Reactions of grape varieties to climate changes in North East Slovenia

S. Vršič[1], T. Vodovnik[2]

[1]*Faculty of Agriculture and Life Sciences, University Centre of Viticulture and Enology Meranovo, Hoče, Slovenia*
[2]*The Maribor Agriculture and Forestry Institute, Maribor, Slovenia*

ABSTRACT

This work examined the trend of changes in temperature from 1950 to 2009 recorded by the Maribor meteorological station, and from 1980 to 2009 the dynamics of grape ripening of early-, medium late-, and late-ripening vine varieties in the Slovenian Styria wine-growing region in North East Slovenia. Based on the data associated with the content of soluble solids, total acidity, and the recommended date of harvest in a particular year, the trends towards shortening of the grapevine growing period were calculated. In general, temperature changes were more significant since 1980 than between 1950 and 1979. The mean annual and seasonal temperature significantly increased, i.e. 0.06°C per year. The growing season was shortened in all studied varieties from 15 to 27 days. Trends showed significantly decreasing content of total acidity, which can be considered explicitly as a consequence of higher temperatures during the growth period and ripening of grape berries. Grapes now ripen at temperatures which are approximately by 2°C higher than 30 years ago. Regarding the total acidity content of the late-ripening varieties, the influence of higher temperatures is positive. Minor changes were found in precipitations rates.

Keywords: vine; growth period; grape ripeness

In the last 20 years the trend towards the warming of the Earth surface can be seen in all periods of the year. Climate models forecast that the average global temperature will rise in the next 50 years (Branković et al. 2010). Milder winters and warmer summers are expected and extremely high temperatures will occur more often, although the risk of low temperatures is expected to be lower (Kohler 2009). Many researchers examined the impacts of climate changes on agricultural production under stressful conditions (Carter et al. 1991, Jones and Davis 2000, Lobell et al. 2006). The importance of these impacts is most evident in viticulture where the quality of wine results from many years of experience and geographic locations of winegrowing regions affected by weather and climate conditions (Kast and Rupp 2009). The increase of UV-B radiation at the soil surface due to the decreased ozone layer can cause changes in the physiology of the vine. The photosynthetic activity, the accumulation of flavonoids and antocyanins, and the concentration of amino acids can decrease. Aromatic profiles can change and the aroma of white wine varieties in particular can be less explicit. Indirectly, the soil respiration may be increased and, therefore, the quantity of the organic mass in the soil may be decreased. The geographical boundary for growing vine will probably move northwards and the selection of the most appropriate varieties for a particular region will be changed (Schultz 2000).

The warming may be more explicit in the cooler half of the year in northern latitudes. Northern regions may again be suitable for viticulture like during the medieval period, from 9 to 13 century AD (Kenny and Harrison 1992, Laget et al. 2008, Flexas et al. 2010). Growing season length and temperatures are critical aspects that have to be taken into consideration to maximize a style of wine and its quality (Jones et al. 2005). The impact

Supported by the Ministry of Agriculture, Forestry and Food of the Republic of Slovenia, Project No CRP:V4-0475, and by the Ministry of Higher Education, Science and Technology of the Republic of Slovenia.

of warming was found to be negative and reduced winegrape quality, which varied from region to region (Webb et al. 2008). Increases in yield variability in the warmest vintages were found by Ramos et al. (2008) and Keller (2010). Hot summers result in earlier grape ripening and vintages and in some wine-growing regions botrytis is more likely to appear (Petgen 2007, Prior 2007). The tendency towards increasingly extreme weather phenomena (more intensive precipitation) can be seen as a result of climate change, which can increase the possibility of soil erosion, in particular in the vineyards on steep slopes (Vršič et al. 2004, 2011). Variability between seasons in many cases is considerably larger than the one achieved by modifying management practices (Clingeleffer 2010). The estimated increase in temperature for Slovenia is from 0.5 to 2.5°C for the period 2001 to 2030 (Bergant and Kajfež-Bogataj 2004). These effects can already be seen in the wine-growing regions of the north-eastern Slovenia. In the last decade, the vine development phases, sprouting, blooming, and grape ripening, on average, have taken place earlier in comparison to the 1980's.

The aim of our study is to examine the changes of temperature and precipitations rates and their impact on harvest date and grape composition in NE Slovenia, based upon existing viticultural data. This is the first national study of the impact of climate change on winegrape quality aimed at establishing the response of studied varieties to increasing temperatures. We hypothesised that increasing temperatures have and will continue to exert influence on grape ripening in the studied region. This paper presents the results of ripening of White Riesling, Sauvignon Blanc, Welschriesling, and Bouvier varieties.

