ANALYSIS OF THE EFFECTS OF CLIMATE CHANGE ON THREE VINE VARIETIES PRODUCTED IN CASTELLI ROMANI

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Abstract

The climate changes observed in recent years are largely attributed to the anthropogenic effect and the mainly caused by the increase of greenhouse gases in the atmosphere (carbon dioxide, methane, nitrogen oxides), which prevent the dispersion of heat towards the space increasing the energy available on the planet. All this has an impact on agricultural systems, including viticulture. The aims of this work is to pointed out the correlations between climate change and physiology of the vine, analyzing in particular the progress of the maturation of grapes in an area of Castelli Romani (Italy). To this pourpose data from the meteorological station in Ciampino (Rome) and enological data supplied by Casale Certosa farm have been used. The studied grape varieties are Malvasia del Lazio, Grechetto and Merlot. The results confirm the strong link between climatic and enological factors, and it is even more evident as in the recent years the time of harvest has strongly anticipated. This conditions comports the anticipation of vine technological maturity but to the detriment of aromatic precursors whose reductions involves the loss of varietal characteristics.

We conducted a eight-year field study to analyze grapes composition using the fundamental chemical parameters of grape (sugar, titratable acidity, pH), sampling every day for two weeks before harvest from three different cultivar in Lazio and we have correlated the measurements with climate conditions derived from monthly temperature and rainfall measures at vineyard site. The results showed the most important climate change-related effects are advanced harvest times, increased grape sugar concentrations and lower acidities which is correlated with higher grape pH.

Combined with longer hang times aimed at optimizing current perceptions of aromatic grape maturity, climate change has brought about a number of important winemaking challenges derived from grape composition, in particular concerning the expression of varietal grape aromas, microbiological and chemical stability and sensory balance.

Keywords: *climate change, Malvasia del Lazio, Grechetto, Merlot, early harvest.*

1. Introduction

The tight correlation of vintage quality and annual weather conditions is well established. Not surprisingly, historical grape ripening data spanning back over 500 years has even been used as an indicator in climate research (Chuine et al., 2004). The potential effects of climate change on grape production have been discussed early on (Bindi, Fibbi, Gozzini, Orlandini, & Miglietta, 1996; Tate, 2001).

It is a widely accepted dependence of winegrape composition on the local mesoclimate (climate at the scale of a vineyard block). Temperature affects the rate of development or loss of various biochemical compounds in grapes, including the accumulation of sugar, the loss of acids through respiration, and the synthesis and maintenance of color and flavor compounds.

The amount and proportion of these compounds are essential to winegrape quality. Organic acids are important in wine flavor (Coombe, 1987; Kliewer, 1973). Phenolic compounds, including anthocyanins and tannins, contribute to wine color, bitterness, astringency, and anti-oxidant capacity (Downey et al., 2006). Tannin causes an astringent sensation of drying in the mouth (Smith et al., 1996; Thomas, 1995). Webb (2006) demonstrated a strong positive correlation between winegrape anthocyanin concentration and price.
There is clear evidence of changing climate worldwide (Intergovernmental Panel on Climate Change, 2007). Warmer temperatures accompanying climate change may shift the timing of the growing season, with decreased quality from earlier harvests at higher temperatures (Webb et al., 2006). In warmer climates, higher temperatures may result in negative changes in fruit composition. For example, research from vines grown in controlled environments found significantly lower anthocyanin concentrations at maturity in potted grapevines exposed to 30°C rather than 20°C temperature treatments (Yamane et al., 2006). Another greenhouse experiment found that high temperatures (35◦C) both inhibit anthocyanin production, and degrade the anthocyanins that are produced (Mori et al., 2007).
To the extent that fruit quality and price are determined by mesoclimate, a clear and quantitative understanding of the effects of weather on fruit composition is needed. However, not enough is known about the effect of vineyard-scale climate on fruit composition in field conditions.
The goal of this study was to collect detailed temperature measurements at the vineyard scale to point out the correlations between climate change and physiology of the vine, analyzing in particular the progress of the maturation of grapes in an area of Castelli Romani (Italy).

