Viticulture, Enology and Climate Change in the Castelli Romani Area

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1. Introduction

Research in viticulture and oenology is oriented to reach sustainability of vineyard management and to improve the quality of wine. The vineyard management for the quality of wine consists of many facets: the soil and vine management, use of innovative techniques, protection of the vineyard against fungal diseases and pests, reducing the use of pesticides and so on. These and many other good agricultural practices are the basis for sustainable agriculture.

A lot of knowledge has been acquired in viticulture and enology, but an essential element for plant production is out of control and is not containable adequately: the climate. As known, climatic conditions played a decisive role in the formation of specific wine characteristic from certain varieties [13]. The sustainable management of any culture can't escape the effects of meteorological factors and their unpredictable variability. So, the farmer must take into account the mutability of environmental conditions, not entirely predictable, but nonetheless characterized by a warmer temperature trend and less frequent rainfalls [16][18].

In the area of Castelli Romani, in Lazio Region Italy, the vineyards were reduced by 35% between 2000 and 2010, from 10.544 to 6.865 Ha [15]. To reinforce competitiveness of wines of "Castelli Romani Area" is necessary to evaluate the effects of global warming on a local scale, to know how and how much the climate has been changing [8][9].

Acquired new knowledge, the farmer can choose innovative cultivation techniques to adapting crops to new climatic conditions (e.g. late pruning, larger screws, reduction of defoliation, more early harvest and so on). The wine growers will look after the meteorological progress and phenological development of the vineyard, with particular attention to the ripening stage, supported by analysis of the sugar content, total acidity and phenolic compounds; greater attention to the environmental conditions will allow them to carry out the harvest at the optimum time, related to the kind of wine they wish to make.

Among the several definitions of climate, it is believed that the most effective is the one used by the Intergovernmental Panel on Climate Change - IPCC in their papers, where the climate is "the average weather pattern, the statistical description of atmospheric phenomena in terms of mean and variability of physical quantities"[5]. According to the official definition of climate reported in the World Meteorological Organization - WMO website, "Climate, sometimes understood as the "average weather," is defined as the measurement of the mean and variability of relevant quantities of certain variables (such as temperature, precipitation or wind) over a period of time, ranging from months to thousands or millions of years.

The classical period is 30 years, as defined by the WMO. Climate, in a wider sense is the state, including a statistical description, of the climate system [18].

In the final decades of the last century, some meteorologists have raised the alarm for a predictable change in the climate of the planet, presumably caused by human activities and, in particular, by increase of greenhouse gases into the atmosphere.

Many sources, supported by environmental data observed over the last three decades, predict an intensification of weather phenomena (IPPC 2014) due to global warming, a term which indicates the increase of the average temperature of the Earth.

According to WMO the minimum data base to talk about some climate change consists of a time series which shall include at least thirty years [5].

Most of the authors who treated on climate change believe to be need to point out that is still difficult to predict its influence and it is more appropriate to focus on global warming, because it is measurable.

The variety of forecasts obtained using *ad hoc models* shows how these predictions are difficult, because the scenario would be influenced in a different manner on the bases of the climate zones. Perhaps, you could talk about micro-climatic changes, that could bring about substantial differences into contiguous territories.

The link between climate and agriculture is very tight and the influence of climate is stronger in presence of natural environments and even where agriculture is practiced by natural cycles. Climate change is going to redraw the boundaries in latitude and altitude, of vegetation and geographical cultivation limits [3][12][14].

In the past, climate change acted undisturbed on the climate zone boundaries; nowadays, man is partially able to mitigate the effects of climate by improving farming techniques and by means of genetic improvements.

Regarding the wine world, many authors agree that climate change could have serious consequences both on the grapevine crop and on wine processing; essentially, they have been summarized in the following points the effects of climate change [1][2][3][4][8][9][10][11][12][13][14]:

- earliest bud burst and earliest grape harvest;
- lengthening of the vegetative stage;
- influence of warmer climate on the period of grape harvest and on the quantity and quality of the products;
- reduction of the differences between the cultivars on harvesting calendar;
- reduction of net income;
- new plants in colder areas;
- decrease in rainfall and consequent need of emergency irrigation;
- negative effects originated by extreme weather events (flood, hail storms, drought, sun, late frost);
- effects of CO_2 and other Greenhouse Gases - GHG high concentration in the atmosphere;
- introduction of new diseases.