MATERIAL AND METHODS

This study was carried out using the data from the Maribor meteorological station (46°32'N, 15°49'E); elevation 275 m a.s.l. This station provides a good reference of the general structure for temperature and precipitations in Slovenian Styria, the biggest wine-growing region in Slovenia. Daily temperature (mean, maximum, and minimum) and precipitations were recorded between 1950 and 2009. We obtained data from the Environmental Agency of the Republic of Slovenia. An analysis of climate change for the periods 1961–1990 (representing the 20th century), 1950–1979, and 1980–2009 was performed.

The majority of vineyards are predominantly planted on steep slopes with an inclination of 30 to 50% and at an altitude of 250 to 350 m. The mean annual temperature of the investigated area for the referenced period 1961–1990 was 9.7°C; the mean monthly minimum in January was –1.3°C, and the mean monthly maximum in July was 19.6°C. The average annual rainfall was 1045 mm, and more or less equally distributed over the whole year.

For more information of wine region and general guidelines on potential quality and style of wine, the growing degree-days (GDD) (Winkler et al. 1974), and Huglin index (HI) (Huglin 1978) were calculated. The precipitation data were summed up for annual and growing seasons.

The data of the weakly monitoring of grape ripening in the period from 1980 to 2009 for early-, medium late-, and late-ripening vine varieties were statistically analysed. Only in this wine region in Slovenia, the data for these varieties are available for such a long period. The data were collected from eight locations in vineyards around the Maribor meteorological station (wine region Slovenian Styria), and recorded by the Agriculture and Forestry Institute in Maribor to calculate the trends.

For the weekly monitoring of the grapes ripening for each variety, 200 berries have been taken at each location since 1980. Based on the data associated with the sugar content and total acidity in grape juice and the recommended harvest date, the trends towards shortening of the growing season in a particular year were calculated. The harvest date was set in accordance with the Wine Act of Slovenia when the sugar content reached approximately 76°Oe (the limit for quality wine), and 84°Oe (the limit for wine of superior quality). In the case of bad vintages, the harvest date was set according to the sugar content for quality wine or, in the case of the very bad vintages, according to the state of health of the grapes (at the beginning of the1980's).

The variables were evaluated by basic descriptive statistics. Since some of the parameters examined in the study were not normally distributed, a more stringent nonparametric Mann-Kendall trend test (MK-test), with a 95% significance level, was applied to all series (Hirsch et al. 1991). In addition, all time series were tested for autocorrelation using the Durbin-Watson statistic and in some series a serial correlation was detected. The Mann-Kendall test, as well as other distribution-free or parametric tests, is very sensitive to an autocorrelation (persistence) effect.

RESULTS AND DISCUSSION

Structure and trends of temperature. The Slovenian Styria region's climate is continental, characterized by considerable seasonal temperature variability, cold winters, and moderately hot summers. For winegrape maturity potential, the location is considered intermediate based on growing season average temperature (Jones 2006), with 16°C in reference period 1961–1990 and 17°C between 1980 and 2009 (Table 1). The general climate parameters for the period 1950–2009 are: average annual temperature (10°C), growing season temperature (16.4°C – April to September), average dormant temperature (3.5°C – October to March), annual mean maxima (15.2°C) and annual mean minima (5.5°C). The average growing degree-day (GDD) value from April to September and the average Huglin index were 1227 and 1789, respectively (Table 1). These value place Slovenian Styria in Huglin's temperature climate type suitable for the group of Pinots, Chardonnay, White Riesling, Sauvignon Blanc, Sylvaner, Cabernet Franc, and Gamay (Huglin 1978).

Significant annual warming has been observed since 1950. Table 1 provides the trends of annual mean maxima, mean minima, and mean annual temperature. Between 1950 and 1979 only annual mean minima was significantly increased at a rate 0.6°C per decade. No significant changes were observed in mean annual temperature. Decreases in annual mean maxima and GDD (Table 1) were not significant. In fact, the trend of annual mean minima showed significant increase by 1.8°C, and mean temperatures in dormant season by 1.4°C. These increases affected the increase of mean

Table 1. Mean annual and seasonal temperatures, mean temperatures in dormant season (October to March), growing degree days (GDD) and Huglin index at the Maribor station (NE Slovenia) since 1950 for different periods (reference periods 1961–1990, 1950–2009, 1950–1979 and 1980–2009)

