ASPECTS ON THE IMPACT OF CLIMATE CHANGE ON VITICULTURE

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Abstract. Climate change is an incontestable phenomenon, one of the major threats to the environment and implicitly over humans. According to the European Environment Agency, climate changes mean global warming, increased sea and ocean temperatures, average global sea and ocean elevation, water acidification, shrinking glaciers due to the extensive melting of glaciers, desertification of green areas, and intensification of extreme meteorological phenomena (floods, long and prolonged drought, storms, etc.). Regarding vine culture, it is known that the main restrictive factors are climate factors, which have a decisive importance on this plant. Temperature and humidity, mainly determine the optimal run of the annual biological cycle of the vine, so of the phenophases. The main forecasts show that temperature variation will increase considerably in most wine regions in Europe. Thus, the increase in temperature will have serious implications for viticulture, especially as regards the plant-water relationship. Changes in the phenology of varieties are already recorded, with the forced triggering of the parga stage and the ripening of the grapes. Due to the fact that the grains of the grapes do not reach the varietal sizes, their must efficiency decreases. Some specialists also show that elevated temperatures and the lack of rainfall during the summer, to ripen grapes, prevent the attack of gray rot and favor the accumulation of sugars.

Keywords: climate change, vine, *Botrytis cinerea*.

Rezumat. Aspecte privind impactul schimbărilor climatice asupra viticulturii. Schimbările climatice reprezintă un fenomen incontestabil, una dintre marile ameninţări asupra mediului şi, implicit asupra omului. Potrivit Agenției Europene de Mediu modificările climatice implică creşterea temperaturilor medii la nivel global, creşterea temperaturii apei mărilor și oceanelor, creşterea globală medie a nivelului mării și oceanelor, acidifierea apei acestora, micşorarea calotelor glaciare datorată topirii extinse a gheţarilor, deşertificarea zonelor verzi, precum și intensificarea fenomenelor meteorologice extreme (inundații, seceta dură și prelungită, furtuni etc.). În ceea ce priveşte cultura viței de vie se cunoaşte faptul că principalii factori restrictivi sunt factorii climatici, care au o importanță hotărâtoare asupra acestei plante. Temperatura și umiditatea, în principal determină derularea optimă a ciclului biologic anual al viței de vie, deci a fenofazelor. Principalele previziuni arată că variația temperaturii va creşte considerabil în majoritatea regiunilor viticole din Europa. Astfel, creşterea temperaturii va avea implicații grave pentru viticultură, în special în ceea ce privește relația plantă-apă. Se inregistrează deja modificări ale fenologiei soiurilor, declanșarea forțată a etapei de pârgă și de maturare a strugurilor. Datorită faptului că boabele strugurilor nu mai ajung la dimensiunile caracteristice soiurilor randamentul în must scade. Sunt și unii specialiști care arată că temperaturile ridicate și lipsa precipitațiilor în cursul verii, spre maturarea strugurilor împiedică atacul putregaiului cenușiu și favorizează acumularea zaharurilor.

Cuvinte cheie: schimbări climatice, vița de vie, *Botrytis cinerea*.

INTRODUCTION

Climate changes affect fauna and flora, whose geographic distribution tends to head north. Climate deregulations have an impact on agriculture, human health, and generally on the social and economic framework. Although climate changes have been witnessed throughout the planet's history, present phenomena can have consequences that will overcome the responsiveness of natural and human systems. These systems risk being permanently altered or even destroyed.

According to numerous studies carried out over the past decades, temperature fluctuations and all extreme climatic phenomena are correlated with the CO_2 concentration in the atmosphere. The increasing concentration of carbon dioxide is a worrying phenomenon, and over the past decade scientists have confirmed that CO_2 has always been the main driver of climate change over the Earth's history. Carbon gas reduces atmospheric permeability for the Earth's reflected radiation to space, thus emphasizing the atmosphere's ability to keep the sun's heat longer than necessary through the greenhouse effect.

Studies on CO_2 in the Earth's atmosphere show that over the last 800 000 years, the concentration in this gas has never been higher than at present. According to PETIT et al. 1999, over the last 420 000 years, CO_2 concentration has peaked between 180 and 300 ppm.

If, for 500 years, the CO_2 concentration remained stable at about 270 ppm (EHLERINGER & CERLING, 1995) at the beginning of the nineteenth century (the start of the industrial revolution), CO_2 emissions increased by almost 50%, today the concentration value being about 400 ppm.

