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THE EFFECT OF DROUGHT ON THE PHYSIOLOGY OF SOME WOODY SPECIES FROM SOUTHWESTERN ROMANIA

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ABSTRACT

The determinations carried out between July and September 2021 in the Comanesti Hills aimed to establish the effect of the prolonged drought in this area on the physiological processes in the young trees of the species Quercus cerris, Q. Robur and Q. freinetto. The results obtained showed that all three species were affected. It was found that drought reduce the amount of water in the leaves, change the ratio of free water / bound water, reduce photosynthesis. The reduction of the stomatal conductance was the main factor that led to the decrease of photosynthesis, but also the lower content of pigments can be considered a determining factor. The peculiarities of the leaves of the species Q cerris have constituted to a certain extent a protective factor for the young trees of this species.

INTRODUCTION

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.https://www.myclimate.org/information/faq/faq-detail/what-are-the-effects-of-climate-change/

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. How some forest species have managed to cope with this situation is trying to elucidate by the determination presented in this paper.

The effect of drought on plants is complex and plants 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 does not only affect 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 Zhanget 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 SM 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 Yuriko 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 (Osakabeet 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 reduced 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_2fixation 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).

MATERIAL AND METHOD

The determinations were made in July-September in the Comanesti Forest, Mehedinti County. The species studied were *Quercuscerris, Q.robur*and*Q.frainetto.*Young trees were analyzed.

*Quercuscerris*has a good adaptability to a variety of differentsite conditions. It is relatively tolerant to drought (more than theother oak species of the same region) air pollution, andcan grow in a wide range of soil types including weakly acid, pseudogley or even shallow calcareous soils, as long as theyare not too dry. When established it devlops a taproot and deeplateral root branches, helping it to remain windfirm. It is lightdemandingbut can grow under a light woodland canopy. It hasmany pioneer characteristics, including good germination rates ofseeds and fast early growth. It also has a high resprouting capacity (de Rigo et al, 2016).

Quercusrobur L. is one of the most valued tree species of deciduous temperate forests. However, in the last decade, serious oak declines and loss of adaptation plasticity have been reported throughout Europe as a consequence of drought (Vastag E. et al, 2020)

Quercusfrainetto is a species native to Balkan Peninsula, and also present in South Italy and North-West Turkey. Despite being also known as Hungarian oak, its presence in Hungary is sporadic and mainly resulting from previous introduction. This oak is an element of the sub-Mediterranean flora, and is usually associated in mixed groups (as well as hybrids) with other oak species across its distribution range. It has been traditionally managed in coppiced forests for firewood and timber production in combination with livestock grazing. As other oaks, it is suffering a period of decline, due to climate change and human pressure although its future distribution is predicted to expand in response to expected warming(Mauri A.et al, 2016).

The hills of Comăneşti are located in Mehedinţicounty, west of the Motru river and they belong to the Bala commune, Comăneşti village. The altitude varies between 150-402 m, the coordinates being lat. 44 ^{0}58', long. 22 ^{0}54'.

Being located in the south-west of the country and of the Getic Piedmont, the researched territory is in the regime of the Central European climate with sub-Mediterranean influences. According to Köppen's classification, the researched territory falls in the area of cold humid climate, with conditions specific to oak (according to Buia et al. 1961, from Costache I., 2011).

The multiannual average air temperature which is characteristic for this area is in the range of 10.1 - 11.5 degrees Celsius.

The average isotherm for winter is between 0 and -10 ^{0}C, and the average temperature of the coldest month (Jan.) is -10 ^{0}C (www.mehedinti.insse.ro)

During the warm July-August period, the maximum temperature often exceeds 32^0 C. Atmospheric precipitations amount to between 500–793 mm annually.

Regarding the relative humidity of the air, the maximum values are registered in autumn, and the minimum ones in summer. The atmospheric circulation is marked by the advection of the maritime air masses from the west, with a high degree of humidity and of the subtropical or continental ones from the east (www.mehedinti.insse.ro)

In 2021, according to the *MeteoBlu Archive*, July was characterized by temperatures of over 30 Celsius degrees, with a maximum of 41 Celsius degrees. It was just a rainstorm in the middle of the month. The amount of precipitation was 12 mm. In August, temperatures of 41 Celsius degrees were recorded in a few days, and the amount of precipitation was lower (6 mm at the end of the month). In September, there was only 3 mm of rain. Temperatures ranged from 25 to 33 Celsius degrees during the day.

The analyzed physiological indices have been the photosynthesis intensity, transpiration intensity,stomatal conductance, total water content, the water types (bound and unbound water), the content of pigments.