2. Materials and methods

2.1. Site

The study took place in private, commercial farm "Casale Certosa"; it extends to the slopes of Castelli Romani, in the municipality of Rome (Italy). The vines are grown using spurred cordon pruning system. The cultivar varieties are Malvasia di Candia, Merlot and Grechetto. The vineyard is planted with integrated pest management program, with a low fertilization and irrigation. Since 2004 the company has been certified organic.
We selected sites with vines that were at least five years old, so that vines would be at full canopy cover and maturity, with two different rootstocks: 420A (medium vigor and drought-resistant) for Merlot and SO4 for Malvasia di Candia and Grechetto (poor vigor and resistant to moisture).Row orientations were generally northwest–southeast. Site location was chosen based on reported temperatures to span as wide a range as possible within the region.

2.2. Berry collection and processing protocol

We conducted a eight-year field study to analyze grapes composition using the fundamental chemical parameters of grape (sugar, titratable acidity, pH). To ensure a representative sampling to draw valid conclusions over the scale of a vineyard, berry samples were collected following the recommendations of Zoecklein (2001) to sample a minimum number of berries from a maximum number of vines and to collect approximately 500 berries per vineyard for an accurate sample. Once clusters were selected, they were flagged, and the same clusters were sampled during each growing season for all years; here we report results from samples taken at full maturity (commercial harvest), as well as samples taken midway between veraison and harvest. Berries were sampled from different positions (shoulder, middle, and tip) and depths (superficial or inner berries) within a cluster. Berry samples were immediately processed for analysis.

2.4. Climate data collection

The meteorological data come from the meteorological station located since 1947 in Roma-Ciampino, refer to the "Meteorological Service of Military aeronautical” and to the “ World Meteorological Organization". The station covers to the area south-east of Rome and therefore also includes the farm “Casale Certosa”. Measurements of temperature and rainfall were logged once every 10 min.

2.5 Sum temperature active (STA)

This index is calculated by adding the average daily temperatures mesured in the period that coincides with the growing season of variety (March-October), of a thermal threshold of development (Biological zero). For the vine the biological zero is fixed to the value of 10°C.

$$STA = \sum_{March}^{October} (\text{average temp. } -10\ ° C)$$

This index is very important to describe the thermal availability of area taken into consideration. The areas with wide thermal availability, such as Southerners, are given for late vines, while in areas with low thermal availability early grapes are preferred. For early grapes grown in areas with high availability is required well-timed harvest of grapes to avoid qualitative loss mainly of acidic component.

3. Results

The curves of ripeness of the 3 varieties have been developed with the data relative to the sugar content, titratable acidity and pH values provided by the company. We have reported only the results concerning sugars accumulation (Figures 1, 2 and 3).

