affected and earlier dates of flowering, veraison and harvest have been observed for a number of varieties in the region of Sremski Karlovci (Ruml et al., 2013). The next step in the research will be to relate trends in phenology to trend in climatic variables and to identify temperature indices that have the greatest impact on vine growth and production.

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