Photosynthesis, transpiration and stomatal conductance were determined with the portable Lci apparatus.

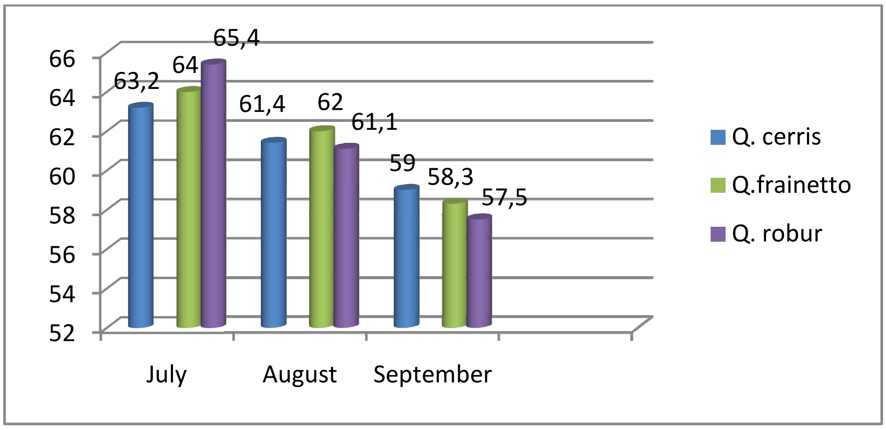
The total water content was determined gravimetrically by drying the plant material at the oven at 105 ^{0}C.The water forms (bound and unbound) were determined by the Artihovski method (Boldor O., 1983).

The quantity of chlorophyll pigments from the leaves has been determined with the Minolta chlorophyll meter.

RESULTS AND DISCUSSIONS

The total water content of leaves

The total water content of the leaves was determined for the three species in the middle of each month. Three plants from each species were chosen. The graphical data (graph 1) represent the average of the determinations performed on the leaves at the base of the stem, in the middle and from the top area. It is found that as the drought sets in, the amount of water decreases. The lowest water content was determined in September. In July, because June was a rainy month, the amount of water in the soil did not affect the plants. As the drought set in, the water content decreased. Of the three species, the least affected was *Q. cerris.*



Graph. 1. The total water content (%) of leaves in young trees from*Quercus*genus

The free and bound water

The water forms were determined in parallel with the determination of the total water.

It was considered important to determine the forms of water because it can give information about the physiological conditions of plants. The higher amount of bound water highlighted in September shows that the plants were severely affected (graph 3).

The amount of free water, circulating and used in the various biochemical reactions, has been significantly reduced in all three species (graph 2).

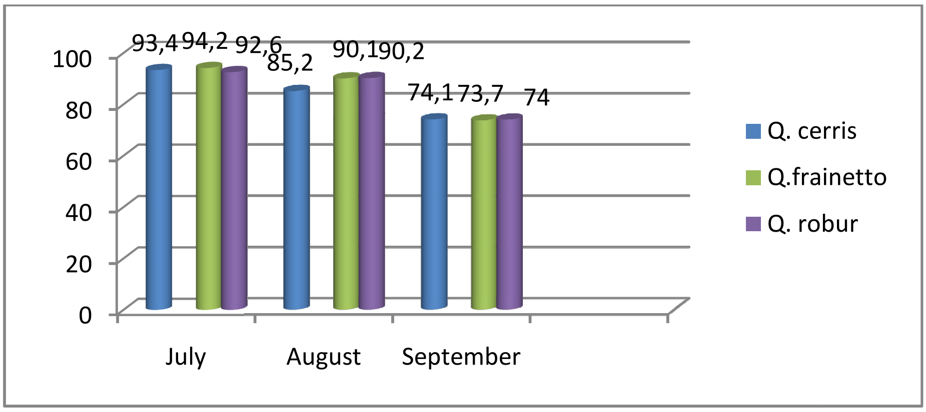
It is generally considered that bound water ensures resistance to stress, but to establish resistance to water stress, several parameters must be taken into account.

