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THE INFLUENCE OF EXTREME TEMPERATURES ON THE PHYSIOLOGY OF SOME WOODY SPECIES FROM THE SOUTHWEST AREA OF ROMANIA

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ABSTRACT

The temperature differences recorded in recent years have allowed studies to be carried out to explain how plants react to climate change. Both cultivated and wild plants are affected.
In the present study, the physiological parameters of 4 woody species that grow spontaneously in the south-western area of Romania were determined: Juglans regia, Populus nigra, Morus alba and Tilia platyphyllos.
The determinations indicated significant differences in the phenology of these species but also in terms of the intensity with which some vital processes are carried out.
It is obvious that the studies presented cannot be generalized, but they constitute a first step in establishing the influence exerted by extreme temperatures on the analyzed plant species.

INTRODUCTION

Temperature is a major factor affecting the rate of plant development. The higher temperatures expected with climate change and the potential for extreme temperature events will certainly affect plant productivity.

The effects of temperature are enhanced by water deficits and excess soil water, demonstrating that understanding the interaction between temperature and water will be necessary to develop more effective adaptation strategies to offset the impacts of extreme temperature events associated with climate change.

The rate of plant growth and development depends on the temperature around the plant and each species has a specific temperature range represented by a minimum, maximum and optimum.

Temperature changes expected over the next 30-50 years are expected to be in the range of 2-3 °C (Intergovernmental Panel Climate Change, 2007).

Heat waves or extreme temperature events are projected to become more intense, more frequent and last longer than what is currently observed in recent years (Meehl et al, 2007). Extreme temperature events can have short-term durations of several days, with temperature increases of more than 5 °C above normal temperatures.

Extreme events occurring during the summer period would have the most dramatic impact on plant productivity; however, there has been little research done to document these effects.

Temperature, along with other climatic factors, exerts a great influence on vegetation, on plant physiology, intervening in all important processes: respiration, transpiration, photosynthesis, growth, flowering, fruiting. It also conditions the internal structure, morphology, but also the spread of plants. Thus, in a certain region only those plants will grow for which the temperature will not exceed the maximum and will not fall below the critical minimum.

Vegetative development (the rate of emergence of nodes and leaves) increases as temperatures rise to a species optimum. For most plant species, vegetative development usually has a higher temperature optimum than reproductive development. Cardinal temperature values for selected annual crops are given by Hatfield et al. (2011) for different species. Thus, an extreme event for a tropical plant will be at a higher temperature than for a plant native to the temperate zone where the maximum growth temperature is 25 °C versus 38 °C. In understanding extreme events and their impact on plants, we will need to consider the plant's response to weather temperature.

One of the phenological stages more susceptible to high temperatures is the pollination stage. Maize pollen viability decreases with exposure to temperatures above 35 °C (Dupuis and Dumas, 1990). The effect of temperature is enhanced at high vapor pressure deficits, because pollen viability (prior to silk reception) is in function of pollen moisture content, which is strongly dependent on vapor pressure deficit. During the endosperm division phase, as temperatures increased to 35 °C from 30 °C, the potential rate of seed growth was reduced along with final grain size, even after the plants returned to 30 °C (Fonseca and Westgate, 2005)

Exposure to temperatures above 30 °C impaired cell division and amyloplast replication in maize kernels, which reduced seed size and ultimately yield (Commuri and Jones, 2001).

Rice (*Orzya sativa* L.) shows a similar temperature response to maize because viability and pollen production decrease as the daytime maximum temperature (Tmax) exceeds 33 °C and ceases when Tmax exceeds 40 °C (Kim et al, 1996).

Current rice cultivars flower near the middle of the day, making Tmax a good indicator of heat stress on sterility. These exposure times occur rapidly after anthesis, and exposure to temperatures above 33 °C within 1–3 h after anthesis results in anther dehiscence, pollen shedding, pollen grain germination on the stigma, and pollen tube elongation, which has a negative impact on reproduction. Observations in rice show that anthesis occurs between about 9 and 11 am (Prasad et al., 2006 b) and exposure to high temperatures may already be occurring and will increase in the future.

Projected increases in air temperature throughout the remainder of the 21st century suggest that grain yields will continue to decline for major crops due to increased temperature stress on all major grain crops (Hatfield et al., 2011).

Beyond a certain point, higher air temperatures negatively affect plant growth, pollination, and reproductive processes (Sacks and Kucharik, 2011). However, as air temperatures rise above the optimum, instead of falling at a rate proportional to the rise in temperature, crop losses accelerate. For example, an analysis by Schlenker and Roberts (2009) indicated that yield increases for corn, soybeans, and cotton would increase gradually with increasing temperatures from 29 °C to 32 °C and then decrease sharply with increasing temperature above this threshold.