Parameter	Period	Mean	SD	Trend/year	*P*
Annual temperature	1961–1990	9.66	0.59	0.032	0.003
	1950–2009	9.97	0.89	0.035	0.000
	1950–1979	9.46	0.61	0.021	0.183
	1980–2009	10.48	0.85	0.060	0.008
Annual mean maximum	1961–1990	14.76	0.74	0.032	0.010
	1950–2009	15.16	0.96	0.028	0.000
	1950–1979	14.71	0.67	–0.007	0.866
	1980–2009	15.60	1.01	0.071	0.031
Annual mean minimum	1961–1990	5.25	0.62	0.048	0.001
	1950–2009	5.50	1.02	0.050	0.000
	1950–1979	4.78	0.74	0.060	0.001
	1980–2009	6.21	0.70	0.057	0.001
Growing season temperature (April to September)	1961–1990	16.01	0.60	0.018	0.103
	1950–2009	16.40	0.95	0.036	0.000
	1950–1979	15.81	0.54	–0.008	0.955
	1980–2009	16.99	0.89	0.061	0.003
Dormant season temperature (October to March)	1961–1990	3.30	1.00	0.046	0.053
	1950–2009	3.54	1.14	0.034	0.002
	1950–1979	3.12	1.06	0.047	0.119
	1980–2009	3.96	1.08	0.060	0.058
GDD (April to September)	1961–1990	1157.7	100.5	3.100	0.069
	1950–2009	1226.7	160.3	6.105	0.000
	1950–1979	1125.7	89.3	–0.700	0.895
	1980–2009	1327.5	152.4	10.107	0.002
Huglin index	1961–1990	1709.7	121.8	2.975	0.088
	1950–2009	1789.3	182.8	5.850	0.000
	1950–1979	1687.3	113.3	–3.289	0.268
	1980–2009	1891.4	183.3	11.327	0.004

annual temperature, but not significantly for this period. Mean annual and seasonal temperature and GDD were slightly below the mean of reference period (1961–1990).

The changes between 1980 and 2009 generally appeared to be strongest. A significant trend of annual warming was observed in annual mean minima, mean maxima, and mean annual temperature at a rate of 0.57, 0.71, and 0.60 per decade, respectively. Mean seasonal temperatures were increased at a rate of 0.61°C per decade and GDD at a value of 101, respectively (Table 1). Temperatures in dormant seasons were increased by 0.60°C per decade. Mean annual temperature in the period from 1980 to 2009 was 10.48°C, in the last decade (2000–2009) it was 11.2°C, which was higher by 1.5°C compared to the mean annual temperature of representing period 1961–1990 (9.7°C).

Similar trends can be seen in mean growing season temperatures. The trend of increase between 1980 and 2009 was 0.061°C per year, with a mean temperature of 17°C. In the last decade (2000–2009) it was 17.7°C, which was higher by 1.7°C compared to the representing period (16°C). Similar trends were also found in other European wine regions, with growing season warming by 1.7°C, on average, over the last 30 years (Jones et al. 2005).

A marked increase was in GDD (April–September), the mean for the investigated period 1980–2009 was 1.328 (Table 1). During the first decade (1980–1990) of this period, GDD exceeded the value of 1300 only three times, and in the second decade (1990–1999) five times (in two years it was even higher than 1400). In the last 10 years (2000–2009) the value of GDD was lower than 1.300 only in one year (mean for this decade was 1.421), and in three years it was higher than 1.500 (in dry year of 2003 even higher than 1.700). In the last 10 years of the 20th century, the mean GDD was 1.314. The Huglin index (HI) is often used in viticultural analysis in Europe, notably in the classification of viticultural regions, adaptation of cultivars to climatic conditions, characterisation of terroirs, grape ripening and positioning of phenological stages, monitoring of vine physiological and biochemical development, and wine styles (Tonietto and Carbonneau 2004, Maaß and Schwab 2010). A trend showed significant changes in the last 30 years (Table 1). Huglin index and GDD trends were similarly increased, namely by 339 units (11.3 units per year) and by 303 units (10.1 units per year), respectively.

Regarding the arrangement of grape-producing areas into climate-maturity groupings (Jones 2005, 2010) based on the average growing season temperatures in the last 10 years, it can be assumed that this investigated region proceeded from the middle of the second (intermediate), to the middle of the third (warm) climatic-maturity group. If the warming trend continues over the next 30 years similarly to the studied period 1980–2009, it can be expected, that the studied growing area may proceed to the third climatic maturity group. This was presented with different models (Jones et al. 2005, Branković et al. 2010), which represent an increase of GDD of around 12 units or more per year. Our results show the same trends.

The results for the summed up annual and growing season precipitations are less clear, and the differences are not statistically significant (Figure 1). But dryer conditions with more frequent and longer droughts with possible adverse effects on yield and quality are more likely to occur in the future.

