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Grapevine genotypes with potential for reducing the carbon footprint in the atmosphere and cultivation in a biological system

Eugeniu Alexandrov[1], Boris Gaina[2]

[1] Institute of Genetics, Physiology and Plant Protection of the State University of Moldova
[2] Academy of Sciences of Moldova

*Corresponding author: alexandrov.eugeniu@gmail.com

Abstract. The concentration of CO_2 in the atmosphere is increasing from year to year. Taking into account the calculations of the greenhouse gas inventory, it was found that approximately 70% of CO_2 in the atmosphere is absorbed by vegetation (forests, agricultural land, etc.). In the Republic of Moldova, agricultural land constitutes 75% of the total area of the country. The use of agricultural land with genotypes of agricultural plants that have a high potential for capturing CO_2 from the atmosphere would significantly contribute to reducing the volume of this gas in the atmosphere. The use of agricultural land with genotypes of agricultural plants that have a high potential for capturing CO_2 from the atmosphere would significantly contribute to reducing the volume of this gas in the atmosphere. The purpose of the study is to determine the capacity for absorbing carbon from the atmosphere by grapevine genotypes, using the light saturation curve method for photosynthesis. At the same time, it allows us to identify plant genotypes resilient to climatic factors with the possibility of cultivation in a biological system. The interspecific grapevine genotypes (*Vitis vinifera* L. ssp. *sativa* D.C. x *Muscadinia rotundifolia* Michx.) were used as the object of study: Amethyst, Alexandrina, Augustina, etc. and the intraspecific grapevine genotypes (*Vitis vinifera* L. ssp. *sativa* D.C.): Muscat of Alexandria, Sauvignon, Cabernet, etc. Using the light saturation curve method for photosynthesis, it was found that the interspecific genotypes: Amethyst, Alexandrina, etc. have a CO_2 absorption capacity from the atmosphere twice as high as the intraspecific grapevine genotypes: Muscat of Alexandria, Sauvignon, Cabernet, etc. At the same time, the interspecific genotypes Amethyst, Alexandrina, etc. allow cultivation in a biological system without the use of phytosanitary products for the prevention and control of diseases and pests.

1. INTRODUCTION

Based on many years of research, it has been established that the concentration of CO_2 in the atmosphere before the industrial revolution was approximately 300 ppm, while the current pollution level is approximately 430 ppm. The increase in the concentration of carbon dioxide in the atmosphere leads to a disruption of the balance of climatic factors on the planet, as a result of which some genotypes of living organisms will not be able to adapt to new environmental conditions in a short period of time. Greenhouse gases in the atmosphere are mainly the result of anthropogenic activity and based on the volume of these gases emitted, CO_2 is the greenhouse gas emitted in the largest amount, approximately 80% [10-12]. According to greenhouse gas inventory calculations, it has been established that lands covered with vegetation (forests, agricultural land, urban and rural green spaces, etc.) play a decisive role in absorbing greenhouse gases from the atmosphere – about 70% [9; 13; 14]. The situation can be influenced by using various methods of absorbing CO_2 from the atmosphere: physical and chemical - using membrane absorption methods and various adsorbents in technological processes; biological - using plants, algae and soil bacteria, which also fix carbon. A fairly effective method is the cultivation of plant genotypes on agricultural land, as well as planting forest genotypes of plants with an increased potential for absorbing carbon from the atmosphere on unsuitable land for agriculture. At the same time, this represents a profitable activity, selling green quotas (equivalent to produced CO_2) to economic agents that are unable to cope with the technological process of absorbing greenhouse gases emitted into the atmosphere. On the basis of these lands it is possible to create “carbon farms”. Such “*carbon farms*” have been created in the USA, Australia, Finland, Sweden, etc. [10; 11]. To mitigate the effects of climate change, it is not enough to plant crops, restore/reconstruct forest ecosystems, and develop agricultural lands with plant genotypes adapted to climate factors; it is necessary to reduce greenhouse gas emissions from all sources of pollution. The share of the agricultural sector in total anthropogenic greenhouse gas emissions worldwide is about 13%, or about 5-6 gigatons of CO_2 per year [12; 13]. The aim of this study is to determine the potential for carbon absorption from the atmosphere by grapevine genotypes of intraspecific and interspecific origin using the light saturation curve method for photosynthesis, which allows us to identify plant genotypes with potential resistance to climatic factors and an increased ability to absorb carbon from the atmosphere.

