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# FUNCTIONAL RELATIONSHIPS BETWEEN THE HEMIPARASITIC PLANT *RHINANTHUS RUMELICUS* Velen AND ITS HOST SPECIES

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## *ABSTRACT*

*Rhinanthus rumelicus Velen is a hemiparasitic herbaceous species commonly found in hill and lowland meadows, particularly in areas where arable land has been abandoned and converted into grassland. As a result, it can be inferred that this species has an impact on community structure, vegetation zonation, and the dynamics of plant populations.*

*Physiologically, the species extracts a portion of the raw sap from its host plants. The photosynthesis process occurs with intensities similar to those of autotrophic plants. Research has indicated that Rhinanthus rumelicus plants exhibit a more intense respiration process compared to their host plants. While the intensity of their photosynthesis is within the normal range for a unit of leaf surface, the quantity of organic substances generated by this process is minimal, as these substances are primarily consumed during the respiratory process.*

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

## INTRODUCTION

Hemiparasitic plants are a taxonomically diverse group of angiosperms that rely in part on host plants for nutrients and water, which they acquire by attaching to host roots or shoots using specialized structures known as haustoria and by penetrating the xylem of host. The site of attachment to the host classifies the hemiparasite as either a root parasite or a stem hemiparasite (Musselman and Press, 1995).They can play key roles in determining community structure and function and should be considered as both keystone species and allogenic and autogenic ecosystem engineers. The combination of both topdown and bottom-up effects means that they can have considerable impact on multiple trophic levels within communities, affecting population dynamics, diversity and distributions of co-occurring host and nonhost plants, invertebrates, birds and mammals. Further, despite their minimal contact with the soil system, they may also impact greatly on the soil biota and soil resources: this can have further consequences for cooccurring organisms. Parasitic plants are clearly major and key components of many ecosystems, given the considerable extent of their impacts (even when minor components of ecosystems), the diversity of ecosystems in which they occur, and the diversity of organisms with which these parasites interact (Press, M.C., Phoenix, G.K.,2005).

Hemiarasitism often severely reduces host performance, leading to changes in competitive interactions between host and non-host plants and a cascade of effects on community structures, diversity, vegetation cycling and area (Pennings and Callaway, 2002).

The impact on the plant community is further increased as semi-parasitic plants simultaneously parasitize and compete with co-existing plants; their own productivity and populations therefore depend both on the "quality" of the hosts they parasitize and on the strength of competition from neighboring plants. In addition, uptake of mineral salts from the host plant may have consequences for organisms at other trophic levels , and this could impact nutrient cycling and soil water relations. Importantly, such major impacts can occur even when hemiparasitic plants are minor ecosystem components.

Because reductions in host growth are often greater than parasite growth, reductions in plant community productivity are often observed. Rhinanthus species, for example, have been shown to reduce total productivity in European grasslands by between 8 and 73% (Davies et all., 1997).

Joshi et al. (2000) represented that the reduction of community biomass by Rhinanthus is lower in grasslands that have greater functional diversity. They proposed that greater plant diversity could buffer the effects of overexploitation of individual host species, so that less sensitive conspecifics would compensate for the biomass loss of more sensitive species. In addition, Matthies and Egli (1999) found host biomass is reduced most under low nutrient conditions, suggesting community-level impacts may also be greatest where parasite-acquired resources (such as nutrients) are limiting.

The impact on community structure can also be large. First, impacts on host performance shift competitive balances from host species to non-host species and ultimately result in community change. Very often, the most heavily parasitized species are competitively dominant, in which case parasitism facilitates the maintenance of competitively subordinate species (Press, 1998). The preference (by choice or chance) of *Rhinanthus spp.* for its hosts, for example, is well known to reduce grass biomass and facilitate increased plant abundance (Davies et al., 1997). The introduction of Rhinanthus species is therefore used as an effective management tool to restore high fertility/low diversity grasslands to high diversity grasslands (Westbury and Dunnett, 2000).

Conversely, where preferred hosts are competitively subordinate, parasitism can reduce the abundance of subordinate species, allow greater dominance of more abundant species, and thereby reduce community diversity. One such case was observed in sand dune systems, where Gibson and Watkinson (1989) showed that Rhinanthus minor-usually known to increase diversity-tends to reduce diversity by parasitizing preference for subordinate species. In addition, putative preferred host species may not necessarily decrease in abundance where the abundance of other potential hosts is high enough to "hide" the parasite's preferred host. For example, N-rich legume species are well known to be good (preferred) hosts for *Rhinanthus spp*., but in the study by Davies et al. (1997), Rhinanthus actually increased, rather than reduced, legume abundance in European grasslands. Davies et al. (1997) proposed that high density of grasses overcomes host preference so that grasses are more parasitized and more suppressed because their roots are much more likely to be encountered than the roots of Fabaceae family plants.