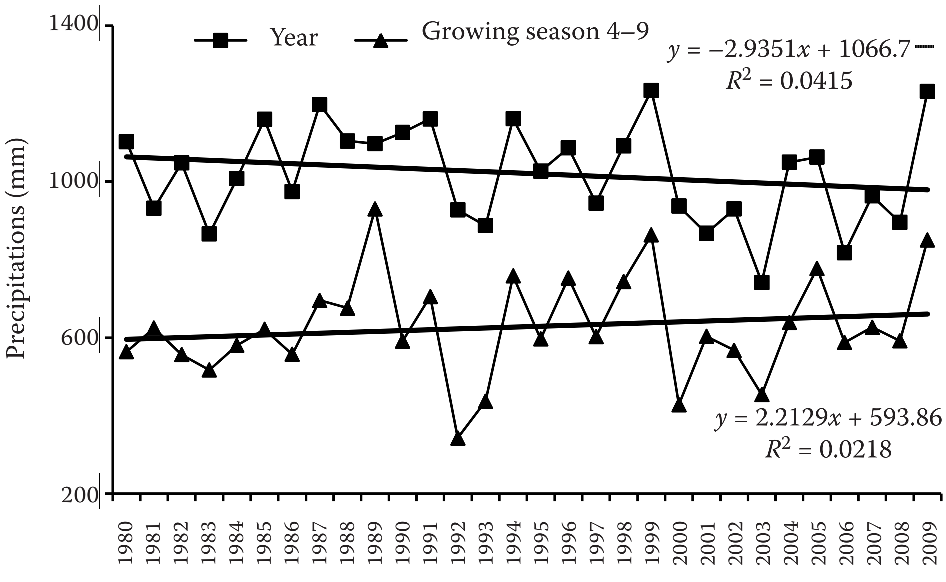

Figure 1. Average annual and seasonal precipitation rates (mm) in Maribor for the period 1980–2009 (Environmental Agency of the Republic of Slovenia)