In their opinion, the consequences could be serious at the marketing stage of the product, they can be beneficial or detrimental (winners and losers)[1]. Furthermore, they believe it's important try to

reach a dynamic relationship between legislation, producers and consumers [2]. In this regard, at present, the wine market shows some structural problems; it needs to predict whether and how the global warming will change the consumer orientation. In fact, it is likely that will take place a change about the quality of the product that would modify the consumer behaviour in accepting changes in the tipicity of wine [3].

It should also consider that the climate change may affect soil conditions as desertification, faster consumption of organic matter and rapid nitrification of organic, ureic and ammoniacal nitrogen and so on.

The aim of this work was to verify the presences of any change in viticulture as a result of a climate change. The surveyed area is the vine-growing area of the Castelli Romani (between Rome south-east and the city of Latina) that is the most important and well-known viticulture district of Lazio Region.

2. Materials and methods

In this paper, because the reason above mentioned, we used the maturation curves of the last two decades, of some vine grape varieties, detected in the experimental vineyard of CREA-ENC (Council for Agricultural Research and Analylis of Agricultural Economics – Viticulture and Enology), Home of Velletri (RM), focusing the data on the three-year periods 1994/96, 2001/2003 and 2010/2012.

At last seven varieties of vine grapes have been selected, whose maturation curves from 1993 to 2014 have been revealed.

The varieties examined are described in Figure 7 and Figure 8 (Harvesting time differences, by grapevine cultivars, in the triennium examined). There are: an international cultivar (*Cabernet sauvignon*), two national ones (Trebbiano and Fiano) and others coming from Lazio (Ottonese, Malvasia puntinata, Cesanese and Cesanese di Affile).

Regarding the aim of this work, the climatic data taken into account for the Castelli Romani area, are from Ciampino and Latina, weather stations belonging to Air Force meteorological network. They have a series of weather data from 1951 and 1960, respectively and well represent climate variability of the area examined.

We considered average temperature (minimum, maximum and annual temperatures) and total rainfall of two sites.

2.1 Climate change

The data are indicating quite clearly that in the last 30 years, the weather trend has gone to meet some changes never recorded over the last centuries [6] [7].

In Figures from 1 to 4 are represented average annual temperatures and cumulative rainfall of those two stations.

Fig. 1: Average annual temperatures in Roma-Ciampino weather station (1984-2014)