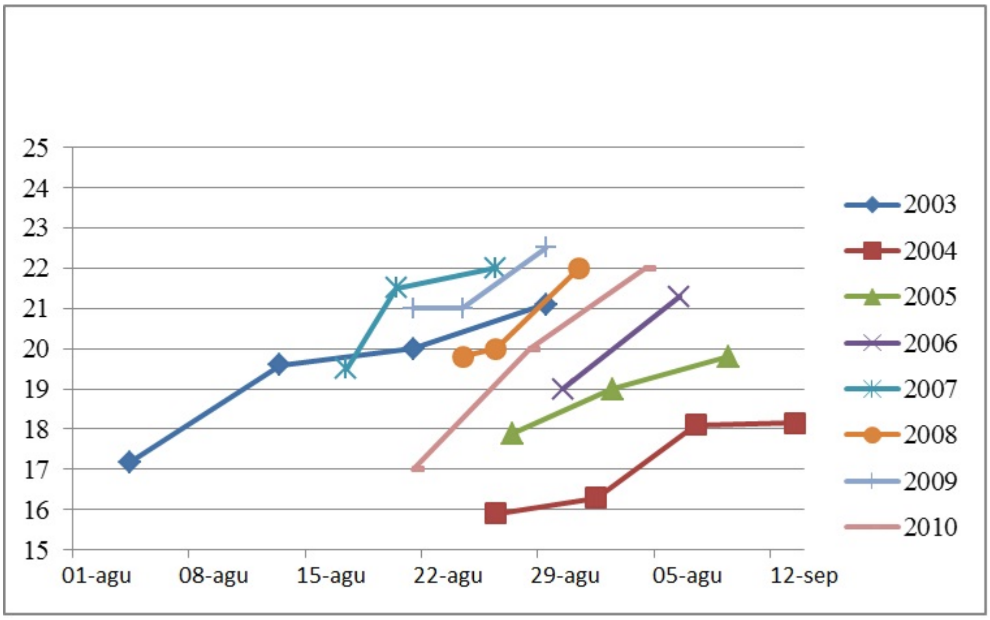

Figure 1: interannual comparison of the sugars accumulation in grapes of cultivar Grechetto

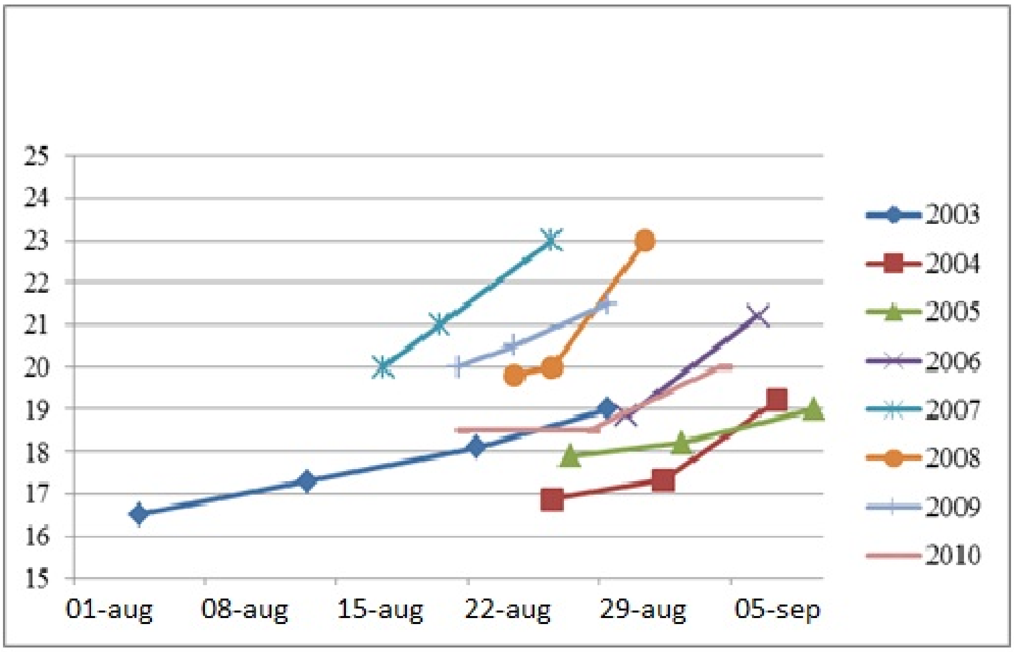

Figure 2: interannual comparison of the sugars accumulation in grapes of cultivar Malvasia del Lazio

