THE INFLUENCE OF CLIMATIC CHANGES ON THE WOODY VEGETATION OF THE MEHEDINTI PLATEAU GEOPARK

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Abstract

In the climatic conditions of the Mehedinți Plateau, the plant species of sub-Mediterranean origin have adapted to a certain duration and variation of the thermal and precipitation regime during the growing season, in correlation with their demands on temperature and humidity. The climatic disturbances observed in recent years (short periods with very abundant precipitation, very long periods of drought, springs with very low temperatures, at the limit of freezing), can create serious imbalances in these plants. From a phenological point of view, the plants started growing in 2021, at the beginning of April. In 2022, in the same period, the plants were still resting.
Compared to the data from the spring and summer of 2021, in 2022 the water content of the leaves was lower and much lower values of the photosynthesis process were recorded. As a consequence, the growth rate was seriously affected. Young plants were more strongly affected than mature trees.

Key words*: photosynthesis, chlorophyll, water, drought*

INTRODUCTION

Because the Earth is a system where everything is connected, changes in one area can lead to changes in all others. The consequences of climate change now include, among others, intense droughts, water scarcity, severe fires, rising sea levels, flooding, melting polar ice, catastrophic storms, and declining biodiversity.
https://www.un.org/en/climatechange/what-is-climate-change

As the global climate is a highly interconnected system that is influenced by many different factors, the consequences usually result in positive or negative feedback effects. This refers to developments that are self-enhancing due to the occurrence of certain conditions. These tipping points are the crossing of thresholds for which certain consequences can no longer be avoided, even if temperatures were to be lowered again later.
https://www.myclimate.org/information/faq/faq-detail/what-are-the-effects-of-climate-change/

It is not scientifically possible to assign individual weather events to the current climate change, however, it can be statistically proven that global warming will increase the probability of extreme weather events. The sixth IPCC report from 2021 states that “Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred”.
https://www.myclimate.org/information/faq/faq-detail/what-are-the-effects-of-climate-change/

According to the report of the European Environment Agency, in Romania, climate variability will have direct effects on sectors such as agriculture, forestry, water management, the residential and infrastructure sector, it will lead to changes in periods of vegetation and the displacement of the demarcation lines between forests and meadows, will increase the frequency and intensity of extreme weather phenomena http://www.eea.europa.eu

The changes in the climate regime in Romania fit into the global context, considering the regional conditions: the increase in temperature will be more pronounced during the summer, while in the north-west of Europe the most pronounced increase is expected during the winter.

https://www.meteoromania.ro/clima/adaptarea-la-schimbarile-climatice

Although they are considered more resistant than herbaceous species, woody species are also affected by drought.

Increased mortality of trees during and after drought has been observed in recent years (Anderegg et al., 2013). However, the mortality process in trees is poorly understood, as indicated by Meir et al. (2015), and the question of how exactly trees are killed by drought remains unanswered (Hartmann et al., 2013). Drought affects both tree hydraulics and C balance because trees, as with all vascular plants, respond to decreasing soil water availability with stomatal closure, thereby reducing C assimilation rates. Consequently, long-lived plants such as trees might be forced into a negative C balance, by mobilizing stored C to fulfill metabolic needs, until reserves are eventually depleted (Sala et al., 2010). In the southwestern part of Romania, the summer of 2021 was characterized by high temperatures and a period of almost three months without rain. Under these conditions, the damage to forest species, especially seedlings, was serious.

If the mature trees have a well-developed root system and have benefited from water accumulated in the soil during the spring, the seedlings have been severely affected by the prolonged period of drought. The drought period was then extended in the fall.

The winter was also extremely dry, without precipitation, and in 2022, the spring brought no rain at all. The rains returned only in the middle of the year

The effect of drought on plants is complex and they respond with many protective adaptations. During drought, plants suffer from dehydration of cells and tissues, as well as a considerable increase in body temperature. Thus, the low water content caused by drought is usually accompanied by high body temperatures. Drought affects plants in different ways. Various ecological groups or even individual species have different types of drought responses. (Henckel P.A, 1976). Photosynthetic systems are susceptible to damage during responses to water deficit stress. Xiangbo Zhang et al (2018) observed a lower photosynthetic rate and lower efficiency of PSII electron transport in the drought seedlings. The closing of stomata is a well-known mechanism plants use to avoid water loss in response to drought stress, but this adaptation also results in decreased CO_2 assimilation and lower photosynthetic efficiency (Assman S.M et al, 2016) Under water deficit conditions, cell division and dry matter accumulation reportedly decrease because of inhibited light harvesting (Hayano-Kanashiro C., 2009).