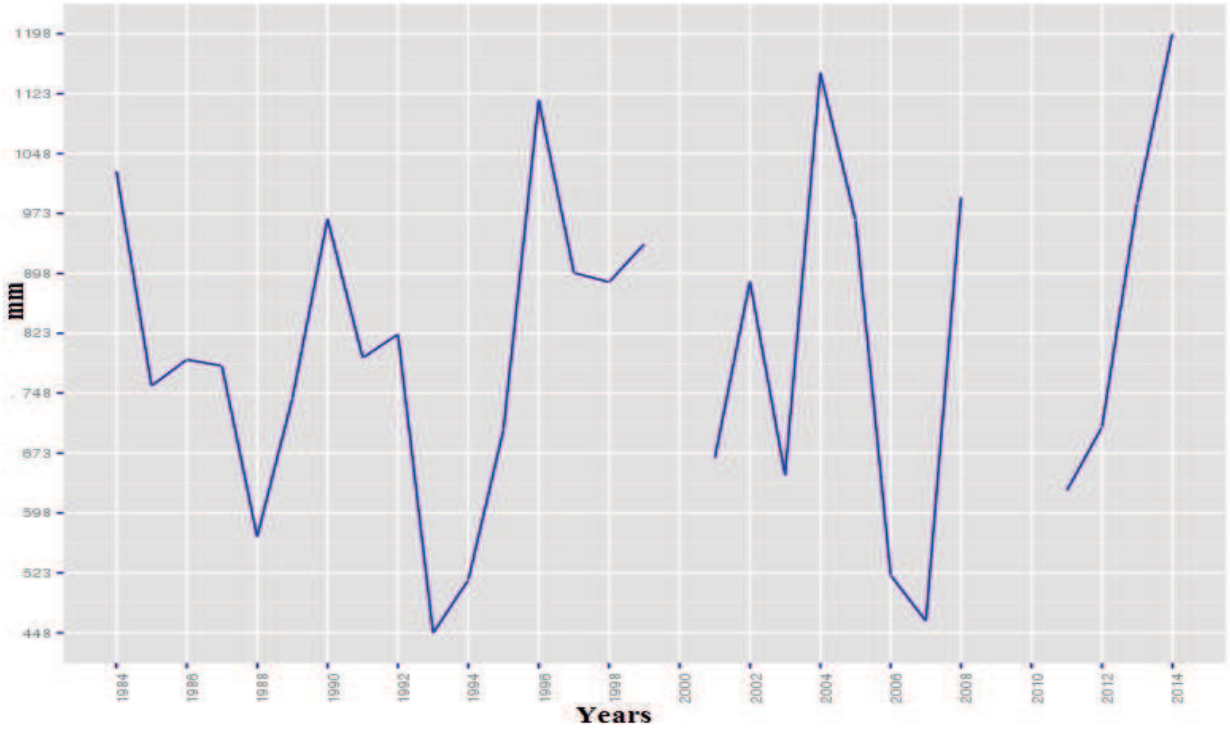

Fig. 2: Cumulative rainfall totals in Roma-Ciampino weather station (1984-2014)

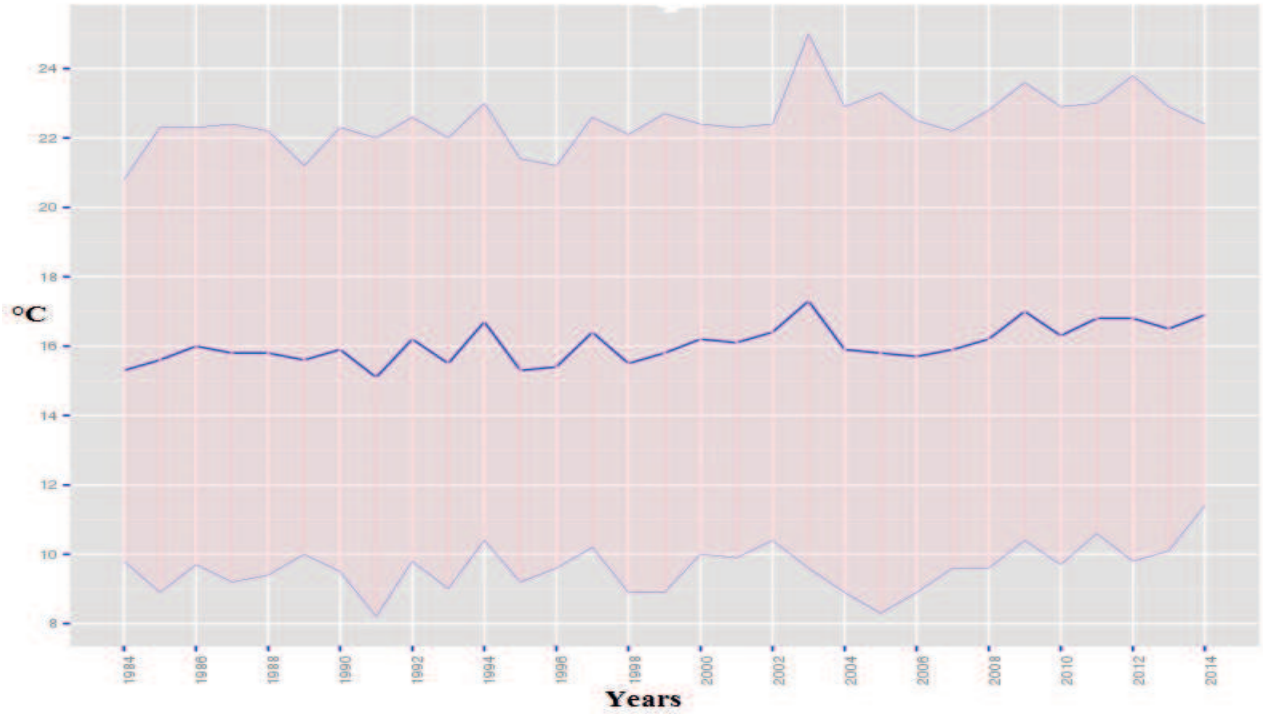

Fig. 3: Average annual temperatures in Latina scalo weather station (1984-2014)