The transpiration of leaves

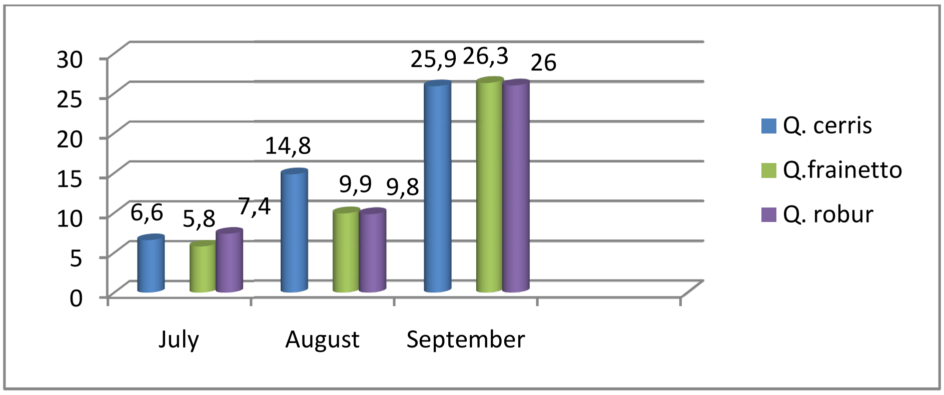
Under the climatic conditions from the researched area, the transpiration of the leaves showed significant variations during the three months of analysis. If in July the values of transpiration reached the value of 4.8 mmol/m^2/s , in August, at the same temperature in the assimilation chamber (36 Celsius degrees) and the same active photosynthetic radiation (1374 µmol /m^2 /s) , transpiration had lower values especially in *Q robur* and Q. *frainetto.* In September, at the same temperature and light intensity, the values were minimal.

Reducing transpiration values can have different causes. One of the causes may be the protection mechanism of the stomata. In drought conditions, they close and thus save water. Another cause may be the much smaller amount of circulating (free) water in the body of the plant (graph 3). Most likely both causes must be considered.

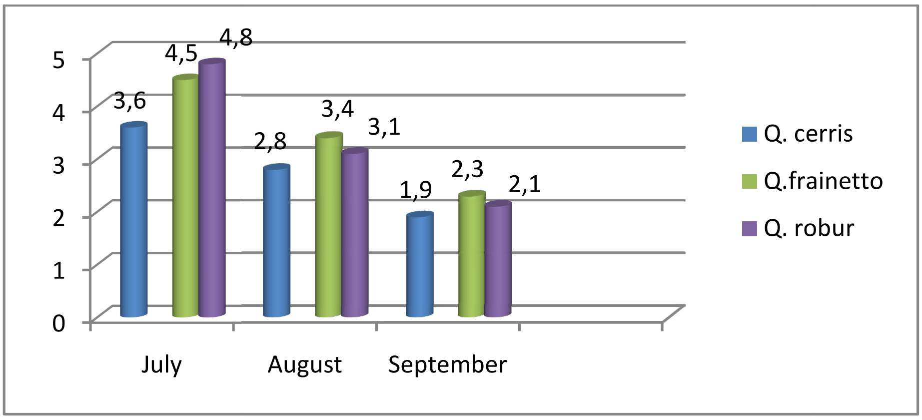
The lowest values of transpiration were recorded in the young trees of the species *Q. cerris* throughout the determinations (graph 4).



Graph 2.The content in free water ofleaves(%of total water)



Graph 3.The content in bound water of leaves (%of total water)

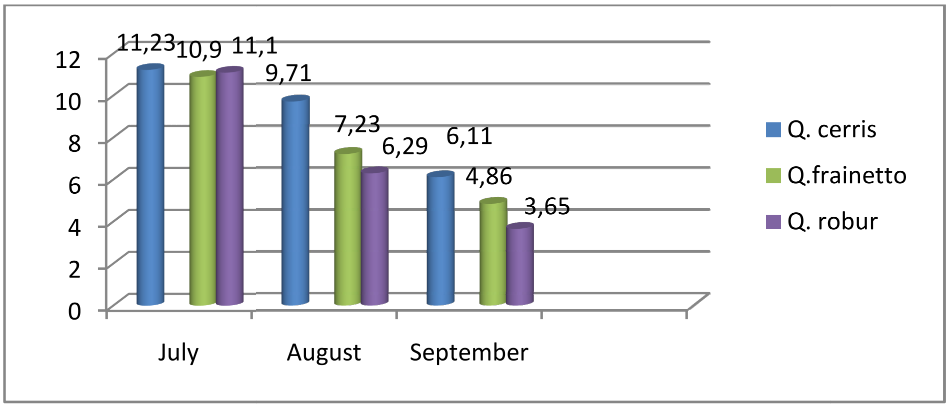


Graph. 4. The variation of leaves transpiration (mmol / m ^{2} / s)

Intensity of photosynthesis

The intensity of photosynthesis was determined under the same conditions as leaf transpiration. In the case of this process, a significant reduction was observed as the drought set in. The lowest values were recorded in September for all three species (graph 5).