Carbohydrate metabolism is one of the most important plant processes for absorbing the energy generated during photosynthesis, and its substrates have been reported to be involved in drought stress responses in addition to acting as energy sources. Changes to the expression of genes associated with carbohydrate metabolism alter the carbohydrate contents of different tissues. Additionally, drought stress also induces the accumulation of different sugars, including glucose (Min H.,2016). Water stress adversely impacts many aspects of the physiology of plants, especially photosynthetic capacity. If the stress is prolonged, plant growth, and productivity are severely diminished. Plants have evolved complex physiological and biochemical adaptations to adjust and adapt to a variety of environmental stresses. The molecular and physiological mechanisms associated with water-stress tolerance and water-use efficiency have been extensively studied (Osakabe et al, 2014)

Plant growth is anchored by photosynthesis; however, excess light EL can cause severe damage to plants. EL induces photo-oxidation, which results in the increased production of highly reactive oxygen intermediates that negatively affect biological molecules and, if severe, a significant decrease in plant productivity. Water stress that induces a decrease in leaf water potential and in stomatal opening leading to the down- regulation of photosynthesis-related genes and reduced availability of CO_2, has been known as one of the major factors in the stress (Osakabe et al, 2014).

Scarcity of water is a severe environmental constraint to plant productivity. Drought-induced loss in plants probably exceeds losses from all other causes, since both the severity and duration of the stress are critical. Various management strategies have been proposed to cope with drought stress. Drought stress reduces leaf size, stem extension and root proliferation, disturbs plant water relations and reduces water-use efficiency. Plants display a variety of physiological and biochemical responses at cellular and whole-organism levels towards prevailing drought stress, thus making it a complex phenomenon. CO_2 assimilation by leaves is reduced mainly by stomatal closure, membrane damage and disturbed activity of various enzymes, especially those of CO_2 fixation and adenosine triphosphate synthesis (Farooq M.et al, 2009).

Unlike herbaceous plants, woody plants are characterized by extensive secondary growth, which itself can respond to drought conditions. For example, the diameter of the xylem conduits, responsible for the transport of water, and the thickness of their cell walls can be modified, resulting in increased resistance against cavitation in the vascular tissues). Consequently, trees seem to have evolved mechanisms to cope with dehydration conditions that are distinct from those of herbaceous plants (Brunner I.et al, 2015). It is well documented that tree species adapted to dry climatic regimes generally have higher root-to-shoot ratios and deeper root systems than species that are more suited to mesothermal climatic conditions (Hartmann, 2011). In a survey of 62 tropical tree species, seedlings from dry forests were found to have a higher belowground biomass and deeper roots than seedlings from moist forests (Markesteijn and Poorter, 2009). Therefore, tree species adapted to dry conditions tend to invest more biomass into longer-lasting root organs, thus optimizing water uptake, while simultaneously minimizing water loss from transpiration. These patterns have contributed to the hypotheses that trees respond to water deficit by increasing root-to-shoot ratios and rooting depth (Brunner I.et al, 2015).

MATERIALS AND METHODS

In the current study, determinations have been made on spontaneous woody species from the Mehedinti Plateau area, which has been severely affected by drought in recent times. The area where the study has been conducted overlaps with the Mehedinti Plateau site which is of community importance and has ten types of natural habitats. The flora consists of trees, shrubs and herbaceous species distributed in accordance with the geological structure, soil and climate characteristics, geomorphological structure and altitude. The Mehedinţi Plateau is framed between the Getic Plateau (E-SE), the Southern Carpathians (N-NW), the Getic Subcarpathians (NE), the Banat Mountains (W) and the Danube Corridor (SW). The Mehedinţi Plateau represents one of the smallest but better individualized geofigureal regions of the country, occupying only 0.33% of its surface. The presence and large extent of calcareous rocks makes the Mehedinti Plateau the area with the most varied and almost the densest karst phenomena per surface unit in the country.

https://www.atestate.ro/atestate/turism/podisul-mehedinti-potential-si-valorificare-turistica-1433

The vegetation is characteristic of low mountains and falls within the area of sub-Mediterranean oak forests, with *Quercus pubescens, Q. virgiliana, Q. cerris, Q. frainetto, Carpinus orientalis, Q. dalechampii, Celtis australis*, *Juglans regia, Corylus colurna.* Balkan beech forests (*Fagus sylvatica ssp. moesiaca*) are also found in the area (Roman N, 1974).