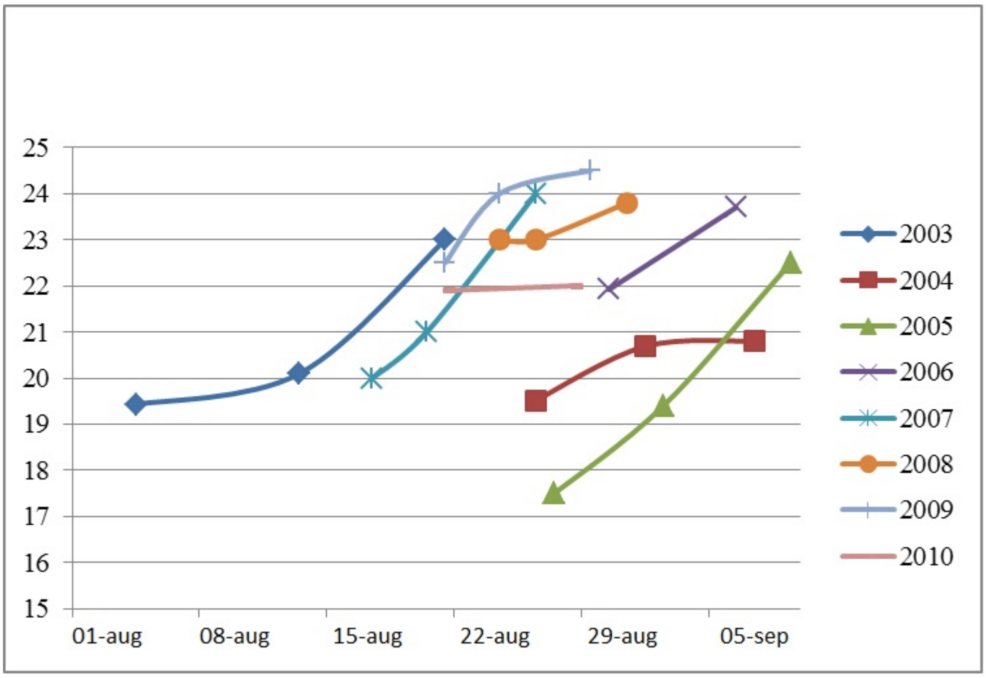

Figure 3: interannual comparison of the sugars accumulation in grapes of cultivar Merlot

The examination of the graphs shows both the anticipation of the harvesting period that a different rate of accumulation for sugars for more recent years. The only exception is the harvest of 2003, which has been very early, due to summer with very high temperatures and little rainfall phenomena, climatic conditions that justify the low accumulation of sugars.
The fact that 2003 was not the year earlier for Grechetto would suggest that this cultivar is quite resistant to drought.

Table 1: mm of rainfall per months

	2003	2004	2005	2006	2007	2008	2009	2010
January	132,1	77	65,8	55,8	38,2	134,6	74,2	84,8
February	16,51	121,6	105,8	67,8	116,6	59,4	64,4	2
March	14	111,4	98,6	43,4	64,4	145,6	62,6	24,2
April	72,39	152,8	83,6	43	27	45,2	129,2	96,2
May	8,89	112,2	16,4	32,4	82,8	164	21	116,8
June	0,76	58,2	23	17,2	26	29,8	41,2	40,6
July	0	65,8	8,6	33,4	0,2	4,0	7,8	5,2
August	18,01	23,4	58,8	32,6	9,0	2,2	22,2	8,0
September	69,34	31,6	67,4	201	37,8	60,6	68,8	19,2
October	122,7	154	0	18,8	37,4	70	129,4	60,6
November	98,81	176,2	100,4	61,8	58	192,2	147,6	107,4
December	61,98	230,2	231,6	57,4	32,4	266,2	114	154
TOTAL	**615,49**	**1314,4**	**860**	**664,6**	**529,8**	**1173,8**	**882,4**	**719**

Table 2: Rainy days per months

	2003	2004	2005	2006	2007	2008	2009	2010
January	8	9	8	7	8	9	9	11
February	10	10	11	9	13	6	10	1
March	6	8	11	7	7	16	9	2
April	5	15	11	4	4	7	8	7
May	3	9	3	4	5	8	5	14
June	3	5	3	4	3	5	5	6
July	0	2	1	4	0	1	2	1
August	1	2	3	2	2	1	3	3
September	4	3	3	7	5	4	7	5
October	7	11	0	4	7	8	5	12
November	10	10	7	5	11	14	8	10
December	12	15	17	7	6	14	12	8
TOTAL	**69**	**99**	**78**	**64**	**71**	**93**	**83**	**80**

From the data relative to the rainfall of the period considered (Tables 1 and 2) the driest year was 2007, while the wettest was 2004, which was also the year with more rain in the summer months. With regard to the months before the harvest, the driest July took place in 2003 and 2007, while for the month of August the driest year was 2008, then 2010 and 2007. We would like to emphasize, to better assess the effectiveness of information contained in Tables 1 and 2, that for the water needs of the vine, with the same mm of rainfall it is more effective a higher number of rainfall events.

Regarding thermal trend, in Table 3 the thermal monthly STA from March to October for the eight years have been reported.