Temperature increases may cause yield decreases of between 2.5% and 10% in a number of economically valuable crop species throughout the 21st century (Hatfield et al., 2011). Other evaluations of temperature on crop yield produced different results. Lobell et al (2011) showed yield decline estimates between 3.8% and 5%;

Schlenker and Roberts (2009) used a statistical approach to estimate wheat, corn and cotton yield declines of 36% to 40% in a low CO2 scenario and between 63% and 70% for high emission scenarios of CO2.

Assessments of the impact of temperature change have focused on the effect of average changes in air temperature; however, increases in minimum air temperature may be more significant in their effect on growth and phenology (Hatfield et al, 2011). Minimum air temperatures are more likely to increase under climate change. While maximum temperatures are affected by local conditions, particularly soil water content and evaporative heat loss as soil water evaporates (Alfaro et al, 2006), minimum air temperatures are affected by changes in mesoscale of atmospheric water vapor content. Therefore, in areas where climate change is expected to cause increased precipitation or where irrigation is prevalent, large increases in maximum temperatures are less likely to occur than in drought-prone regions. Minimum air temperatures affect the respiration rate of plants at night and can reduce biomass accumulation and crop yield (Hatfield et al., 2015).

Welch et al (2010) cited by Hatfield and Prueger (2015) found that higher minimum temperatures reduced grain yield in rice, while higher maximum temperatures increased yields; because the maximum temperature rarely reached the optimum critical temperature for rice. However, in the scenario of future temperature increase, they found that maximum temperatures could decrease yields if they approach the upper limit of the threshold.

Perennial crops have a more complex relationship with temperature than annual crops. Many perennial crops have a chilling requirement where plants must be exposed to a number of hours below a certain temperature threshold before they can flower. For example, chilling hours for apple (*Malus domestica* Borkh.) range from 400 to 2900 hours (5-7 °C), while cherries (*Prunus avium*) require 900 to 1500 hours with the same base temperature (Seif and Gruppe ,1985) cited by Hatfield and Prueger (2015).

Grapevine (*Vitis vinifera* L.) has a lower chilling threshold than other perennials, with some cultivars as low as 90 h (Reginato et al. 2010, cited by Hatfield and Prueger (2015).

Increasing winter temperatures may prevent chilling hours from being obtained, and projections of warmer winters in California have shown that by the mid-21st century, plants requiring more than 800 hours may not be exposed to sufficient chilling, with except for very small areas in the central Valley (Luedeling et al., 2009, cited by Hatfield and Prueger, 2015).

Climate change will impact growth requirements for fruit trees.

Hatfield et al. (2014) cited by Hatfield and Prueger (2015) showed that under a warming climate, adequate chilling hours for perennial crops for fruit development may not be met. Innovative adaptation strategies will be needed to overcome this effect because of the long-term requirements for genetic selection and fruit production once perennial crops are established.

MATERIAL AND METHODS

The experiments were carried out on spontaneous woody species: *Juglans regia, Morus alba, Populus nigra, Tilia platyphyllos.*

The purpose of the determinations was to analyze the reaction of the plants to the action of the temperature, which presented large variations, both diurnal, seasonal and annual. The determinations were made in the year 2023 during the period April - October and in the year 2024 in the months of March and April in Mehedinti Count, Romania. The studied physiological parameters were: intensity of photosynthesis, content in assimilatory pigments, growth rate.

From a phenological point of view, in the climatic conditions of the year 2023, the period of leaf appearance, flower appearance and fruiting were noted. In the year 2024, the dates of the appearance of the first leaves, the moment of flowering and of the formation of the fruits were noted.

The intensity of the photosynthesis process was determined with the Lci portable device that measures the respective parameter with great precision and also has the advantage that the leaves of the analyzed plants can be kept on the plant, so that at intervals of time, new determinations can be made on the same leaves. In this way, graphs can be made regarding the diurnal dynamics, but also the seasonal dynamics of this physiological process. In addition, the device also measures the temperature in the assimilation chamber, as well as the amount of water vapor and light intensity, factors that influence all the vital processes of the plants.

The content of chlorophyll pigments was determined directly on plant leaves with the Minolta portable apparatus, which measures and expresses this parameter in SPAD units.