The eco-physiological research was carried out between April 2021 and May 2022 in the Mehedinți Plateau, on the Topolnita Gorges. The area is located in the north-western part of the Mehedinți county, in the eastern part of the Cireșu village and is crossed by the county road (DJ607B) that connects the Marga locality with the village of Bunoaica.

Field studies were carried out for the identification and inventory of some taxa, analyzing them in different vegetation stages and recording their ecological characteristics.

It was considered important to know the phenology of these species, because during the two years, the climatic conditions were characterized by very high temperatures and a lack of precipitation. Moreover, in April 2021, after a relatively warm period that allowed the start of the vegetation process for most plant species, very cold nights followed, with temperatures of -5 C which affected most species of sub-Mediterranean origin present in the area.

https://www.meteoblue.com/ro/vreme/historyclimate/weatherarchive/cire%c5%9fu_rom%c3%a2nia_681597?fcstlength=1m&year=2021&month=4

These thermal fluctuations are not specific to the Mehedinți Plateau, which from a climatic point of view is included in the area with sub-Mediterranean influences.

Because of this, many plants were affected, entering the vegetation period much later, or, more seriously, suffering partial or total destruction of the leaf apparatus.

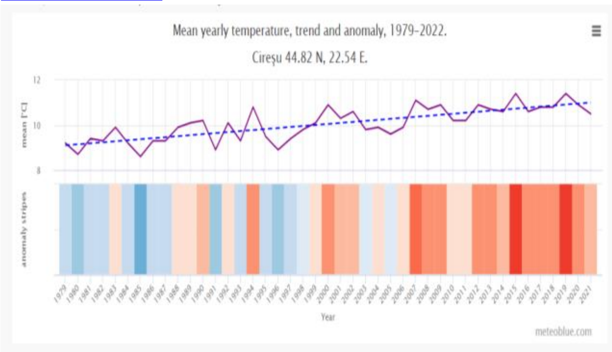
https://www.meteoblue.com/ro/vreme/historyclimate/weatherarchive/cire%c5%9fu_rom%c3%a2nia_681597?fcstlength=1m&year=2021&month=4

From the analysis of the Meteoblue archive, it appears that in the researched area, since 1979, there has been a gradual increase in average annual temperatures, the most pronounced being in the period 2007-2021 (picture 1). The graph shows a temperature estimate for the Cireșu region. The dotted blue line indicates that the Ciresu village is also affected by climate change, which led to an increase in annual average temperature. At the bottom, the graph shows the so-called warming streaks. Each colored band represents the average temperature for a year: blue for the coldest years, red for the warmest

https://www.meteoblue.com/ro/climatechange/cire%c5%9fu_rom%c3%a2nia_681597?month=6

For the month of June, the temperature and precipitation anomaly in the Cireșu area was taken as a model. Recent years have been marked in this month by significant increases in temperatures, associated with a decrease in the amount of precipitation

https://www.meteoblue.com/ro/climatechange/cire%c5%9fu_rom%c3%a2nia_681597?month=6



Picture1.Annual temperature variation in Cireșu-Mehedinti County
https://www.meteoblue.com/ro/climatechange/cire%c5%9fu_rom%c3%a2nia_681597?month=6

From all the woody identified species, eco-physiological studies were carried out on the following species: *Fraxinus ornus, Cotinus coggygria, Syringa vulgaris, Quercus cerris* and *Juglans regia.*The analyzed physiological indices have been the photosynthesis intensity, total water content and the content of chlorophyll.
Photosynthesis was determined with the portable Lci apparatus.
The total water content was determined gravimetrically by drying the plant material at the oven at 105 ^{0}C. The quantity of chlorophyll pigments from the leaves has been determined with the Minolta chlorophyll meter.

RESULTS AND DISCUSSIONS

Phenological observations

In the year 2021, the high temperatures in spring allowed the plants to enter in the vegetation phase quite early. In *Cotinus coggygria*, the leaves appeared in the middle of April, and in *Syringa vulgaris*, the first inflorescences could be observed during this period.
In the specimens of *Cotinus coggygria* located on the slopes with southern exposure, the start of vegetation was faster, but this was a disadvantage, because the very cold nights that followed, with temperatures up to -5 ^{0}C, led to the destruction of the young leaves. In the *Syringa vulgaris* species, the cold period did not lead to any visual damage on the leaves.
In 2022, at the same time, *Syringa vulgaris* had flower buds, while *Cotinus coggygria* was still dormant. In the other species studied, the beginning of May was the start of vegetation.
This delay of almost a month in the onset of vegetation can have serious effects if it is followed by a dry period, because for plants growing on skeletal substrate, the only available source of water is rainwater. If their drying occurs before fruiting, they will not produce seeds, and if the seeds do not reach maturity, the germinative faculty is significantly reduced. Another negative aspect is related to the accumulation of reserve substances, mainly carbohydrates.
The reduced values of photosynthesis and the faster entry into dormancy affect the production of organic compounds that under normal conditions should be translocated to the root and buds. Thus, perennial plants enter the spring of the following year with a deficit of organic substances that should provide the energy necessary to exercise root pressure and bud growth.