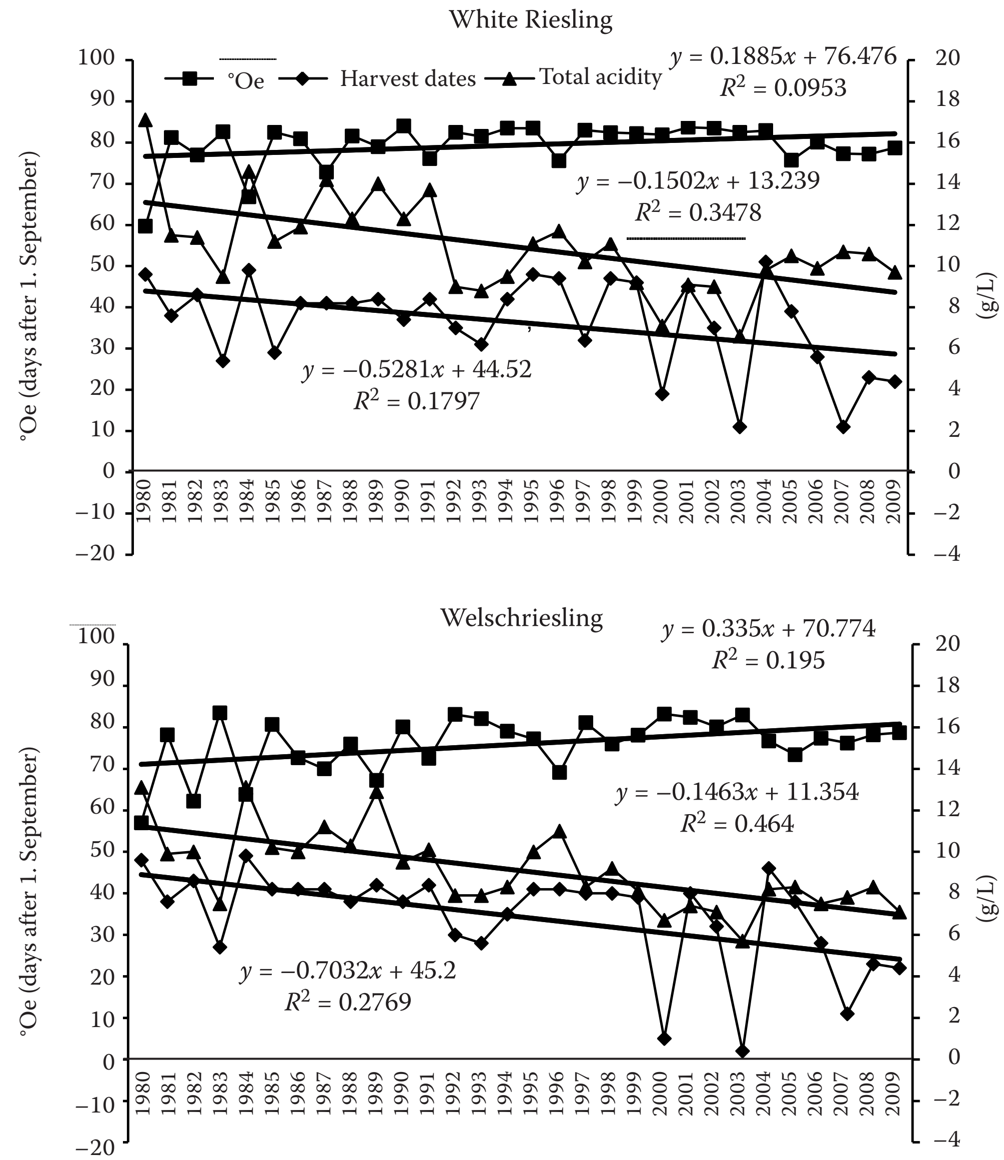

Figure 2. The sugar and total acidity content in grape juice and the recommended harvest date of the late-ripening varieties Welschriesling and White Riesling in the period from 1980 to 2009

Higher temperatures may cause higher rates of evaporation, both from soil and from plants.

Climate change and grapevine ripening. Our results support our hypothesis that there is a trend towards earlier grape ripening in the studied region. The growing season temperatures increased by 1°C in the last ten years, compared to the reference period 1961–1990 (Table 1).

In the case of late-ripening varieties, the growing season (1980–2009) was shortened by 15 (White Riesling) to 21 (Welschriesling) days (Figure 2) in the last decade even by one day per year (especially by variety White Riesling). The trend towards the shortening of the growing season for the White Riesling can be seen particularly due to the dry year of 2003. A similar trend (24 days in the studied period) can be seen in the case of the medium late-ripening variety Sauvignon Blanc. In the last decade, both in 2001 and in 2003, this variety was ripe very early (Figure 3). The growing season was shortened in the early-ripening Bouvier variety by 27 days, but minimally in the period from 1980 to 1999. The main influence on the shortening of the growing season can be due to the dry years (2000, 2001, 2003, 2007, and 2009) in the last decade (Figure 4). The analysis of the data of late and medium-ripening varieties showed that the growing season was shortened particularly in 2000, 2001, and 2003 (Welschriesling, White Riesling) and 2000, 2001, 2003, 2007, and 2009 (Sauvignon Blanc), whose early grape ripening was especially outstanding.

The trend towards the reduction of the content of total acidity can be seen explicitly as a result of higher temperatures during the growing season (especially from the growth of the berries to grape

Sauvignon Blanc

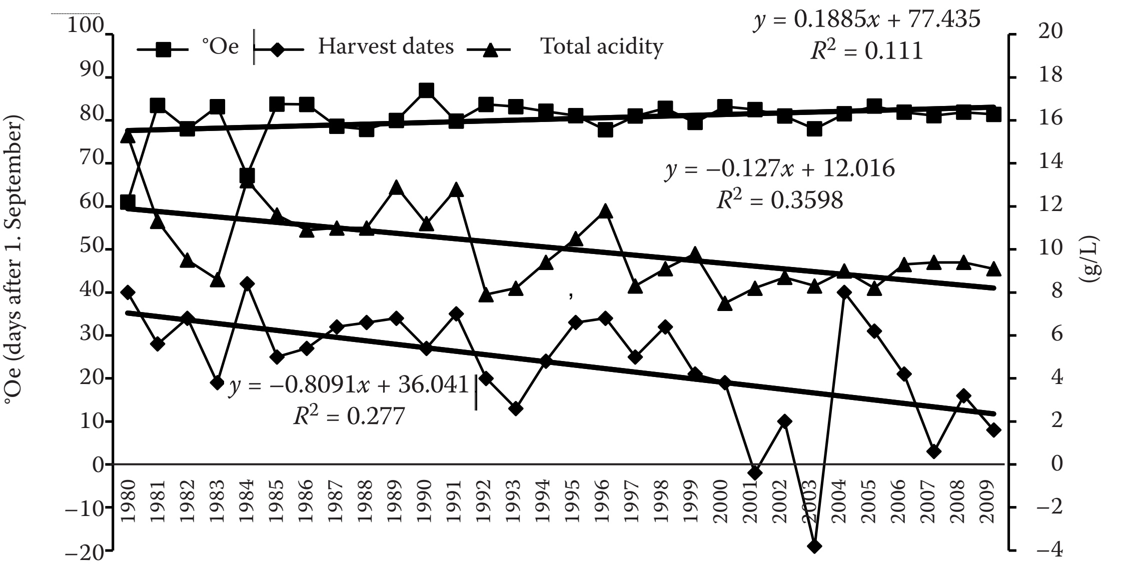

Figure 3. The sugar and total acidity content in grape juice and the recommended harvest date of the medium late-ripening variety Sauvignon Blanc in the period from 1980 to 2009