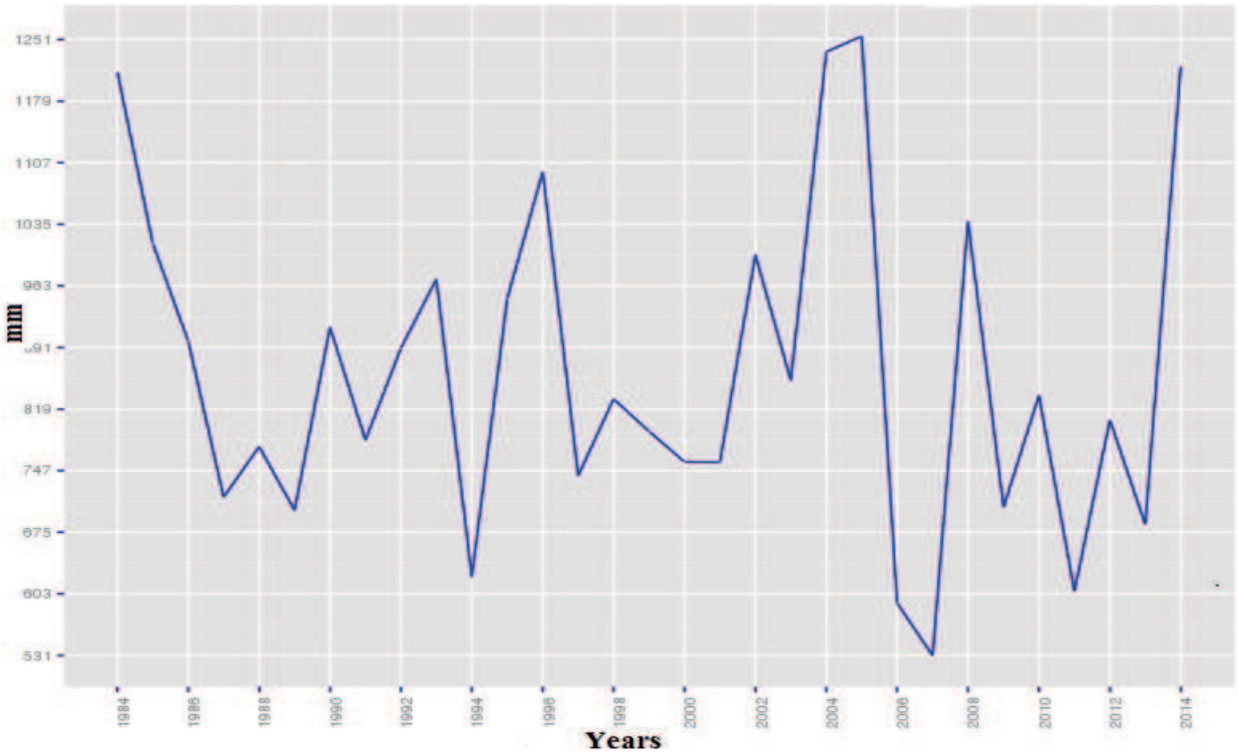

Fig. 4: Cumulative rainfall totals in Latina scalo weather station (1984-2014)

Thirty-year average temperatures of the two stations are shown in the following table: from 1961 to 2010 the average temperature of the three periods has increased by 0.5°C in Roma-Ciampino to 0.4°C in Latina-Scalo, values lower than the continental average (+1.7°C from 1950 to 2014)

ROMA CIAMPINO	LATINA SCALO
1961-1990 15,1 °C	1961-1990 15,5 °C
1971-2000 15,2 °C	1971-2000 15,6 °C
1981-2010 15,6 °C	1981-2010 15,9 °C

increase observed [6], [7], [15], but it is one germ of climate change.
Average temperatures of the three-year periods considered, shown in the Figure 5, are significantly higher than the thirty-year average above mentioned.