Water content of the leaves

The total water content of the leaves was determined in young plants and mature plants in the middle of each month of the analyzed period in 2021. From the figure data, it appears that in May, both young and mature plants recorded the highest content of water. As temperatures increased and droughts set in, a significant decrease in water content was observed, with a minimum in September for *Juglans regia.*
In the other studied species, in September 2021, they had already entered a state of rest, causing the leaves to fall. In *Syringa vulgaris*, young plants entered dormancy earlier, as early as July, while the mature plants entered dormancy in August (graph 1). In October 2021, *Quercus cerris* had also gone dormant.

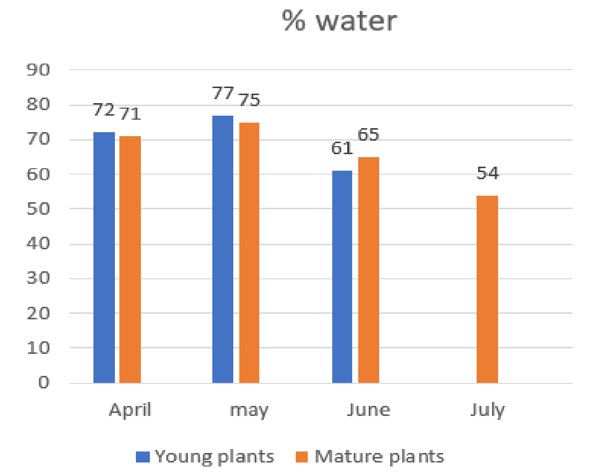


Figure 1. The water content (%) of *Syringa vulgaris* leaves during the year 2021

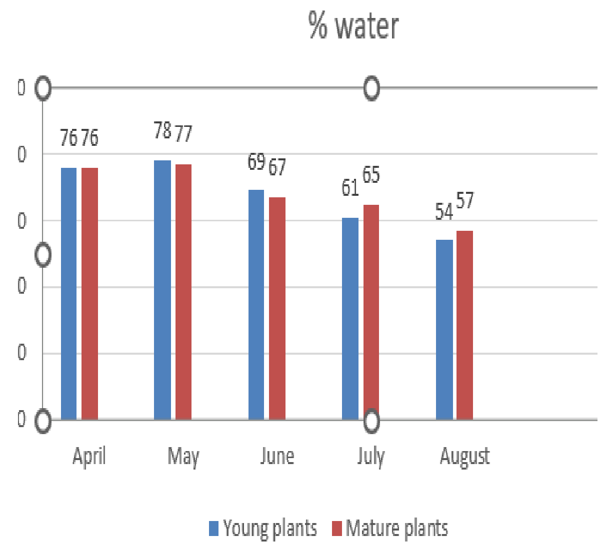


Figure 2. The water content (%) of *Cotinus coggygria* leaves during the year 2021