ripening). In the case of Sauvignon Blanc, White Riesling, and Welschriesling this reduction was approximately 3.8–4.5 g/L, and the content of total acidity was around 8, 8.5, and 7 g/L, respectively (Figures 2 and 3). Considering the content of total acidity, it can be calculated that the chemical composition of the grape juice was influenced by the increasing temperatures. There was a strong correlation between the total acidity and HI for all studied varieties (Figure 5). In other studies it was observed that warmer growing season results in the earlier harvest date, lower production, higher quality of wine and vintage rating (Jones et al. 2005, Blanco-Ward et al. 2007, Ramos et al. 2008).

With regard to the content of total acidity this influence of higher temperatures is positive, since the trend towards the reduction of acids is approaching optimal values. The situation is somewhat different in the early-ripening Bouvier variety. The trend of total acidity reduction was about 3 g/L, and the content of total acidity was around 5.5 g/L (Figure 4). Thus, in the early-ripening varieties, the content of total acidity often does not remain at an adequate level due to the influence of increasing temperatures.

The findings show that in the growing season dryer conditions and longer droughts with possible adverse effects on yield and quality are more likely to

Bouvier

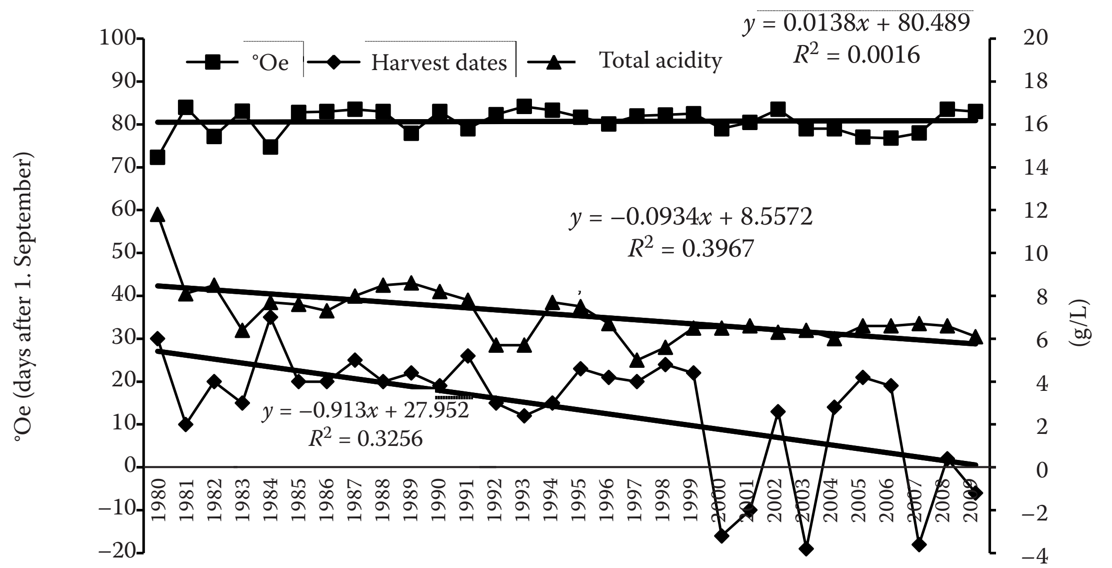

Figure 4. The sugar and total acidity content in grape juice and the recommended harvest date of the early-ripening Bouvier variety in the period from 1980 to 2009