Of the three species, the lowest photosynthesis was recorded in *Q. robur*, and the highest value was found in *Q. cerris.*

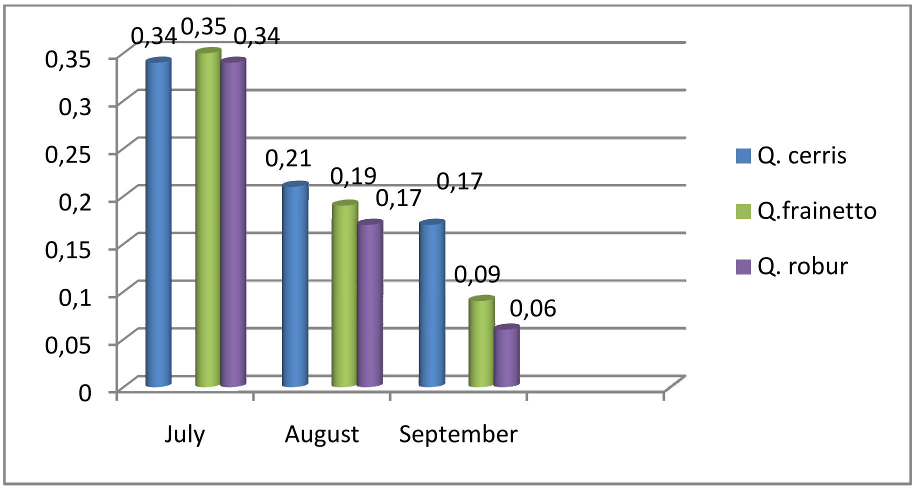


Graph 5.The variation of photosynthesis process (µmol /m^2 /s)

Stomatal conductance

The stomatal conductance had high values in July, but began to decline progressively. The lowest values were determined in September for all species. *Q. cerris* also showed lower values but less than in *Q. frainetto* and *Q. robur*(graph 6).

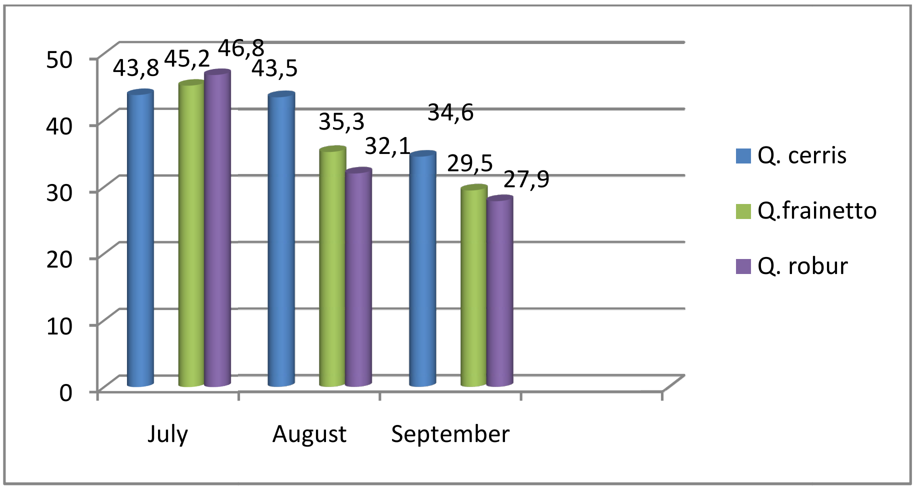
DeligazAyse, Bayar Esra(2017) found also that at *Q. cerris,* drought stress decreased stomatal conductance, but significantly increased accumulations of total soluble sugars.



Graph 6. The variation of stomatal conductance (mol /m^2 /s)

Content in clorophyll pigments

The drought induced changes to chlorophyll contents (Xiangbo Z. et al, 2018).
The amount of chlorophyll in the leaves had the highest values at *Q.robur* in July (46.8 SPAD).
In August, there was a reduction in chlorophyll in *Q. robur* and *Q. frainetoo*(graph 7)
At *Q. cerris* there was no difference from the previous month. In September, the values were lower for this species as well. This explains also the much lower values of the photosynthesis process.



Graph.7. The content in clorophyll pigments (SPAD unities)

CONCLUSIONS

- In the researched area, the drought caused important physiological changes in the young trees of the species *Q. cerris, Q. robur* and *Q. frainetto*

- The water content of the leaves decreased in parallel with the change in the ratio between free and bound water.
- Lower values of stomatal conductance led to a significant reduction in photosynthesis and transpiration
- The content of chlorophyll pigments was also reduced in all species studied
- Of the three species analyzed, *Q. cerris* had the smallest changes in physiological processes. It can therefore be said that this species is better adapted to drought

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