In addition to CO_2, other greenhouse gases are also covered by the Kyoto Protocol: methane (CH_4), nitrous oxide (N_2O) and anthropogenic fluorinated gases (so-called "F gases") grouped into: hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulphur hexafluoride (SF_6). In addition, we mention the ozone-depleting substances controlled by the Montreal Protocol: chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) and halons (***. EPA www.epa.gov).

All these gases, which create stratospheric ozone layer imbalances, increase the equivalent concentration in CO_2, reaching carbon gas values between 470 and 490 ppm. According to SCHULTZ, 2000, if greenhouse gas emissions continue to rise at the same rate in the last part of our century, the equivalent CO_2 concentration will double. The carbon gas equivalent of the main greenhouse gases is shown in Table 1 (***. EPA www.epa.gov):

Table 1. The equivalent in CO_2 of the main greenhouse gases.

Greenhouse gas (other than CO_2)		**Equivalent in CO_2**
	Methane	1 tonne =28.36 tons CO_2
	Nitrous oxide	1 tonne = 265-298 tons CO_2
	Flux gases: sulphur hexafluoride	1 tonne = 23 500 tons CO_2

Being one of the major by-products of burning fossil fuels (for electricity, industrial, transport, households, etc.), billions of tons of CO_2 are emitted each year. Other sources of carbon dioxide, as well as other greenhouse gases, are: wood burning for food and heating, agriculture, industry, landfills, use of fluorinated industrial gases, human activity, etc. In addition to these man-made sources, natural gas sources must also be mentioned: volcanic erruptions, fires, rotting processes in oceans and swamps, etc. (***. ONERC, 2014; ***. EPA, 2017).

In addition, global warming produced by excess gas leads to other phenomena, producing in turn a significant increase in greenhouse gas concentrations, as in a vicious circle. An example is permafrost, which has collected enormous quantities of methane in its course over millions of years. Through its melting due to global warming, huge amounts of methane can be released into the atmosphere, with a devastating effect on the environment.

According to experts in the field (***. IPCC, 2014), carbon dioxide emissions will show spectacular increases along with the technological progress of some emerging countries, such as China, India and Brazil, which account for about 40% of the world's population.

A problem that is raised with consistency when it comes to CO_2 emissions is the need for a complete review of the ways in which society is organized; thus limiting the waste and establishing optimal ways to solve it, limiting the excessive consumption of food and non-food, unnecessary transportation of goods, etc.

MATERIAL AND METHOD

In order to assess the main aspects of the impact of climate change on the environment, in general and on vine in particular, a number of bibliographic databases have been extensively studied, including the Intergovernmental Panel on Climate Change (IPCC), the Intergovernmental Oceanographic Commission of UNESCO, the United States Environmental Protection Agency (EPA), the European Environment Agency, etc. Also, the Kyoto and Montreal Greenhouse Gas Regulations have been highlighted (***. EUROPEAN ENVIRONMENT AGENCY, 2016).

RESULTS AND DISCUSSIONS

CONSEQUENCES OF CLIMATE CHANGE

Temperature. As a consequence of the increase in greenhouse gas concentrations over the last 150 years, the continental average temperature has increased by about 0.8°C and Europe by about 1°C (***. A.E.M., 2016).

According to the UN, global average temperature has increased by about 1 degree in 2015, for the first time since the pre-industrial era. As a result of the double accumulation of greenhouse gases, a temperature increase in Central and Western Europe is expected to range between 2.5 and 5°C by the end of the 21st century; at a global level, the annual average temperature is expected to increase by about 1.8°C - 4°C (***. www.greenfacts.org). In Europe, the highest temperature increases occur in the southern continent and in the Arctic region.

The IPCC report for 2014 highlights the consequences of climate change in terms of temperature: in general, thermal differences between seasons and continents will be lower; also, the temperature increase will be stronger at the poles than at the equator, also, the temperature increase will be stronger at the poles than at the equator, on continents than in oceans, during nighttime than during daytime, in winter than in summer.

Rainfall. Although future precipitation changes are more difficult to establish, changes are foreseen in the total amount of rainfall, but especially changes in their annual distribution. Climate patterns predict an increase in precipitations in winter, the result of an acceleration of the hydrological cycle at European level. This increase will, however, be associated with a decrease in the amount of precipitations in the summer season for most territories. Also, rainfall is expected to be more quantitatively significant at higher and lower latitudes in most subtropical regions. In Europe, precipitations decrease in the southern regions and grow in the north and northwest of the continent.