RESULTS AND DISCUSSIONS

In 2023, the phenological evolution was followed from April to October for all species. In the year 2024, due to the much higher temperatures since the beginning of spring, the start of vegetation of the plants was observed as early as March, the gap compared to the previous year being almost two months for some species. This demonstrates the fact that climate changes leave their mark on the evolution of plants, both in spontaneous species and in those introduced in culture.

As for the air temperature, in April 2023, according to the Meteoblue archive, the maximum recorded was 14 ^{0}C.

https://www.meteoblue.com/ro/vreme/historyclimate/weatherarchive/drobeta-turnu-severin_rom%c3%a2nia_678817?fcstlength=1m&year=2023&month=4

In the same month of 2024, the maximum temperature was 28 ^{0}C, on most days exceeding the temperature recorded a year ago. For this month of the year, we can speak of extreme temperatures, which even exceeded the normal temperature of the period by 15 degrees.

https://www.meteoblue.com/ro/vreme/historyclimate/weatherarchive/drobeta-turnu-severin_rom%c3%a2nia_678817?fcstlength=1m&year=2024&month=4

In these thermal conditions, most of the plants came out of dormancy, showing a very accelerated growth rate. Towards the end of April, the cold wave with negative temperatures during the night affected the more sensitive species, the most visible damage being observed in Juglans regia.

Juglans regia, which in April of 2023 had not started growing, in April had almost fully developed leaf apparatus and even formed fruits. That is why the low temperatures recorded during two nights seriously affected this species.

In *Morus alba*, in mid-April the inflorescences were fully formed, while a year ago the leaves were just beginning to appear.

In *Populus nigra* also, in April 2023 the leaves had not appeared, instead, in 2024 they had the maximum size characteristic of the species.

Tilia platyphyllos also had a different evolution during the two years of study, at the end of April 2024 already having the flower buds formed.

Diurnal and seasonal variation of photosynthesis in spontaneous woody species

The intensity of the photosynthesis process was determined in the year 2023 in each month of the vegetation period to create the graphs regarding the seasonal variation. Following the analysis of these graphs, it is found that the photosynthesis process recorded a maximum in June for all the species studied, followed by a reduction in the intensity of the process, although it had to remain at high values until the time of fruiting. The reduction in photosynthesis was due in 2023 to very high temperatures associated with very low soil moisture.

At *Juglans regia*, the low temperatures in the spring of 2023 delayed the start of vegetation. For this reason, the first determinations were made on young leaves in May. In October, it already entered in state of rest and for this reason photosynthesis could no longer be determined (figure 1).

In May 2023, the graph of the diurnal variation of photosynthesis in the *Juglans regia* species was made, showing an increase in intensity directly proportional to the light and the temperature, with a maximum at 4 pm and a minimum in the early hours of the morning (figure 2).

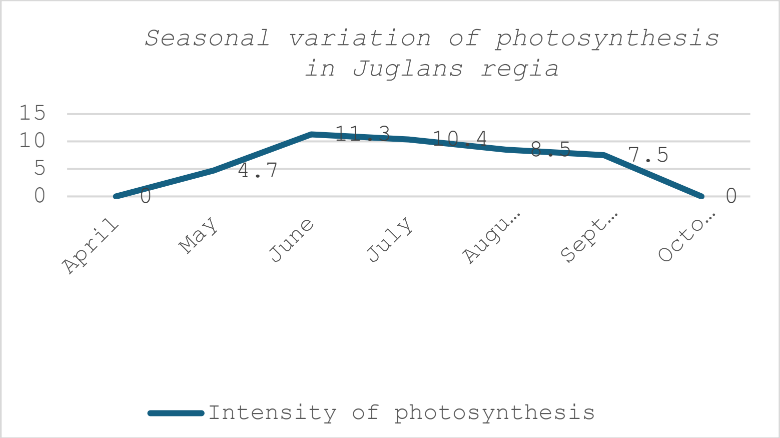


Figure 1. Seasonal variation of photosynthesis (μmol/m^2/s) in *Juglans regia* leaves in 2023

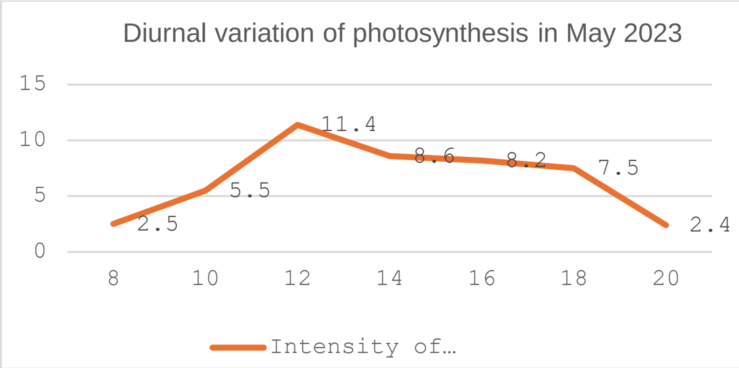


Figure 2. Diurnal variation of photosynthesis in *Juglans regia* leaves in May 2023

In June, the highest value of photosynthesis was recorded at 12 o'clock, after which there was a reduction due to the reduction of atmospheric humidity and the closing of the stomata (figure 3).