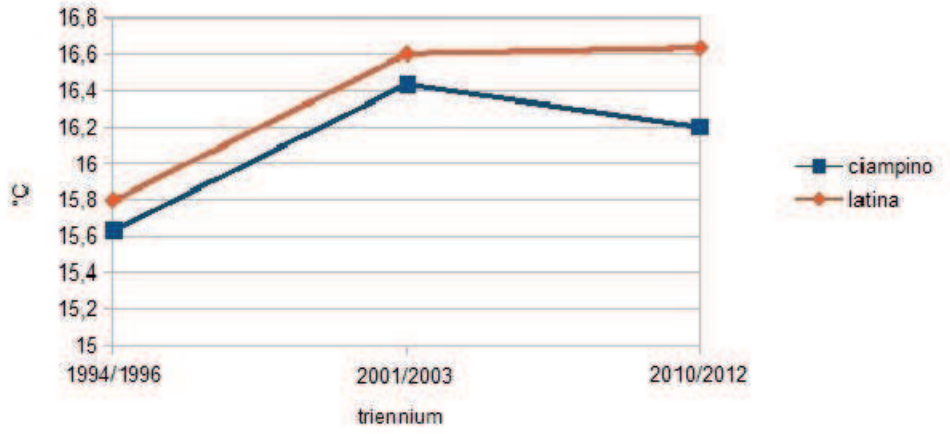

Fig. 5: Triennial average of annual medium temperature in the two weather stations

In Figure 6, the annual cumulative rainfall is represented (total reference three-year periods); there is an almost linear decrease of the data.

So, we are in the presence of an environment change, although not yet strongly affected by global warming,, it is likely to be tested by measures purely biotic(ISPRA). In Roma-Ciampino, the average temperature in the third triennium, compared to the previous one, is falling, because of the influence of the 2003 exceptional warm year.

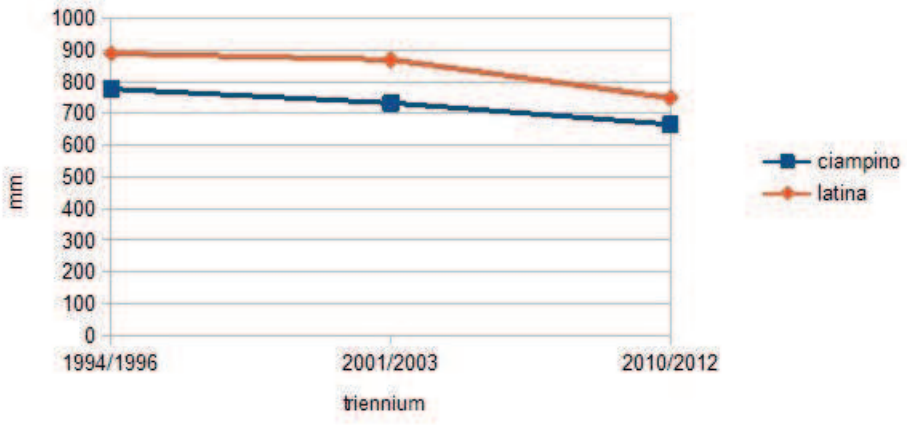

Fig. 6: Triennial average of cumulated rainfall in the two weather stations

3. RESULTS AND DISCUSSION

3.1 Exam Of Grape Maturation Curves and Harvest Time

The grape is not always harvested when the sugar content, pH and total acidity are at the optimum state; that is due to the variability of the yearly weather, in particular when it is unfavourable as, for example, a rain occurs just before the harvest (that can alter the content of sugar) or a particularly warm and wet weather occur (that can generate an increase in the virulence of some diseases and can also alter the normal function of plant nutrition). So, it was decided to standardize the data.

Basically, it is assumed that the harvest takes place when the content of must in sugar must have reached 18° Brix in white grape varieties and 20° Brix in the red ones; this content was calculated as the daily medium increase in sugar in the last phase of grapes ripening, up to the level specified.

Considering the equality of vegetative and nutrition conditions, regarding to the effects of global warming, it was found that the observed cultivars reacted in a different way with temporal differences of harvest of the grapes.

Figure 3 and 4 show the dates (Day Of the Year - DOY) when the seven cultivars reach their maturity.