Levels of seas and oceans. A consequence of the increase in global temperature is the melting of the ice and, implicitly, the increase of the sea level; so floods will be recorded in low-altitude areas, as well as altered geography of coastal areas (TOWLE et al., 2015a; b).

If during the last 50 years the planetary ocean level has increased by about 10 cm, some climate models indicate an increase ranging from 25 to 98 cm by the end of the century (***. I.O.C.U, 2017). One thing worth noting when it comes to raising sea and ocean levels is that out of the 20 metropoles of the world, 16 are located near different seas or oceans. Also, according to the same climate models, about 20,000 islands are estimated to disappear from the geography of the planet (5th IPCC Report).

Acidification of sea and ocean water. The planetary ocean (which accounts for 90% of the planet's water) is the main source of precipitation, absorbing most heat from continents; it seems that the marine environment absorbs about 90% of this heat, mitigating the impact of global temperature (EKSTROM et al., 2015).

In terms of CO_2 emissions, the ocean is a regulator of carbonic acid concentration, more effective than forests (MANZELLO et al., 2008). Since the beginning of the industrial age, the global ocean absorbs more than 30% of CO_2 emissions, the amount absorbed annually nowadays being unprecedented. According to Christopher Sabine of the United States Oceanic and Atmospheric Administration (***. NOAA, 2017), the ocean absorbed about 120 billion tonnes of carbon produced from human activities in 1800. The same agency reports that about 20-25 million tonnes of CO2 is added every day to the planetary ocean (***. www.notre-planete.info).

So, by the end of the nineteenth century, the pH value of marine waters has remained constant. However, nowadays, the acidity of the ocean is rising, with a pH value less than 0.1 times the value since the start of the industrial revolution. It seems that by the mid-21st century, the amount of CO_2 that is absorbed by this ecosystem will lead to changes in the acidity of the upper layers of the ocean, the pH of water dropping even by 0.3; these changes are recorded for the first time in 20 million years of earth history (TOWLE et al., 2015a; b) and will have serious repercussions on biodiversity.

As far as marine life is concerned, it is already found that more than 25% of the corals are affected, as it is estimated that by the middle of our century about 50% of them will disappear. Other marine organisms containing calcium carbonate, including some plankton species, as well as non-carbonated organisms, will be affected if the CO_2 concentration increases and decreases the pH level (TRIBOLLET et al., 2006a; b; EZZAT et al., 2015). Increasing temperatures, combined with acidification of water, pose a serious threat to coral reefs; in general, all marine species, from bacteria to marine mammals will be affected by climate change (TOWLE et al., 2015a; b).

In terms of oxygen production the situation is worrying, too. The planktonic ecosystem produces oxygen through photosynthesis, consuming carbon dioxide. However, there are many oxygen-free "dead" areas, especially in some coastal areas, such as the Gulf of Mexico. These areas began to be mapped after massive fish deaths were recorded in the early 1990s due to crossing these oxygen-free areas (SAMBROTTO et al., 2003). The lack of oxygen is related to the huge amounts of waste from human activities evacuated in these areas as well as to the rise in temperature (***. http://www.lemonde.fr/climat).

Consequences on human society. Climate changes that will primarily impact the environment and biodiversity will have a significant impact on human societies. Increased temperatures will result in higher levels of evaporation at ground and plant level, which will increase the frequency and severity of drought periods. On the other hand, floods and other extreme phenomena will have adverse effects on agricultural production and water resources will drop. According to the UN, climate change could have as a consequence, by 2080, that over 100 million people could live in extreme poverty and nearly 600 million could suffer from malnutrition (***. FUTURA SCIENCE. 2014).

THE INFLUENCE OF CLIMATE CHANGE ON VINEYARD CULTURE

Temperature changes will entail variations in the hydrological cycle, regimes, frequency and duration of precipitations. Since most traditional European vineyards are not irrigated, one of the future challenges will be to ensure access to water and irrigation of plantations.

The increase in greenhouse gas concentrations will have, according to many specialists (LONG et al., 2004), a strong impact on agricultural and natural ecosystems, including on vines, an impact already observed in most plants, annual and perennial. A few examples are: the intensification of photosynthesis process, the increase of biomass production, better water use (BINDI et al., 1996; BINDI et al., 2001; SALAZAR-PARRA et al., 2012); these phenomena are sometimes associated with a decrease in the weight of grape grains (JONES, 2006).