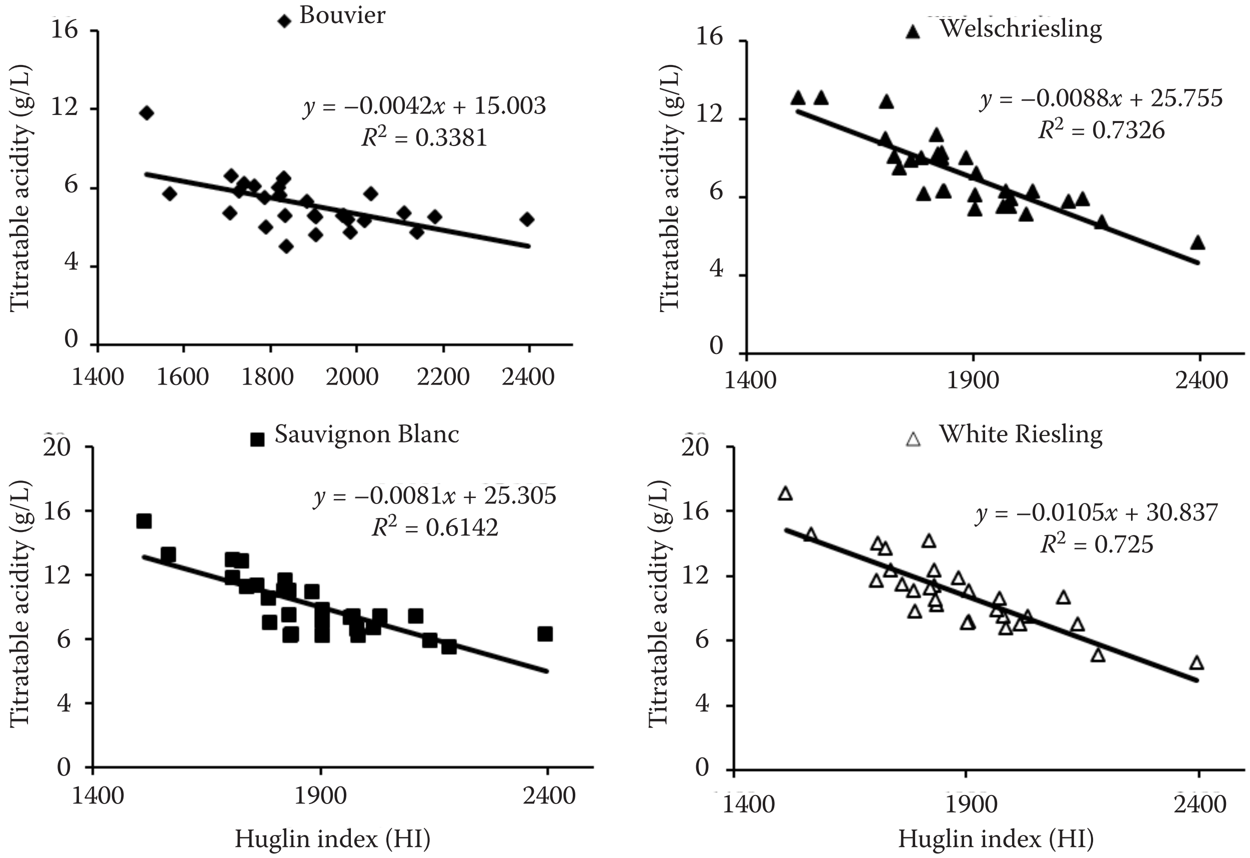

Figure 5. Correlation between total acidity (g/L) and Huglin index (HI) in different varieties (Bouvier, White Riesling, Welschriesling and Sauvignon Blanc) in the period from 1980 to 2009

occur. These environmental conditions, which also become more common in NE Slovenia, necessitate some adaptations in existing vineyard management practices to preserve certain specific characteristics of the wines produced in this wine region, especially the technique of arrangement and care of vineyards and management (Vršič 2011). In specific situations the early varieties will be suitable for the location less exposed to the sun. In this wine region, this is possible because the majority of vineyards are on steep slopes with different sun exposures. More negative influences of climate change can be expected in the case of early-ripe and aromatic varieties (lower acid, bitter substances, atypical aromas, and wine aging, etc.), whereas the growing season in the case of late varieties may be shortened. Due to climate change, the selection of rootstocks will have an increasingly decisive significance (the acceleration and retardation of ripening), in particular in areas where the so-called 'tropical' days are frequent. The results of this research could be useful for simulating the effects of increasing temperatures in other wine regions in Slovenia and other regions with moderate climate that have no available data of grape ripening for such a long period, i.e. from 1980 to 2009.

REFERENCES

Bergant K., Kajfež-Bogataj L. (2004): Some methods for the preparation of regional scenarios of climate change. Acta agriculturae Slovenica, *83*: 273–287. (In Slovenia)

Branković Č., Srnec L., Patarčić M. (2010): An assessment of global and regional climate change based on the EH5OM climate model ensemble. Climate Change, *98*: 21–49.

Blanco-Ward D., García Queijeiro J.M., Jones G.V. (2007): Spatial climate variability and viticulture in the Miño River Valley of Spain. Vitis, *46*: 63–70.

Carter T.R., Parry M.L., Porter J.H. (1991): Climatic change and future agroclimatic potential in Europe. International Journal of Climatology, *11*: 251–269.