In Figure **3**, it is shown the difference (in days) of ripening time, for each cultivar, during the three triennium; the average period of maturation, for the same cultivar, has a different length in the three three-year terms. Except for Ottonese and Cesanese, the general trend is a reduction of the maturation process; the yellow histogram (2010-2012) is generally shorter than blue (1994-1996) and orange (2001-2003) ones.

Figure 4 shows the difference (in days) between the harvesting date of the first period (1994-1996) and third one (2010-2012).
The most significant differences concerned Cesanese d'Affile (-24), Trebbiano giallo (-24) and Fiano (-23).

Also Malvasia puntinata (-16) and Cabernet Sauvignon (-14) presented a substantial advance of the time of harvest.

Cesanese and Ottonese cultivars, however, did not present significant gap and unlike other varieties, would have delayed maturation.

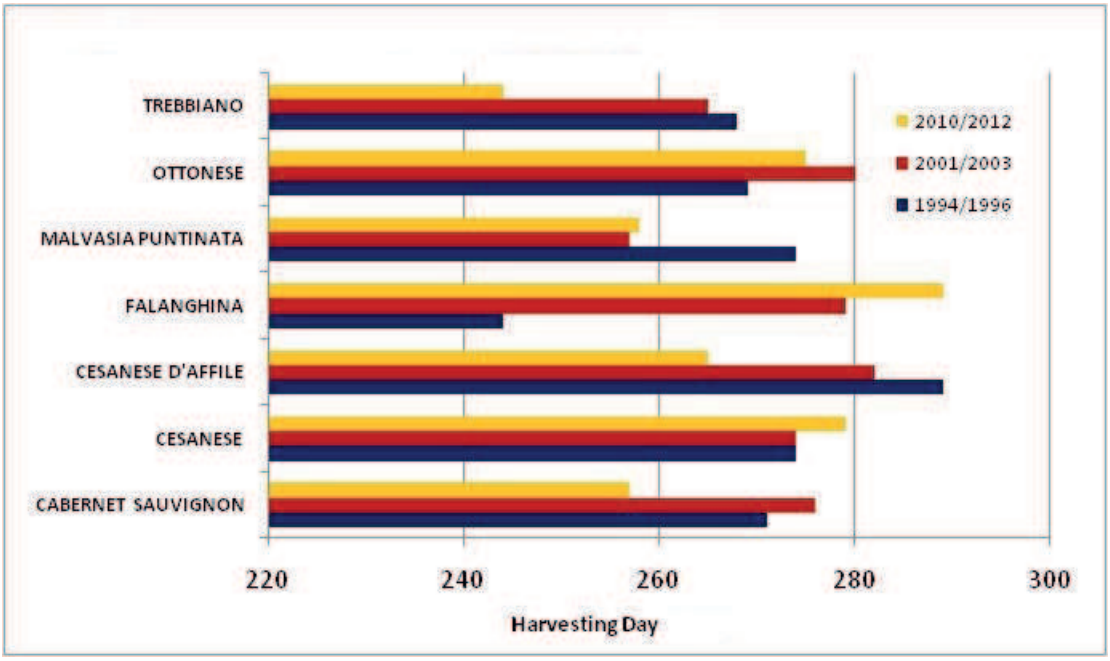

Fig. 7: Harvest Time Triennial Variability

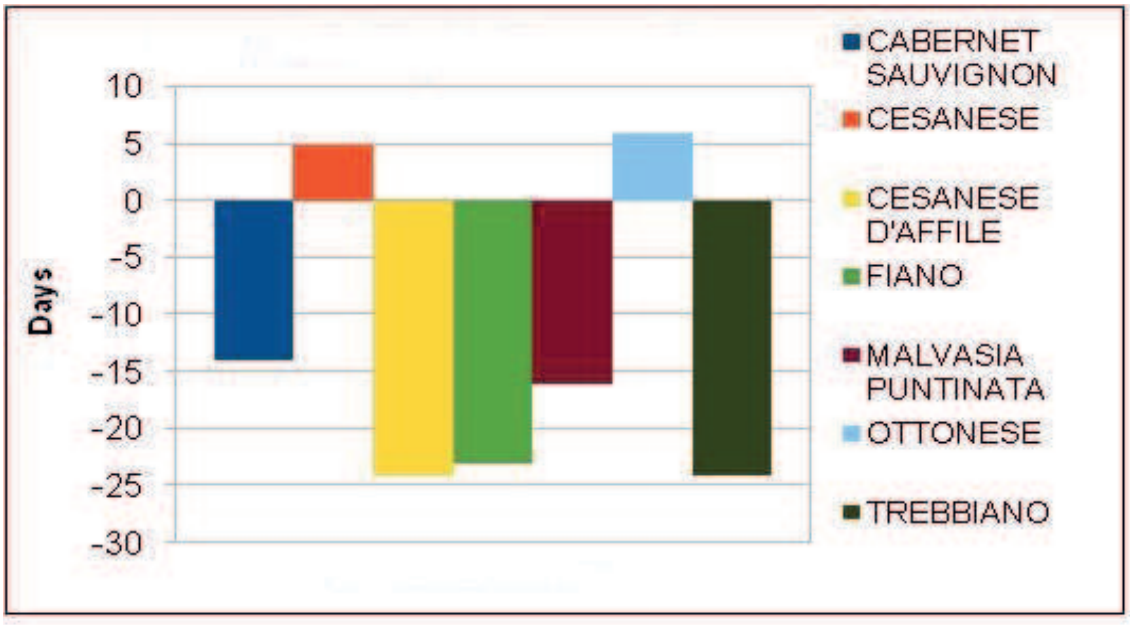

Fig. 8: Variability in Harvest Time

In this paper, we observed variation of harvesting time as evidence of global warming.

Noted variations, despite the reported exceptions, would lead us to think that it will be necessary to change some cultural practices. It is early to define these changes for the area in question, but sure we must prepare for new management types.

The major experts of global warming highlighted some possibility to counter its effects on the vineyards and to achieve the following objectives: to delay the ripening of the grapes; to combat drought; to counter the increase of the pathological potential, included the increase of irradiation.
What techniques can have adopted? What could be already recommended? Researchers have identified interventions that pursue the above objectives.

To delay the ripening of the grapes (which would lead a more acceptable phenolic content) could be adopted measures such as a late pruning, new canopy management, increase leaf/fruit ratio and the use of appropriate genetic material and of rootstocks most suitable.

To achieve others objectives, some of the above actions are eligible (genetic material and rootstocks resistant, appropriate forms of cultivation) and at last, supplemental irrigation. Finally, to counteract the excess of irradiation would be appropriate to think about different forms of shielding.