In the year 2024, in April, the diurnal variation of photosynthesis presented a maximum at 4 p.m., close in value to the maximum recorded in 2023 in the month of June (figure 4). The very high air temperature associated with the high light intensity favored the development of the process with maximum intensity.

Morus alba presented in 2023 a seasonal variation of the process with a maximum in July and a minimum in May when the newly formed leaves had a low chlorophyll content and a small assimilation surface (figure 5). In April of 2024, photosynthesis at noon (figure 6) had a higher value than the value recorded in July of 2023. The fully formed leaves and the large amount of chlorophyll favored this process against the background of extreme climatic conditions (temperatures above 28 ^{0}C).

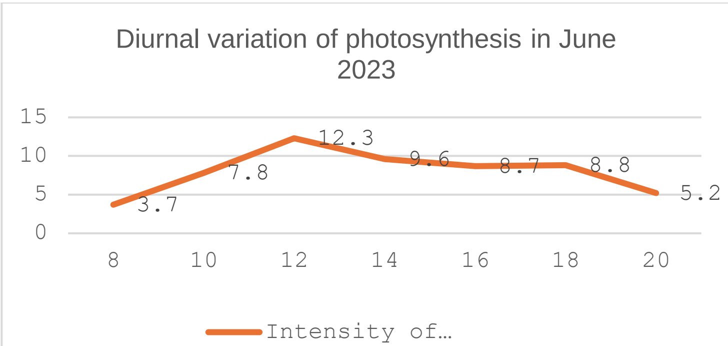


Figure 3. Diurnal variation of photosynthesis in *Juglans regia* leaves in June 2023

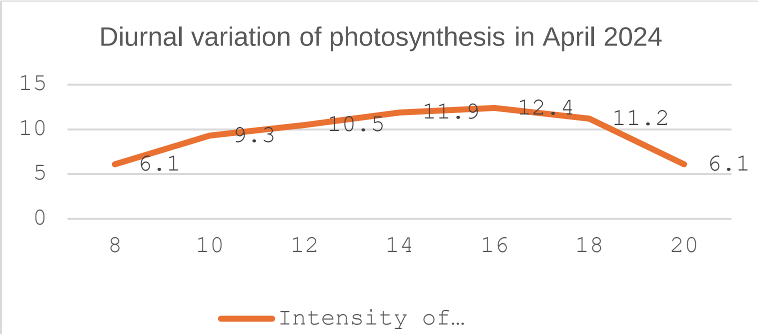


Figure 4. Diurnal variation of photosynthesis in *Juglans regia* leaves in April 2024

In 2023, *Populus nigra* showed a variation in photosynthesis similar to that recorded in *Morus alba*, with small differences in the summer months, when the maximum recorded was higher by about two units (figure 7).

The diurnal variation showed a maximum at 4 pm in May (figure 8), and in June the maximum was recorded at 12 pm, followed by a significant reduction in the process that was maintained until the evening (figure 9).

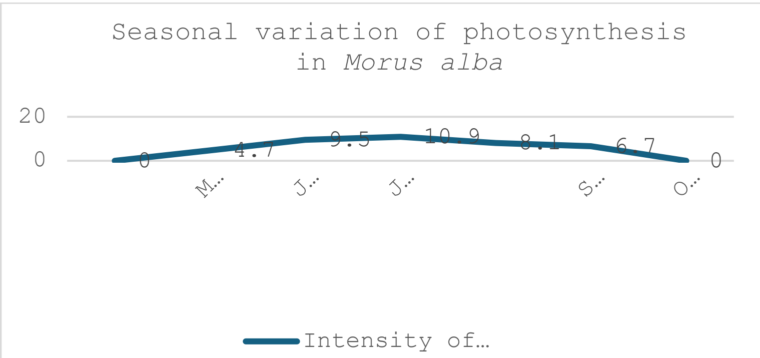


Figure 5. Seasonal variation of photosynthesis (μmol/m²/s) in *Morus alba* leaves in 2023