In addition to the effects of parasitism, annual parasites can further increase diversity by facilitating invasion; for example, an increase in bare soil following late-season death of *Rhinanthus alectorolophus* was observed to facilitate weed invasion and lead to increased community diversity (Joshi et al., 2000). Interestingly, facilitation of invasion was less present in more diverse communities, indicating that a negative feedback mechanism may be operating: once the community reaches a certain level of diversity, invasion may no longer be facilitated; if community diversity decreases again, invasion will increase again (Press, M.C., Phoenix, G.K.,2005).

The effects of parasitic plants on community structure are often dynamic and will change as a function of environmental conditions or the performance of the parasite itself. Therefore, parasitic plants can influence both the rules of the entire vegetation cycle and the area. At the simplest level, an aggressive parasite can lead to the local extinction of a preferred host; this may in turn lead to the local disappearance of the parasite. The original suppressed preferred host is then able to return, and the parasite can then re-establish itself on new host plants (Press, M.C., Phoenix, G.K.,2005).

Such cyclical interactions may also explain why some parasites, such as Rhinanthus minor, appear to move through vegetation. Patches heavily infested with Rhinanthus will rapidly decrease in abundance of the preferred host grass, leaving surrounding uninfected patches with greater grass abundance more suitable for establishing the next generation of young Rhinanthus plants, and Rhinanthus will appear to move over time. Vegetation left behind will quickly recover (Gibson and Watkinson, 1992) and become suitable for *Rhinanthus* again.

In addition to being considered keystone species, parasitic plants can also be seen as ecosystem engineers (organisms that modulate resource availability by causing changes in the physical state of biotic and abiotic materials) (Jones et al., 1994). Within this definition, their role in environmental change is understood. Thus, the death of Rhinanthus plants opens up gaps in community grasslands, thus facilitating weed invasion ( Joshi, 2000 ).

However, parasitic plants can also play a major role as allogeneic engineers, changing the environment by transforming materials from one physical state to another. This role is perhaps best exemplified by their impact on nutrient cycling, particularly root hemiparasites. These plants often occur in nutrient-poor communities, and it is becoming increasingly apparent that their effects on nutrient cycling within these systems can be considerable. The transformation of materials that occurs in this allogeneic engineering process is the unlocking of nutrients from more recalcitrant or less available forms to more labile, available forms (Press, M.C., Phoenix, G.K., 2005).

In addition to their impact on biogeochemical cycling and nutrient availability, parasitic plants can also impact water availability as a result of their very high transpiration rates (Ehleringer and Marshall, 1995) and the additional impact on host plant relationships. By increasing water use in the host plant the hemiparasite can reduce soil water potential and thus reduce the availability of this resource for both host and non-host species (Sala et al., 2001).

Impacts on soil nutrients and water can help maintain a heterogeneous distribution of these key resources. This, in turn, can enhance the biodiversity of co-occurring species at the ecosystem scale, as differences in resource supply will allow different plant species to coexist, each being best suited to each patch with a particular resource composition (Tilman, 1997) .

## MATERIALS AND METHODS

The research used the hemiparasitic plant *Rhinanthus rumelicus* Velen and the host plant *Medicago minima*.

*Rhinanthus rumelicus Velen* is an annual plant in the Orobanchaceae family.

It was previously classified in the family Scrophulariaceae. Stems 15 - 60 cm tall with slightly elongated internodes, vertical, simple or branched, green in color, often with longitudinal black lines, in the upper part dense glandular fibrous until destroyed. The leaves are lanceolate, prominent lanceolate to ovoid, 10 - 30 mm long and 5 - 15 mm wide, dull, toothed, green; Interleaves 1 - 2 pairs or absent. Inflorescence begins at node V-X. The bracts are fibrous glandular, triangular ovoid with a pointed tip, at the end with short, broad, almost identical teeth. Calyx densely scattered to glandular fibrous; the hairs are retained when the fruit ripens. Corolla 20 mm long, yellow; tube slightly curved with upper lip 1.5 - 2.5 mm long 2 - 3 times longer than wide, horizontally inclined, purple teeth; lower lip shorter than upper lip and close to it. The capsule has a length of 8 - 10 mm, rounded ovate. Seeds with a wingspan of 1 mm. https://www.bgflora.eu/Rhinanthus%20rumelicus%20Vel.%20EN.html

The determinations were carried out between May-August 2022 in a xerophilic meadow from Mehedinti County - Romania.

The analyzed physiological indices have been the photosynthesis intensity, transpiration intensity, respiration intensity, total water content, the suction force of tissues and the content of pigments.

Photosynthesis, transpiration and respiration 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 suction force of the parenchyma was determined by immersing equal portions of leaves in solutions with different concentrations of sucrose, determining the isotonic solution and enforcing Avogadro's law .

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

## RESULTS AND DISCUSION

### The intensity of photosiynthesis

Comparative determination of photosynthesis in hemiparasitic plants and host plants indicated similar values of this parameter, the differences recorded can be attributed to the differences that generally occur between species ( figure 1). In conclusion, the hemiparasitic species uses its own organic compounds through its own synthesis and does not use the sap produced by the host plant.