4. Conclusions

In general, it can be asserted that changed climatic conditions have led to different modality and ripening times of the grapes respect to two decades back. This fact has been repeatedly advised by the winemakers and technicians of the area examined. However, the climate extreme limits have/are not been yet reached and the wine making practice is not significantly modified.

Given that the displayed data, with some exceptions, indicate a different way of grape ripening, especially a greater precocity, it is necessary to find new ways of vineyard management and winemaking processes; this requires the development and adoption of new cultivation techniques, in order to counteract the negative effects of global warming. On the cultivation of the vine therefore, you will have to check whether the phenomena theoretically expected correspond to those that are being recorded.

At the same time, we must begin to rethink some winery practices (e.g. quality of yeasts, operating temperatures in the cellars, new constructive models). We refer to the phyto-sanitary conditions, to correction techniques of the must as well as to the changes of some components of the musts and then of the wines, as polyphenols, whose quantity is believed to depend strongly on the weather conditions.

As regards to the area taken into account, given that according to some predictive models, the Lazio Tyrrhenian strip would undergo global warming more slowly compared to other Mediterranean areas, may not exist a compelling need for adaptation. However, we believe that it should work early and better on the introduction of varieties and rootstocks resistant to climatic phenomena that are expected.

Further configurations of changes in the management of the vineyards and wine-cellar practices would require a larger amount of data, which in some cases were not collected and when existing, they are kept by different entities and often are not aggregated. Therefore, it would be appropriate to create a networks of available data (climatological, phenological, phyto-pathological data) from

which we can draw an updated scenario of phenomenology in act that consequently can better lead us to a strategy to contrast the effects of global warming.

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