Clingeleffer P.R. (2010): Plant management research: status and what it can offer to address challenges and limitations. Australian Journal of Grape and Wine Research, *16*: 25–32.

Flexas J., Galmés J., Gallé A., Gulías J., Pou A., Ribas-Carbo M., Tomàs M., Medrano H. (2010): Improving water use efficiency in grapevines: potential physiological targets for biotechnological improvement. Australian Journal of Grape and Wine Research, *16*: 106–121.

Hirsch R.M., Alexander R.B., Smith R.A. (1991): Selection of methods for the detection and estimation of trends in water quality. Water Resources Research, *27*: 803–813.

Huglin P. (1978): New method for evaluating possibilities of thermal environments of vineyards. Comptes Rendus de l'Académie d'Agriculture, France, 1117–1126.

Jones G.V., Davis R.E. (2000): Climate influences on grapevine phenology, grape composition, and wine production and quality for Bordeaux, France. American Journal of Enololgy and Viticulture, *51*: 249–261.

Jones G.V., White M.A., Cooper O.R., Storchmann K. (2005): Climate change and global wine quality. Climate Change, *73*: 319–343.

Jones G.V., Duff A.A., Hall A., Myers W.J. (2010): Spatial analysis of climate in winegrape growing regions in the Western United States. American Journal of Enology and Viticulture, *61*: 313–326.

Kenny G.J., Harrison P.A. (1992): The effects of climate variability and change on grape suitability in Europe. Journal of Wine Research, *3*: 163–183.

Kast W.K., Rupp D. (2009): Effects of climate change on phenology and ripening conditions of grapevine. Mitteilung Klosterneuburg, *59*: 3–7.

Keller M. (2010): Managing grapevines to optimise fruit development in a challenging environment: a climate change primer for viticulturists. Australian Journal of Grape and Wine Research, *16*: 56–69.

Kohler H. (2009): Agricultural meteorology of Rheinland-Pfalz faces global climate change-with weather data since 1946. Erwerbs-Obstbau, *51*: 95–99.

Laget F., Tondut J.L., Deloire A., Kelly M.T. (2008): Climate trends in a specific Mediterranean viticultural area between 1950 and 2006. Journal International des Sciences de la Vigne et du Vin, *42*: 113–123.

Lobell D.B., Field C.B., Cahill K.N., Bonfils C. (2006): Impacts of future climate change on California perennial crop yields: Model projections with climate and crop uncertainties. Agricultural and Forest Meteorology, *141*: 208–218.

Maaß U., Schwab A. (2011): Klimawandel und Sortenwahl. Das deutsche Weinmagazin, *10*: 29–31.

Petgen M. (2007): Reaktion der Reben uf den Klimawandeln. Schweizerische Zeitschrift für. Obst-und Weinbau, *143*: 6–9.

Prior B. (2007): Bestandsführung an Klimawandel anpassen. Das Deutsche Weinmagazin, *10*: 22–27.

Ramos M.C., Jones G.V., Martínez-Casasnovas J.A. (2008): Structure and trends in climate parameters affecting winegrape production in northeast Spain. Climate Research, *38*: 1–15.

Schultz H. (2000): Climate change and viticulture: A European perspective on climatology, carbon dioxide and UV-B effects. Australian Journal of Grape and Wine Research, *6*: 6–12.

Tonietto J., Carbonneau A. (2004): A multicriteria climatic classification system for grape-growing regions worldwide. Agricultural and Forest Meteorology, *124*: 81–97.

Vršič S., Pulko B., Valdhuber J. (2004): The Impact of permanent and short time grass covering on soil erosion, floral composition and nutrient loss. Sodobno kmetijstvo, *37*: 22–26.

Vršič S., Ivančič A., Pulko B., Valdhuber J. (2011): Effect of soil management systems on erosion and nutrition loss in vineyards on steep slopes. Journal of Environmental Biology, *32*: 289–294.

Vršič S. (2011): Soil erosion and earthworm population responses to soil management systems in steep-slope vineyards. Plant, Soil and Environment, *57*: 258–263.

Webb L.B., Whetton P.H., Barlow E.W.R. (2008): Climate change and winegrape quality in Australia. Climate Research, *36*: 99–111.

Winkler A.J., Cook J.A., Kliewer W.M., Lider L.A. (1974): General Viticulture. University of California Press, Berkeley.

Received on June 26, 2011

Corresponding author:

Assist. Prof. Stanko Vršič, University Centre of Viticulture and Enology Meranovo, Faculty of Agriculture and Life Sciences, Pivola 10, SI-2311 Hoče, Slovenia
e-mail: stanko.vrsic@uni-mb.si