2. MATERIALS AND METHODS

To conduct these studies, genotypes of grapevine of intraspecific origin of the group were selected: *Vitis vinifera* L. ssp. *sativa* D.C., such as: Muscat of Alexandria, Sauvignon, Cabernet Sauvignon, etc., and genotypes of interspecific origin *Vitis vinifera* L. ssp. *sativa* D.C. x *Muscadinia rotundifolia* Michx.), such as: Amethyst, Alexandrina, Augustina, etc. [1; 2]. The determination of the ability to absorb carbon dioxide from the atmosphere was carried out using the PTM-48A phytomonitor, which is an automatic system equipped with four sequentially operating cameras fixed on the leaves of plants. As a result of the experiments, the intensity of physiological indicators such as photosynthesis, assimilation, respiration, transpiration, etc. was studied [3; 6; 8]. The time period for assessing the activity of physiological criteria was 72 consecutive hours. Statistical processing of the obtained data was performed using the computer program Statistics 10 (Stat sof INC, USA) and Microsoft Excel 2010 [15; 16].

3. RESULTS

Based on the average annual temperature data for the period 2002-2024, it was established that the average annual temperature is 10.8 ^{0}C, also, comparing it with the average annual temperature, the norm calculated for the territory of the Republic of Moldova, we state the fact that the temperature has increased by 1.33 ^{0}C (fig.1. and fig. 2). Taking into account the average temperature for the region where our studies were conducted, the average annual temperature was determined at 13.73 ^{0}C, and based on the daily temperature estimates for 2024, it was established that the average annual temperature was 15.83 ^{0}C. As a result of the assessments, an increase in the average annual temperature by 2.1 ^{0}C is observed compared to the calculated average temperature [3; 4; 8; 17].

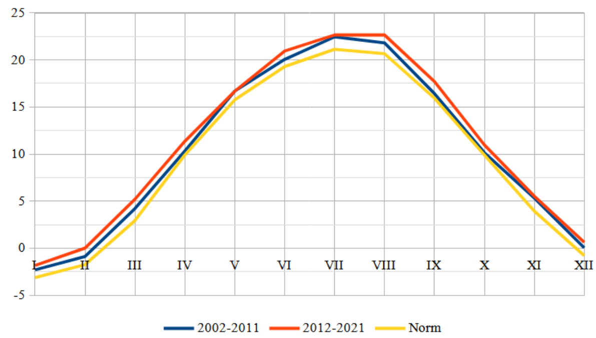

Figure 1. The trend of the average monthly temperature, decade 2002-2011; 2012-2024, Republic of Moldova.

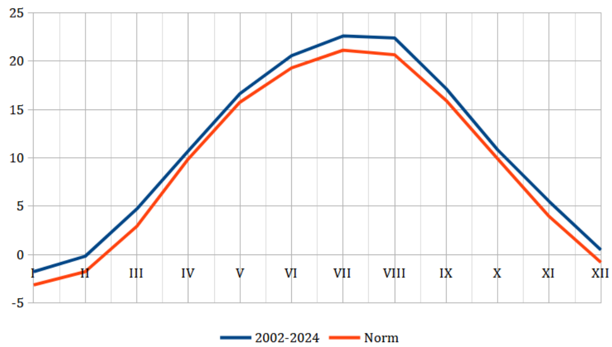

Figure 2. Trend of monthly average temperature, 2002-2024, Republic of Moldova.

Taking into account the average annual temperature value, the norm calculated for the territory of the Republic of Moldova was found to be 9.47 ^{0}C. As a result of the estimates of the average annual temperature values for the last two decades, it was found that for the decade 2002-2011 the average annual temperature was 10.35 ^{0}C, and for the decade 2012-2021 the average annual temperature was 11.039 ^{0}C (fig. 2.). As a result of estimating the average temperature values, we conclude that in the decade 2002-2011, the value of the average annual temperature increased in relation to the value of the average temperature, the calculated norm, by 0.88 ^{0}C. For the decade 2012-2021, the value of the average annual temperature in relation to the value of the average temperature, the calculated norm, increased by 1.57 ^{0}C, and in relation to the value of the average annual temperature for the decade 2002-2011 it increased by 0.69 ^{0}C (fig. 2.). As a result of assessing the intensity of photosynthetic activity of grape genotypes of intraspecific origin *V. vinifera* L. ssp. *sativa* D.C., it was established that the Sauvignon variety has an average intensity of photosynthesis of 2.2 µmol (CO_2)/m^2*s; Muscat of Alexandria – 1.7 µmol (CO_2)/m^2*s, etc. (fig. 4. and fig. 5.).