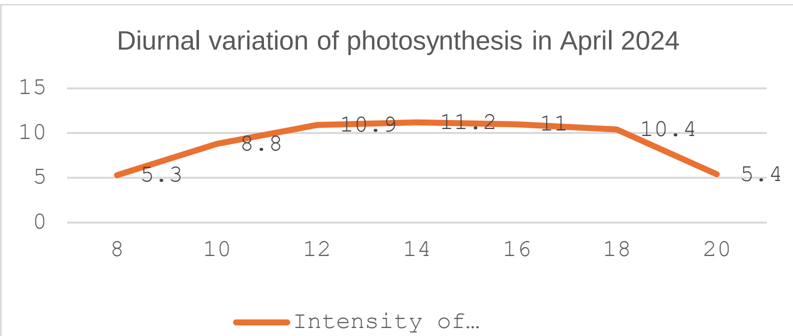


Figure 6. Diurnal variation of photosynthesis (μmol/m²/s) in *Morus alba* leaves in April 2024

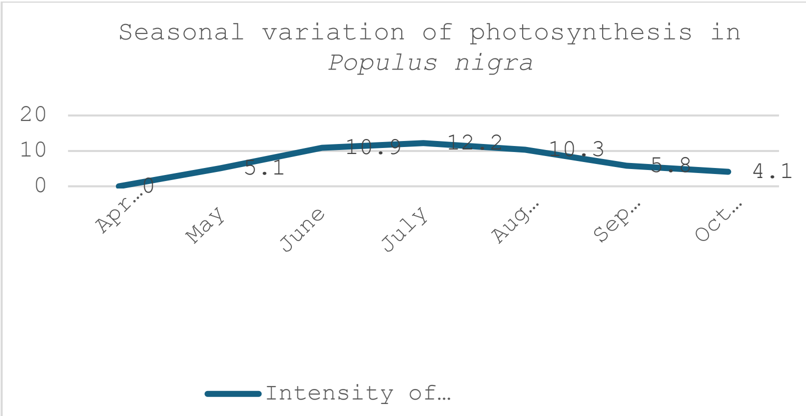


Figure 7. Seasonal variation of photosynthesis (μmol/m²/s) in *Populus nigra* leaves in 2023

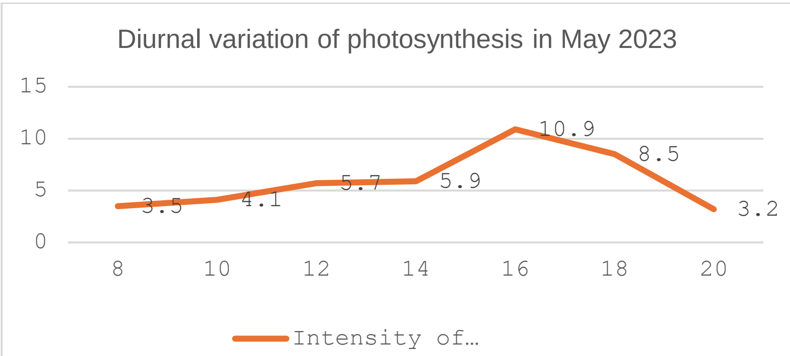


Figure 8. Diurnal variation of photosynthesis (μmol/m²/s) in *Populus nigra* leaves in May 2023

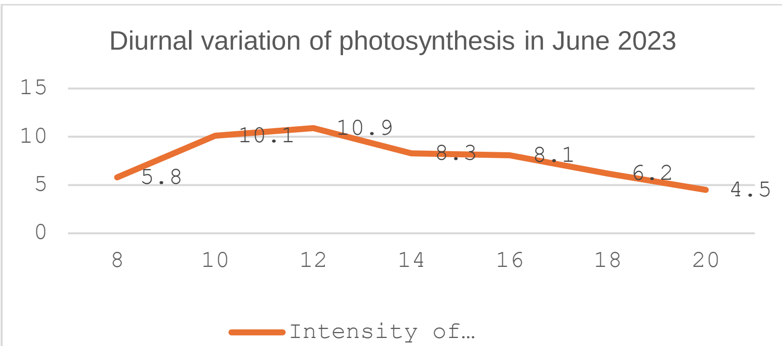


Figure 9. Diurnal variation of photynthesis (μmol/m²/s) in *Populus nigra* leaves in June 2023

In the year 2024, in mid-April the mature leaves presented a higher photosynthesis value than the one recorded in June of the previous year (figure 10).