Achieving a common strategy on European viticulture will be very difficult due to the many factors that need to be taken into account: the diversity of vine plantations, climatic conditions of vineyards, specific microclimates, different soil types.

If we refer generally to the temperate climate vineyards, much of them will be exposed to varying climatic conditions, depending on the harvest year, conditions with a global warming trend. The variability of the rainfall regime will have significant consequences for the vineyard culture. The warm and humid climate during the maturation period will affect many of the varieties that are part of the traditional range of a vineyard. Also, periods of intense drought and heavy rain will lead, on the one hand, to competition between the vineyards for water during drought and, on the other hand, to erosion, strong leakage and increased water infiltration during the the precipitations period.

A great challenge will be the prophylaxis and treatment of vines for partially known diseases and pests that will threaten the development of vine and the quality of grapes. The varieties of white vines will be most affected, especially as they have a limited plasticity (JONES, 2006).

According to the general data on the influence of climate change on vines, there is a gap in the phenological stages: dewlap, flowering, grain formation, prick and maturation; grape harvesting is advanced, depending on the area and the harvest year by 20, even 30 days compared to the 1970s. Changing phenology is the result of increasing the temperature value, the heat requirements that trigger the phenological phases being met earlier. The phenomenon has repercussions not only for the loss of traditional landmarks (traditional "100-day harvesting" rule), but also for the harvesting dates for early and late varieties.

On the other hand, the periods of drought recorded during maturation are less favorable for the development of the *Botrytis cinerea* fungus and therefore to the gray rot attack, one of the major problems of world viticulture. Increased temperatures and lack of precipitation during maturation are conducive to the accumulation of sugars in grapes, so the addition of sugar will no longer be necessary. Instead, the accumulations of organic acids will record very low values, which will lead to unbalanced, "burned" wines with a weak typicality.

High temperatures during the harvest period will lead to an increase in the temperature of the grapes, the thermal dynamics of the winemaking process being modified and very difficult to monitor (SCHULTZ, 2000).

The data from the CLIMATOR (2007-2010) research project shows that in the French wine region Bourgogne there was an increase in the grain weight and therefore an increased yield of the harvest of over 50% compared to 1994 and about 200% over the period between 1070 and 1999 (AdCC & VIGNE, 2012). The factors involved are the increase in CO_2 concentration associated with plant vigor caused by: an important floral induction due to higher temperatures and thermohygrometric variations; an increase in the amount of reserve substances in the vine plant, as the period of time between grape harvesting and the fall of leaves (storage period by the plant) has increased; the application of different cultural practices (removing some of the flowers or grapes in order to grow better the remaining ones).

The increasing yields of grape harvest may, however, have repercussions on the concentration in aromatic compounds and, generally, on the content of volatile compounds which contribute to the specificity and typicality of the variety.

Climate change can affect vine plantations and the risks associated with climatic extremes. These risks are related, first of all, to the loss of or significant reduction of the harvest, and are due to:

- spring frost: although the average number of days of frost is lower, the rise in temperature values has led to the advancing of deforestation and blossom; at the same time, although before breaking leaf buds a lower temperature is needed (vegetative rest, dormancy), it is difficult to establish the dominance of a parameter to the detriment of another; also in this context, the duration of vegetative development stages has decreased;
- severe drought: although a period of drought recorded during grapes maturation is favorable to the accumulation of sugars and the reduction of the risk of cryptogamic attack, however, a period of severe drought, i.e. a water deficit, has repercussions on both vine growth and forced maturation of grapes, negatively influencing the production and quality of grapes and wines;
- excessive temperatures lead to forced firing of grape stage and maturation. In recent years, there has been a tendency for varieties to enter early in the parga (end of July and early August), and the sowing of varieties is far less obvious. The sudden and forced entry of grapes in parga leads to stopping the growth of grapes, and they no longer meet the dimensions of the variety, which negatively influences the yield of the must. Also, in black grape varieties, high temperatures cause the grain to be colored before they reach the typical variety.

Excessive heat also causes partial withering and drying of the foliar appliance, its reduced surface having negative repercussions on the growth of grapes and the accumulation of sugars, and therefore on the quantity and quality of the wine.