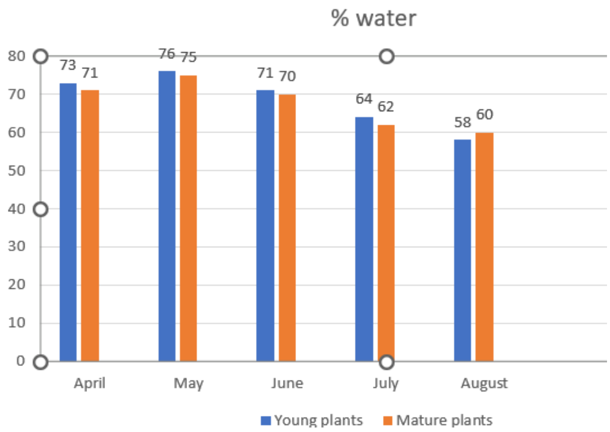


Figure 3. The water content (%) of *Fraxinus ornus* leaves during the year 2021

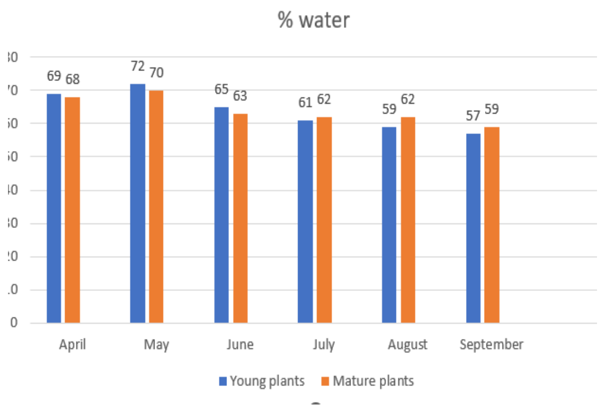


Figure 4. The water content (%) of *Quercus cerris* leaves during the year 2021

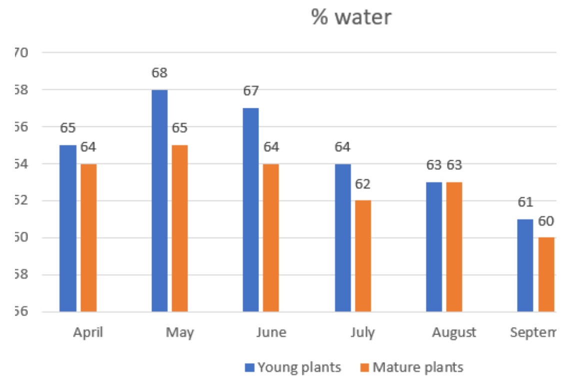


Figure 5. The water content (%) of *Juglans regia* leaves during the year 2021

In 2022, determinations were made in April and May. The species that started vegetation in April: *Fraxinus, Syringa, Cotinus* had lower water content values than during the previous year (figure 6) In May, determinations indicated a decrease in water content due to the onset of drought. Compared to the year 2021, in May 2022 the values of the total water content were lower, for all species studied (figure 7).

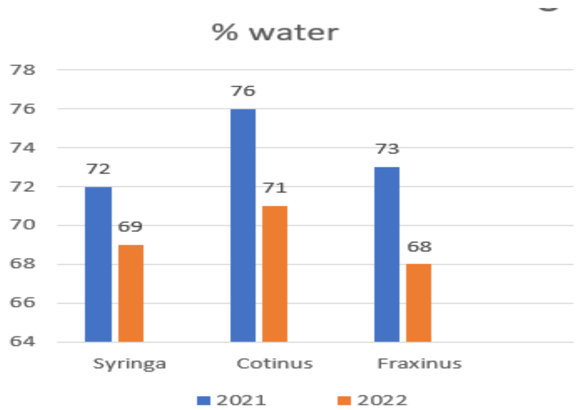


Figure 6. The water content of leaves in the months of April 2021 and April 2022

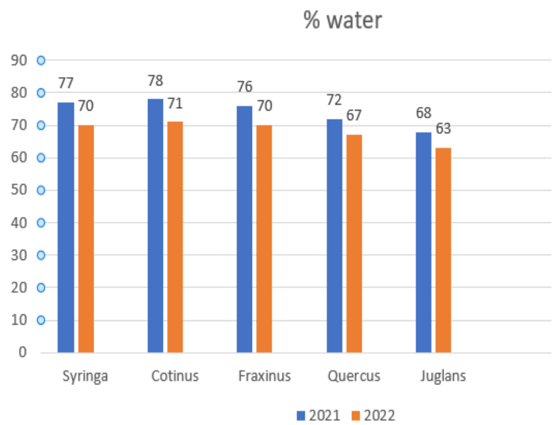
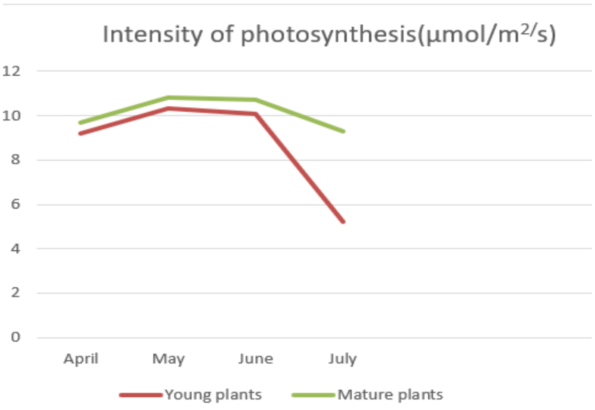


Figure 7. The water content of the leaves in the months of May 2021 and May 2022

The intensity of photosynthesis

In *Syringa vulgaris* leaves, during the year 2021, photosynthesis recorded maximum values in May and early June. A significant reduction in the process followed, much more evident in young plants, more affected by water stress due to the less developed root system (figure 8). The regression observed in July coincides with the degradation process of chlorophylls and the beginning of plants going into dormancy. It is obvious that the young plants, having low values of photosynthesis, have accumulated small amounts of reserve organic substances, thus affecting the growth of the following year.