In rhizogenic interspecific genotypes of grapes *V. vinifera* L. ssp. *sativa* D.C. x *M. rotundifolia* Michx. it was established that the intensity of photosynthesis: BC3-580 – 4.3 µmol (CO_2)/m^2*s; Augustine – 3.8 µmol (CO_2)/m^2*s; Ametist – 4.8 µmol (CO_2)/m^2*s; Alexandrina – 3.1 µmol (CO_2)/m^2*s. (fig. 3. and fig. 4.).

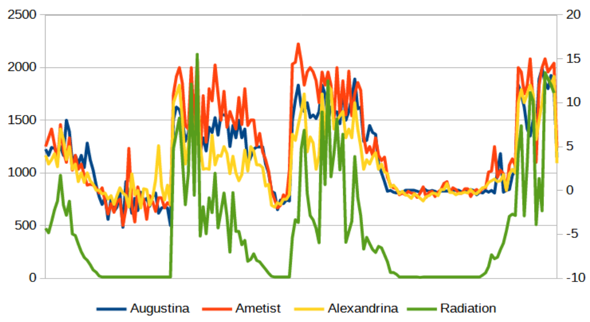

Figure 3. The intensity of photosynthesis (Augustina, Ametist, Alexandrin).

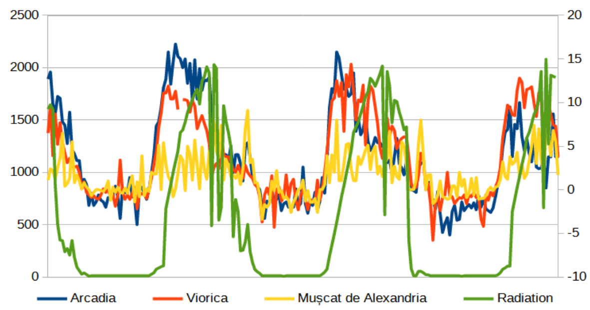

Figure 4. The intensity of photosynthesis (BC3-580, Sauvignon, Bianca).

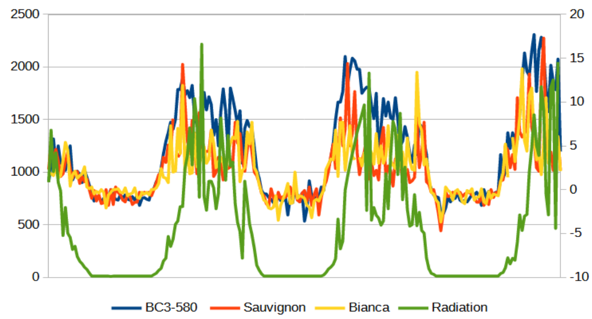

Figure 5. The intensity of photosynthesis (Arcadia, Viorica, Muscat of Alexandria).

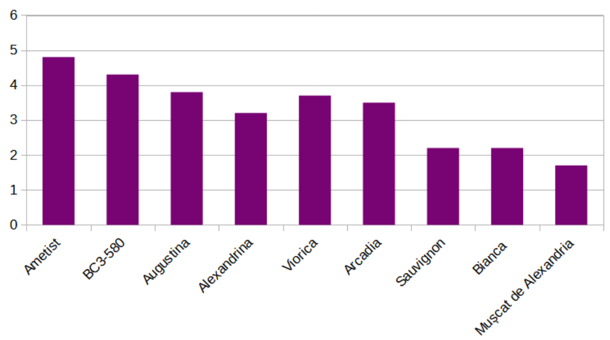

Figure 6. The carbon sequestration coefficient from the atmosphere.