Another problem is the increase in temperature during the voluntary rest period of the vine. As it is known, during this period (in the temperate climate: end of December, early January to late March) the vine is ready to resume its vegetation cycle, but remains in a state of rest only due to unfavorable conditions. Alternatively, alternating temperatures during this period can lead to significant losses of buds, more so than in the deep rest of vineyards due to low resistance to frost. Also, if the average temperatures in this period exceed the biological threshold of the vine, it can enter vegetation (ALBUQUERQUE, 1993). If cold weather occurs later, the vine can be affected even at temperatures of -10, -15 ºC -episodes of extreme precipitations - frequent and aggressive rains - can lead to soil erosion phenomena and loss of fertility in the hilly area; unfortunately, these degradation phenomena are irreversible.

In general, the precipitation regime tends to decrease, as well as have an uneven distribution throughout the year. Drought periods, alternating with periods of abundant rainfall, sometimes torrential and often cold, have a negative impact on the main physiological processes of vines.

There is an increasing tendency of extreme phenomena in recent years, such as hail, strong winds, storms, torrential rains that affect plants. Strong grain can often lead to compromising grape harvest, but also damage to the foliar appliance and even the destruction of wood - the changes to the diseases and pests of the vine represent an important phenomenon and complex, the evolution of the diseases, their intensity, their impact being related to many factors, difficult to analyze in a short period of time (DUTEAU et al., 1981).

There has been an increase in the incidence of pests and diseases caused by vectors that love heat: oidium, wood diseases, cicadas (hemiptera), etc. (SALINARI et al., 2007; MIRA DE ORDUNA, 2010; PANGGA et al., 2011).

Another issue related to the influence of climate changes on the vine concerns the quality of the harvest and, consequently, of the wine; thus, elevated temperatures increase the accumulation of sugars but also the intensity of the process (DUCHÊNE & SCHNEIDER, 2005), a phenomenon involving a disagreement between the accumulation of metabolites: sugars accumulate faster than aromatic compounds and phenolic compounds, the risk of imbalance aromatic and color (BERLI et al., 2008; SADRAS & MORAN, 2012).

The evolution of the main climatic parameters, confronted with the optimal conditions necessary for the development and maturation of the vine, are factors with particularly important effects on a possible other geographic distribution of the vineyards (JONES & WEBB, 2010). The evolution of climatic indicators will play an increasingly important role in the distribution of vine varieties and the simulation of potential plantations (PIERI, 2010).

There is a possibility that, in order to obtain a high quality grape harvest, as well as for the viability and optimal development of vineyards, the geographical distribution of vineyards and vine varieties will be greatly changed. MALHEIRO et al., 2010 shows that new wine regions in northern France may be more suitable for quality viticulture than established vineyards. These geographical changes could have significant indirect impacts on water resources and ecosystems (HANNAH et al., 2013).

From an economic point of view, major changes can be made: for example, increasing alcohol content and changing the aromatic and chromatic profiles of wines can change the hierarchy of consumer preferences and influence prices (PICHERY & BOURDON, 2007). Also, DOCs (Designations of Origin) are particularly important factors in the wine economy by codifying the use of varieties, placing plantings and technical practices to guarantee the quality of origin. The entire economic and institutional system linked to the vine may be affected.

CONCLUSIONS

Changing temperature and hydrological variations will lead to long periods of drought. In this context, where most traditional European vineyards are not irrigated, access to water and planting irrigation must be ensured.

Increasing greenhouse gas concentrations will have an impact on vineyards, especially as regards the intensification of photosynthesis, increased biomass production, better water use, phenomena associated with a decrease in the weight of grapes.

Climate change already leads to a gap in the phenological stages: flourishing, flowering, grain formation, pruning and maturation; grape harvesting is advanced, depending on the area and the harvest year by 20, even 30 days compared to the 1970s. Also, the duration of the vegetative development stages has decreased and the sowing of the varieties is much less obvious.

Seasons of severe drought, with a pronounced water shortage, have repercussions on both vine growth and forced maturation of grapes, negatively influencing the production and quality of grapes and wines.

There has been an increase in the incidence of pests and diseases caused by vectors that love heat: oidium, wood diseases, cicadas, etc.

On the other hand, experts say that the drought periods recorded during maturation are less favorable to the development of the *Botrytis cinerea* fungus and thus to the gray rot attack, one of the major problems of world viticulture. Increased temperatures and lack of precipitation during maturation are favorable to the accumulation of sugars in grapes; however, elevated temperatures leading to increased sugar accumulation, but also to the intensity of the process, imply a disagreement between the accumulations of metabolites: sugars accumulate faster than aromatic compounds and phenolic compounds, the risk of aromatic imbalance and color.

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