Table 3: Sum temperature active (STA)

	2003	2004	2005	2006	2007	2008	2009	2010
March	91,2	65,7	76,5	80,7	115,5	109,8	123,9	87
April	226,8	181,2	166,5	221,1	250,2	205,5	233,1	201,9
May	408	278,4	359,1	345,6	341,7	342,6	397,8	278,1
June	578,4	455,7	484,5	452,4	463,2	458,1	470,1	447,1
July	597	540,3	555,9	594,6	546	543,9	565,2	594
August	626,7	530,7	492,3	514,5	536,7	556,5	603,9	547
September	416,7	434,1	423,6	444,3	396,6	401,1	465,9	402
October	286,8	350,1	272,1	324,3	267,9	311,7	241,8	284,4
STA	**3231,6**	**2836,2**	**2830,5**	**2977,5**	**2917,8**	**2929,2**	**3101,7**	**2841,5**

From these data it is evident that the year with the hottest summer was 2003. Also with respect to this parameter the warmest year was 2003, while 2004 and 2005 were the coldest years.

Combining meteorological data with enological parameters for the three varieties we have obtained some interesting information on the different sensitivity of the cultivars to climatic variations. From Figure 4, it can be observed that for Grechetto the best conditions are realized in the years 2007 and 2008, allowing a considerable accumulation of sugars and the maintenance of an adequate acidic concentration.

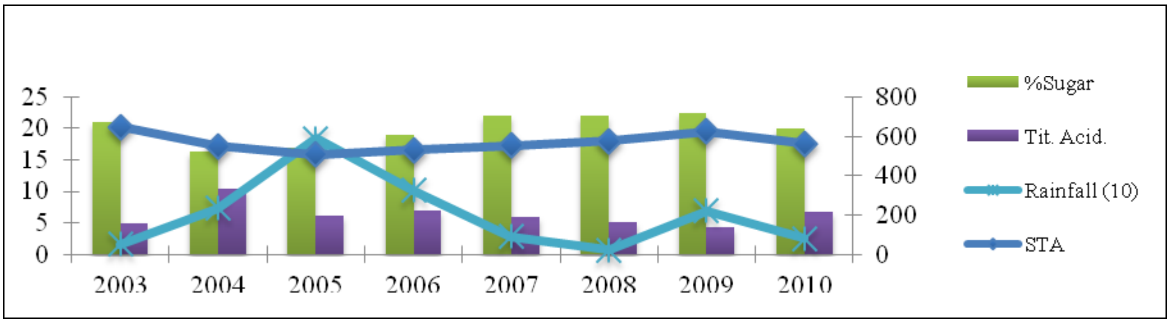

Figure 4: Agro-climatic trend of Grechetto (August)

The 2004 and 2005 were the worst years by an oenological point of view, probably due to the heavy rains of August. A similar trend was also noted for the variety Malvasia del Lazio (Figure 5).

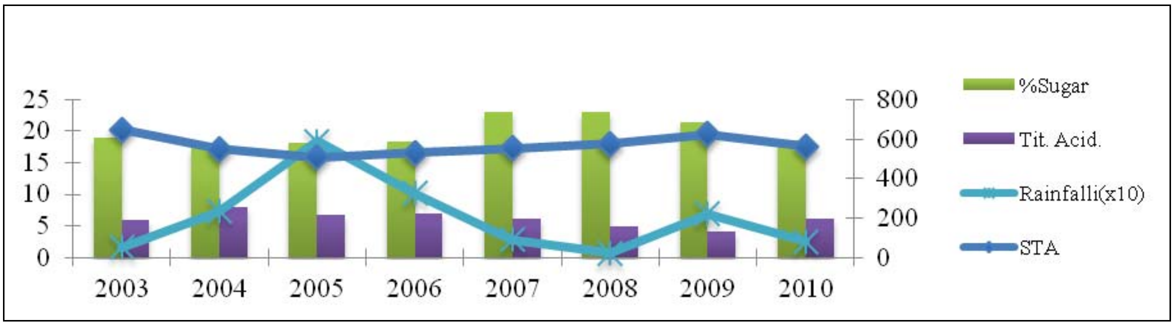

Figure 5: Agro-climatic trend of Malvasia del Lazio (August)

Slightly different was the behavior of variety Merlot; it can be seen from figure 6 that the trend of sugars accumulation follows the curve of the STA; it obviously does not allow us to make a direct correlation, but it suggests a remarkable susceptibility of this variety to this variable.