4. DISCUSSION

Forests, agricultural lands, green spaces, etc. are quite effective at absorbing carbon gases from the atmosphere, but at the same time, this can also be an economically profitable activity. In this case, the efficiency of carbon absorption from the atmosphere by these lands depends on the genotype of the plant used, so it is necessary to create genotypes of plants that have an increased potential for absorbing carbon dioxide from the atmosphere. According to greenhouse gas inventory calculations, it has been established that in the Republic of Moldova forest lands play a decisive role in absorbing greenhouse gases from the atmosphere, accounting for about 62%. Forest lands occupy an area of about 450 thousand hectares (13.6% of the country's territory), the area of agricultural land is about 1,015,693 hectares (about 75% of the country's area) [14; 18]. It is estimated that about 40% of agricultural lands are degraded and yields are below their productive capacity. The main reasons for degradation are: failure to use plant genotypes adapted to the climatic factors of a given area, failure to observe crop rotation, reduction in the sowing of forage and legume crops, deforestation and shelterbelts, etc. The ongoing degradation of agricultural lands sharply reduces the possibility of obtaining adequate yields. As a result of applying the method of the photosynthesis light saturation curve using the PTM-48A phytomonitor, the ability of intraspecific grape genotypes *V. vinifera* L. ssp. *sativa* D.C. and interspecific rhizogenic grape genotypes *V. vinifera* L. ssp. *sativa* D.C. x *M. rotundifolia* Michx. to absorb CO_2 from the atmosphere was studied. Based on the studies conducted, it was found that the coefficient of carbon absorption by grapevine genotypes is: - interspecific *V. vinifera* L. ssp. *sativa* D.C. x *M. rotundifolia* Michx.: Ametиst – 4.8 μmol(CO_2)/m^2*s; BC$_3$-580 - 4.3 μmol(CO_2)/m^2*s; Augustine – 3.8 μmol(CO_2)/m^2*s; Alexandrina – 3.1 μmol(CO_2)/m^2*s; - intraspecific *V. vinifera* L. ssp. *sativa* D.C.: Sauvignon - 2.2 μmol (CO_2)/m^2 * s; Muscat of Alexandria - 1.7 μmol (CO_2)/m^2* s, etc.

Intraspecific genotypes in the *Vitis vinifera* L. ssp. *sativa* D.C. group have a wide plasticity of use, but at the same time do not ensure overcoming the genetic barrier regarding changing climatic conditions.

Appreciating the grapevine genotypes created to date, it is necessary to mention that the cultivation of these varieties requires grafting onto phylloxera-resistant rootstock, which ultimately contributes to the final cost of producing the planting material, as well as the application of chemical treatments to prevent and combat diseases and pests. Thus, a considerable negative impact is generated on the wine-making products. At the same time, as a result of grapevine cultivation, environmental pollution is also produced, increasing the carbon footprint in the atmosphere.

Based on the above, grapevine varieties are needed that can ensure stable annual productivity, superior quality of derived products with minimal impact on the environment. By relying on the specific characteristics of genotypes and using the algorithms of the interspecific hybridization technique and methodology, rhizogenic interspecific genotypes with increased plasticity in terms of their adaptation to climate change are to be created, with beneficial repercussions on sustainable development.

Taking into account the functionality of the taxonomic entities used in grapevine crossing techniques in relation to climatic factors of the species: *Vitis vinifera* L. ssp. *sativa* D.C. (2n=38) and *Muscadinia rotundifolia* Michx. (2n=40) with diminished combinative capacity, which can be overcome by involving two determining genetic factors: *parental* as a hybridization component - *Vitis vinifera* maternal parent, and *Muscadinia rotundifolia* - paternal and *additive* - through backcrosses, it was possible to obtain interspecific genotypes that have resilience to climate change.

5. CONCLUSIONS

1. The average annual temperature for the period 2002-2024 is 10.8 ^{0}C, compared to the average annual temperature, the norm calculated for the territory of the Republic of Moldova, we note that this has increased by 1.33 ^{0}C.

2. Interspecific genotypes of grapes (*V. vinifera* L. ssp. *sativa* D.C. x *M. rotundifolia* Michx.) have a double coefficient of carbon absorption from the atmosphere compared to intraspecific genotypes (*V. vinifera* L. ssp. *sativa* D.C.), as well as increased adaptability to climatic factors.

6. ACKNOWLEDGEMENTS

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