Graph. 8.Variation in photosynthesis intensity (µmol/m ^{2}/s) in *Syringa vulgaris* during 2021

In the leaves of *Cotinus coggygria*, after the photosynthetic maximum recorded in May, there was a reduction in the process, until the end of August when the degradation of chlorophyll occurred and the leaves started to fall (graph 9).

The data in graph 10 indicate, in the case of the species *Fraxinus ornus*, higher values of photosynthesis in mature trees, young plants being more strongly affected by the water deficit at the end of May.

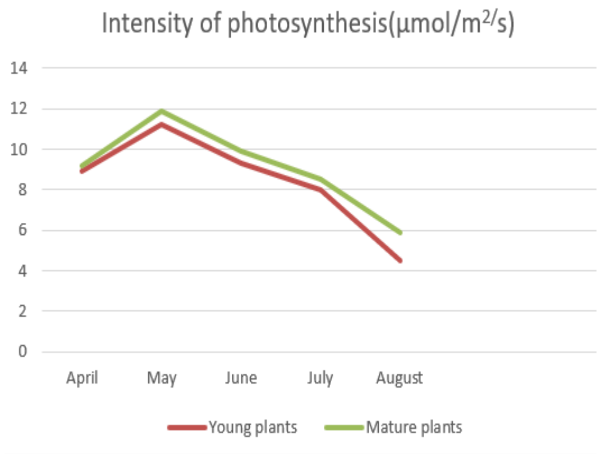


Figure 9. Variation of photosynthesis intensity (µmol/m ^{2}/s) in *Cotinus coggygria* during 2021

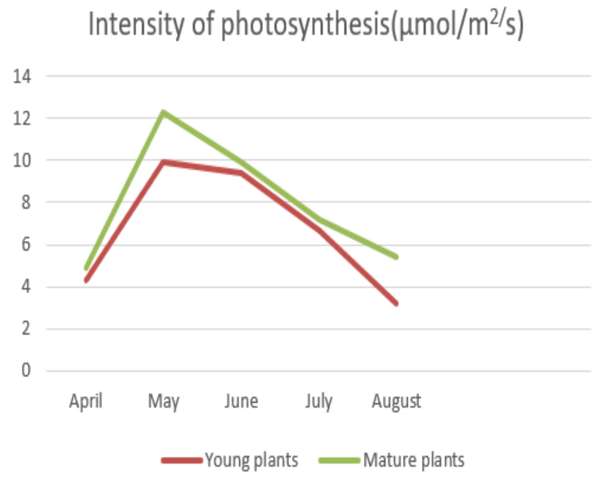


Figure 10. Variation of photosynthesis intensity (µmol/m^2/s) in *Fraxinus ornus* during 2021

In Quercus cerris, the start of vegetation at the end of April was marked by low values of photosynthesis (figure 11).

As the surface of the leaves increased, the process intensified, reaching the maximum value at the end of May. Starting from June, the photosynthesis values started to decrease, the young plants being more affected, as in the case of the other species studied.

Although data from the specialized literature indicate an increased resistance of young plants of *Quercus cerris*, Arab L. et al. (2020) stating that the leaves of oak seedlings generally possess a high plasticity to cope with extreme differences in aridity through immediate responses that are even better developed in plants of arid origin, the data obtained indicate a rather serious damage to the plants from the researched area. If the mature trees have a well-developed root system and benefited from the water accumulated in the soil during the spring, the young plants were severely affected by the prolonged period of drought. And other authors show that in *Quercus cerris*, drought stress decreased stomatal conductance and significantly increased accumulations of total soluble sugars (Deligaz Ayse, Bayar Esra, 2017).