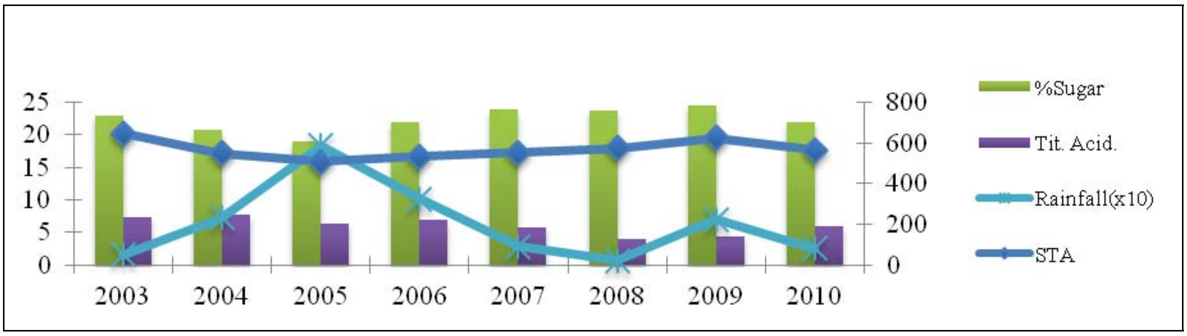

Figure 6: Agro-climatic trend of Merlot (August)

In summary the precipitation is the factor that has a greater influence on Merlot rather than Grechetto and Malvasia Puntinata, while the thermal sums (STA) are a limiting factor for the white grapes used in this thesis.

4. Conclusion

Harvest dates need to be considered carefully since they are based on subjective evaluations of optimum fruit composition in view of ulterior wine quality, whose definition is exposed to individual interpretation and trends, and may also depend on commercial targets, market constraints, processing capacity and other factors. Over the last years there has been a clear inclination towards increased consideration of aroma or polyphenolic maturity in addition to the traditional measurement of technological variables, i.e. sugar and acid levels, leading to longer hang times. However, in spite of the trend toward longer hang times, harvest dates have advanced and fruit maturation occurs earlier. Although the short time frame with available data needs to be interpreted with caution, maturity normalized for sugar advanced 8-10 days between 2003 and 2010 for the three cultivars.

Among the three wine-grape varieties studied, the more susceptible to precipitation is Merlot, while the two white grapes, Malvasia del Lazio and Grechetto, are more sensitive to thermal sums, especially with regard to the content of organic acids.

The predominant factor in this analysis is related to the agro-climatic rainfall events. These, in function of their quantity and frequency, play a fundamental role in the quality of the grapes, and then of the wine.

Combined with longer hang times aimed at optimizing current perceptions of aromatic grape maturity, climate change has brought about a number of important winemaking challenges derived from grape composition. The main microbiological and technological challenges are higher temperatures of harvested grapes delivered to the winery, higher environmental temperatures during fermentations, higher grape berry sugar and, possibly, potassium concentrations, lower acidity levels and higher pH values. The specific methods and technologies that are suitable and available to winemakers to address climate change-associated challenges will depend on the desired wine style and local regulatory circumstances.

This study represents a first step in the analysis needed to provide more information for the wine industry in Castelli Romani area, estimating the potential effects of climate change relating to the zone and grape-vine variety. Future work should pursue questions at both vineyard and the regional scale. At the vineyard scale, environmental measurements at individual vines for variables such as canopy or cluster temperature and light, and plant and soil water status, would help to explain the variability within vineyards and elucidate the role of climate and particularly temperature on fruit composition. Further, improved observations and models of grapevine development and the drivers of grapevine phenology are important for accurate projections of climate change impacts.

On the regional and larger scale, a robust examination of climate effects on viticulture would require a large-N study over many sites and years to detect trends. Viticulturists may want to examine changing canopy management, irrigation practices, and other techniques to promote shadier and cooler conditions in vineyards in Lazio, while they prepare for the warmer conditions ahead.

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