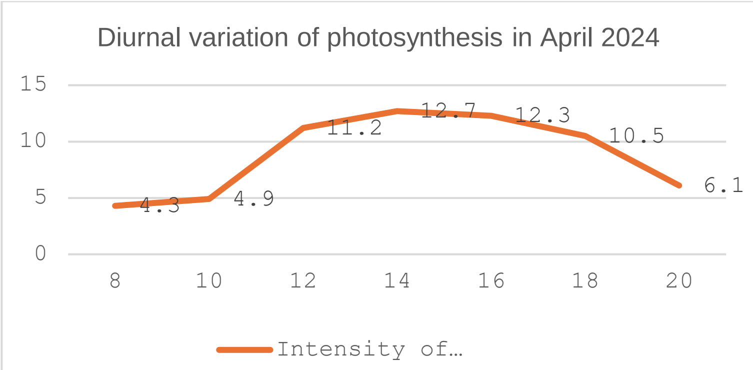


Figure 10. Diurnal variation of photosynthesis (μmol/m²/s) in *Populus nigra* leaves in April 2024

Tilia platyphyllos showed high photosynthesis values in 2023 starting from June to August when the values of the process decreased significantly (figure 11).

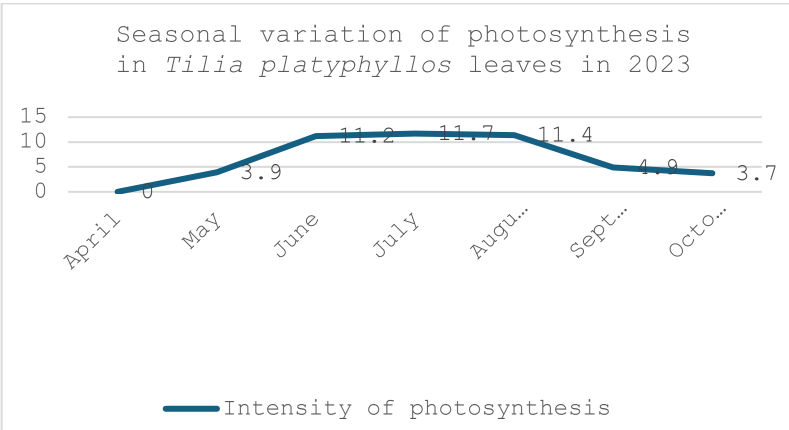


Figure 11. Seasonal variation of photosynthesis (μmol/m²/s) in *Tilia platyphyllos* leaves in 2023

In May 2023, the daytime values were reduced, reaching only 8.34 μmol/m²/s at 2 p.m. (figure 12) Compared to this value, in 2024, since April, photosynthesis had a value of 12.56 μmol/m²/s (figure 13), which proves that already in this month the leaves have reached their maximum size and optimal chlorophyll content.

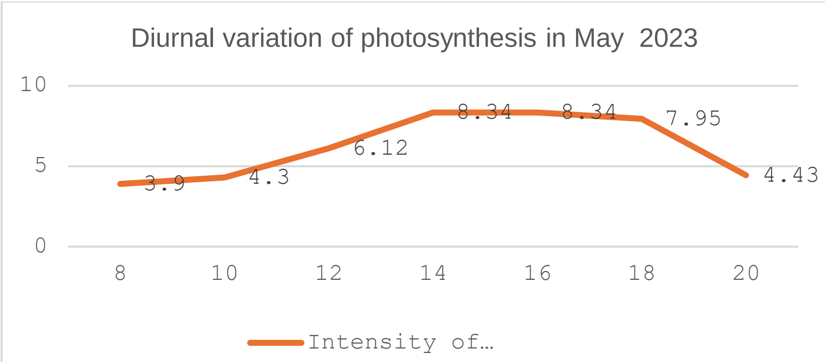


Figure 12. Diurnal variation of photosynthesis (μmol/m²/s) in *Tilia platyphyllos* leaves in May 2023

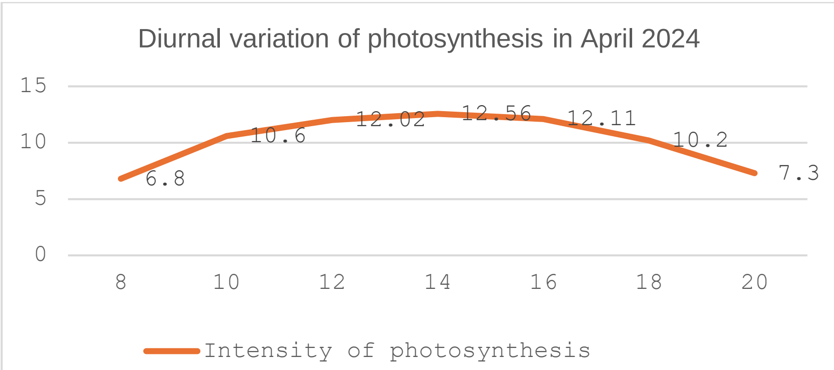


Figure 13. Diurnal variation of photosynthesis (μmol/m²/s) in *Tilia platyphyllos* leaves in April 2024