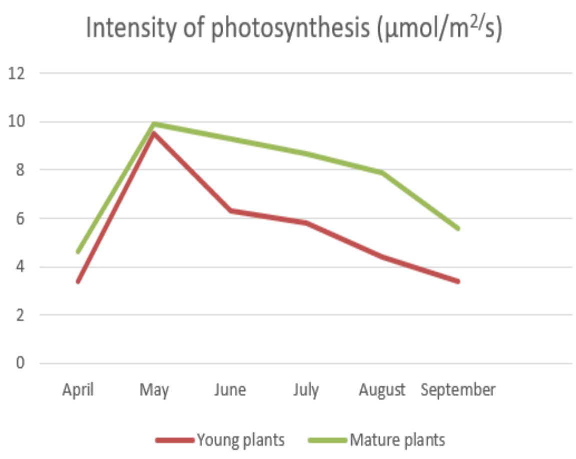


Figure 10. Variation of photosynthesis intensity (µmol/m^2/s) in *Quercus cerris* during 2021

In *Juglans regia*, the first leaves that appeared in May had the highest values of photosynthesis. Towards the end of this month, the values started to decrease gradually, throughout the vegetation period, the minimum value being registered in September (graph 11)

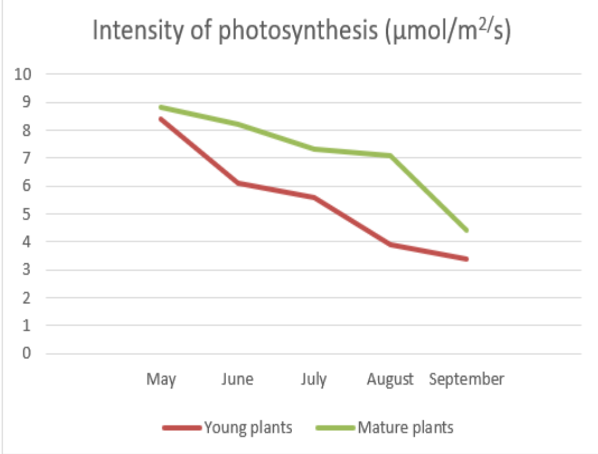


Figure 11. Variation of photosynthesis intensity (µmol/m^2/s) in *Juglans regia* during 2021

A comparative study of photosynthesis determined in the years 2021 and 2022 in the same month (May) shows that in 2022, it saw lower values for all the species (figure 12).
The cumulative effect of the two years of drought has significantly affected the plants.

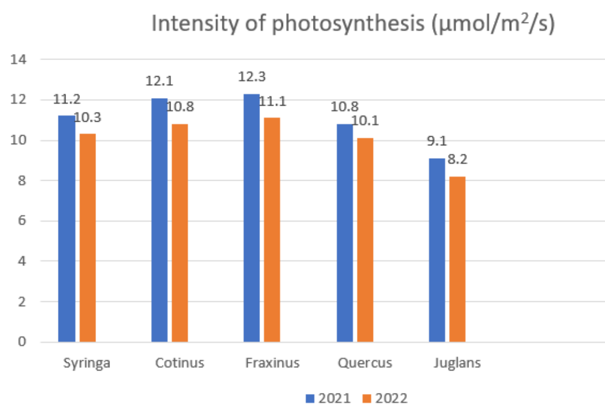


Figure 12. The values of the intensity of photosynthesis in May of the years 2021 and 2022 (µmol/m^2/s)

The content in chlorophyll

Regarding the content in chlorophyll pigments, the determinations were also carried out in the period April-October 2021. The maximum chlorophyll content was recorded in most species in the months of May-June (figures 13-17)

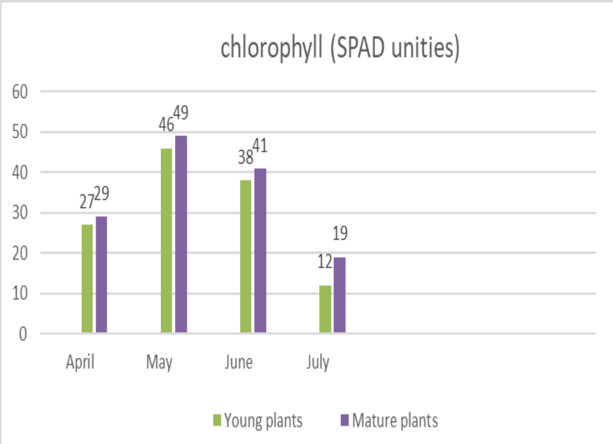


Figure 13. Chlorophyll content of *Syringa vulgaris* leaves (SPAD unities)

The decrease in the amount of chlorophyll can be correlated with the decrease in the water content of the leaves. Water stress determined the partial degradation of chloroplasts and the reduction of chlorophyll synthesis. In most plants, especially young ones, after June, a degradation of chlorophyll and yellow or deep red coloring of the leaves was observed.