Variation of photosynthesis as a function of temperature in spontaneous woody species

The temperature influences the photosynthesis process to a rather large extent, the determining factor being the light, which by intensity significantly changes the values of this physiological process. The two factors act together, therefore it is very difficult to establish to what extent in natural conditions the temperature changes the intensity of photosynthesis.

In April 2024, the middle period, with very high temperatures, over 30 0C, was also characterized by high values of light intensity, cloudiness being absent. Towards the end of the month, starting on April 22, the temperatures suddenly dropped due to the penetration of a wave of cold air, but there was also increased cloudiness, so the low values of photosynthesis were caused by both the lower light intensity and the much low temperature. Thermal variations also influenced the rate of biomass accumulation, because it is determined by the photosynthetic yield (figure 14, 15, 16, 17).

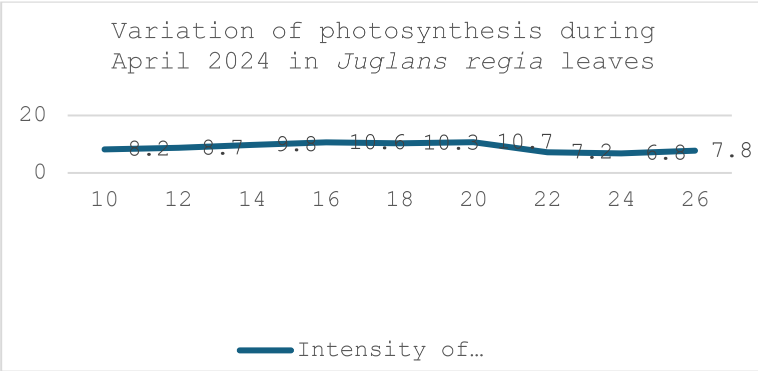


Figure 14. Variation of leaf photosynthesis (μmol/m²/s) during April 2024 in *Juglans regia*

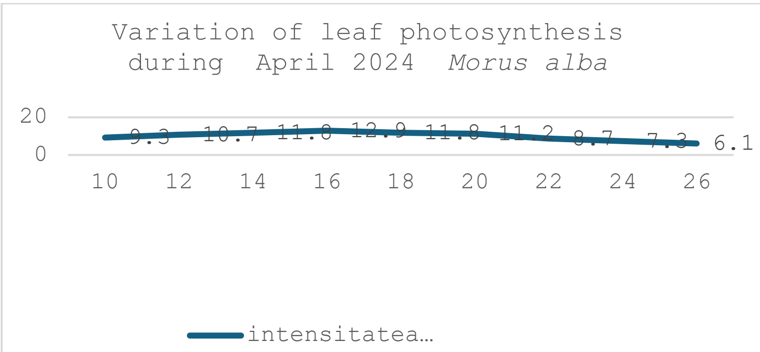


Figure 15. Variation of leaf photosynthesis (μmol/m²/s) during April 2024 in *Morus alba*

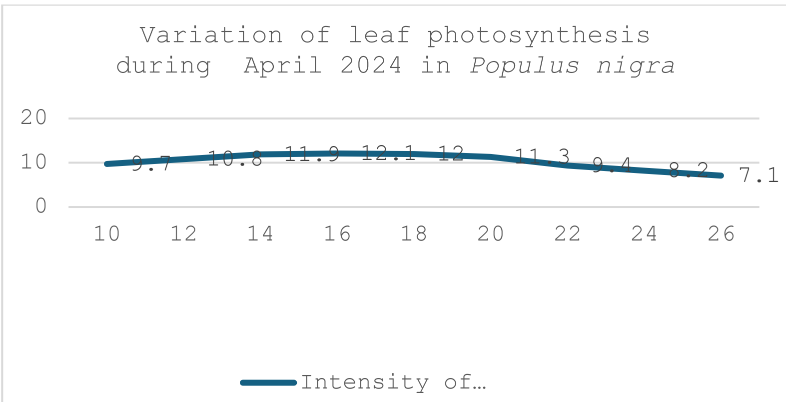
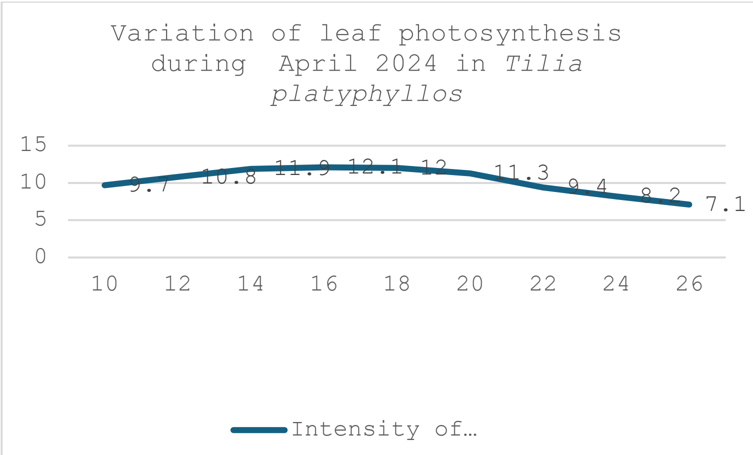


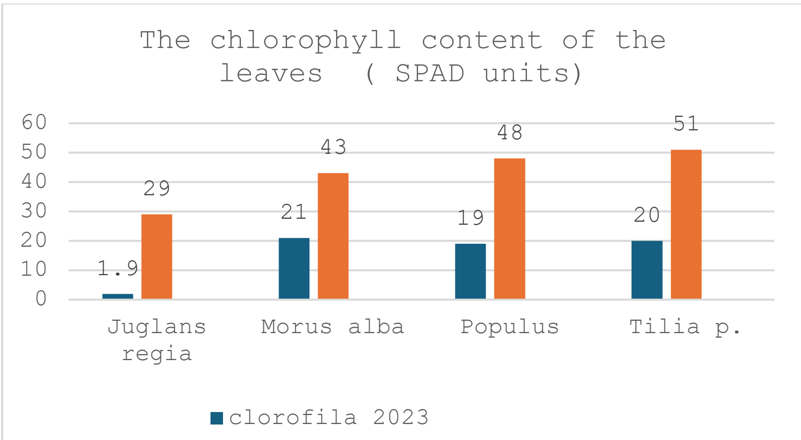
Figure 16. Variation of leaf photosynthesis (μmol/m²/s) during April 2024 in *Populus nigra*



Graph 17. Variation of leaf photosynthesis (μmol/m²/s) during April 2024 in *Tilia platyphyllos*

The chlorophyll content of the leaves was determined during April in both 2023 and 2024. The graphic data represent the average of the determinations made and as can be seen, the differences between the two years are very large in all the spontaneous species studied (figure 18).

If in 2023 the newly formed leaves had a very low chlorophyll content, in 2024 it was close to the values recorded in mature leaves, proof that the growth process of the vegetative part was almost complete.



Graph 18. The chlorophyll content of the leaves (SPAD units) of spontaneous woody species in April 2023 and April 2024

Growth rate of leaves and shoots

Influencing the process of photosynthesis, temperature also influences the growth of plants, but also the moment of triggering the generative stage that marks the appearance of reproductive organs (flowers). In spontaneous woody species, the six-day interval measurement of leaf size during April in 2023 and 2024 indicated significant differences. In 2023 the growth rate was very slow, almost imperceptible, while in April, from the very beginning, the growth was very accelerated.

CONCLUSIONS

Temperature is the factor that influences to the greatest extent the growth and development of plants

- Each plant species has a minimum, a maximum and an optimum of temperature, and large variations of this climatic factor and extremes have a disruptive effect
- The large temperature differences during one month, but also the differences recorded during the two years of the study in the same month of the respective years, allowed the analysis of the plants' behavior at these thermal conditions
- From a phenological point of view, the gap recorded was significant, in some woody species, such as the walnut (Juglans regia). If in April 2023 it had not started growing, in the same month of 2024, the fruits had already formed and the leaf apparatus had reached maturity. For this reason, the damage was more serious, because towards the end of April 2024, the negative temperatures during the night caused the fruits to fall and the necrosis of a significant part of the surface of the leaves
- The photosynthesis process, being dependent on temperature, recorded important seasonal variations, but also diurnal variations
- Since photosynthesis is the process by which all organic compounds are synthesized, including those with a plastic role, a correlation was found between this process and the growth rate of the plants studied

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