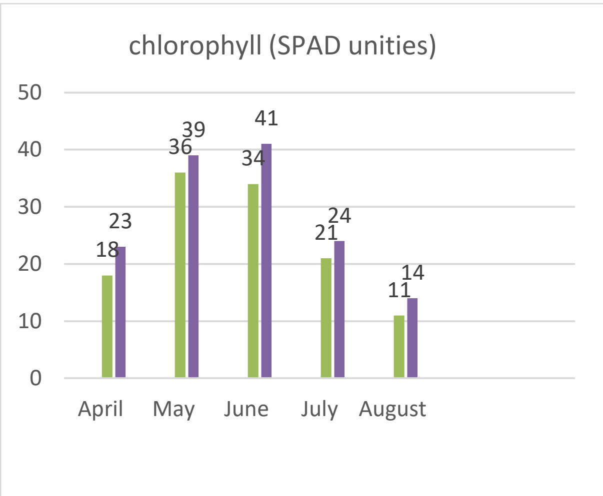


Figure 14. Chlorophyll content of *Cotinus coggygria* leaves (SPAD unities)

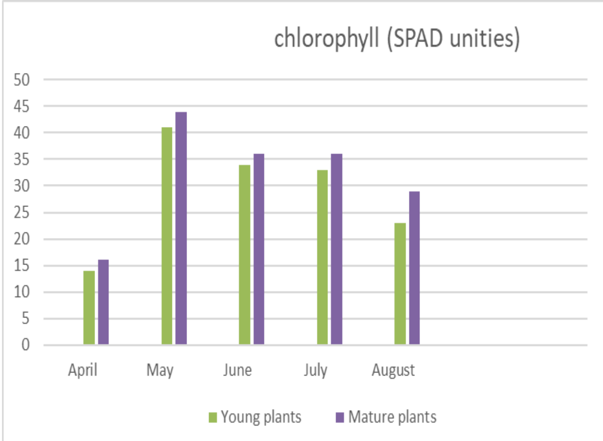


Figure15. The chlorophyll content of *Fraxinus ornus* leaves (SPAD unities)

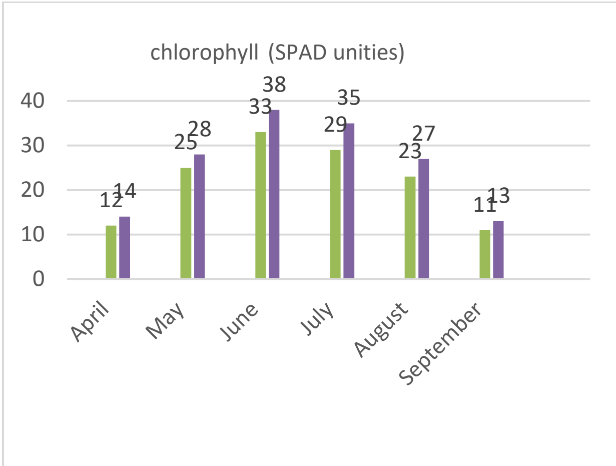
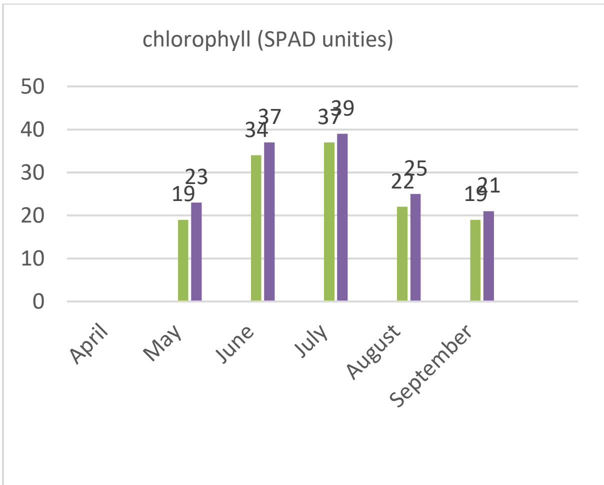


Figure16. Chlorophyll content of *Quercus cerris* leaves (SPAD unities)



Graph.17. Chlorophyll content of *Juglans regia* leaves (SPAD unities)

CONCLUSIONS

In the researched area, besides the increase in temperature, the decrease in the amount of precipitation is the main cause of plant damage

The low water content and the small amount of chlorophyll affect seriously the photosynthesis process, the younger plants being more affected

The obtained data is highlighting the danger of extinction for many plant species over time, due to the inability to adapt to new environmental conditions, all this against the background of the increasingly aggressive anthropogenic impact, which amplifies the effects of climate change

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