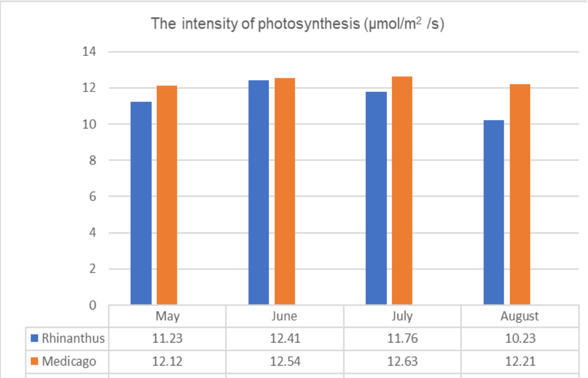

**Figure 1. Leaf photosynthesis intensity in *Rhinanthus rumelicus* and *Medicago minima***

Observing how a hemiparasite works without access to a host gives us great insight in its ability to grow and reproduce autotrophically. It is generally believed that most hemiparasites need access to a host to maintain viable populations because, in greenhouse studies, most have limited growth and flowering when unattached (Lechowski,1996).

In a review of the biology of parasitic plants, Těšitel (2016) argues that hemiparasites are however unable to survive, produce flowers or their growth is greatly reduced and flower production is minimal in hostless cultivation. It is known that non-attached hemiparasites, both annual and perennial, invest more in root development than the attached hemiparasites which, due to access to the host, have been released from the development of their root systems (Matthies 2017). Thus, as expected, unattached hemiparasites invest more in building resources for autotrophic uptake, indicating some degree of autotrophic capacity.

## The intensity of transpiration

Regarding the intensity of transpiration, it is found that hemiparasitic plants have very high values of this process (figure 2). During the entire period of the determinations, *Rhinanthus rumelicus* had almost double values compared to those recorded in the host plant *Medicago minima.* The loss of a large amount of water in hemiparasitic plants must be compensated by higher water consumption and this water is taken from the host plant.

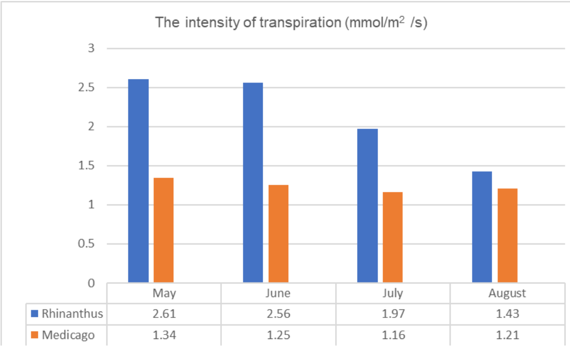

**Figure 2. Leaf transpiration intensity in *Rhinanthus rumelicus* and *Medicago minima***

A very high transpiration rate in hemiparasites is closer to those normally found in autotrophic plants (Lechowski 1996). Evolutionarily, this makes sense; the strategy of wasting high water when not attached to a host is completely counterproductive.

However, not enough studies exist comparing other traits such as stomatal conductance on attached and unattached hemiparasites. For example, some hemiparasites have been shown to maintain levels of K that are much higher than those of their autotrophic hosts when unattached (Luo and Guo 2010) whereas, in other cases, K levels rise dramatically upon host attachment (Lechowski 1995). Since K is involved in the maintenance of abnormally high guard cell turgor in hemiparasites, this could imply that hemiparasites maintain high levels of stomatal conductance even when unattached ( Press and Graves 1995).

## The intensity of respiration

Respiration intensity values were very high in the hemiparasitic species, recording the maximum value during flowering (figure 3).

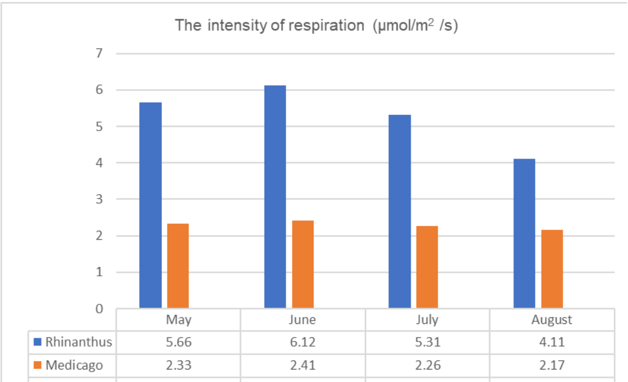

**Figure 3. The intensity of respiration in leaves of *Rhinanthus rumelicus* and *Medicago minima***

This demonstrates that although the respective plants produce enough organic matter, through respiration much of it is oxidized for the purpose of energy production. It is possible that this energy is used for the absorption of raw sap from the host plant. The flowering process also requires a large amount of energy that is provided by cellular respiration. *Medicago minima* has much lower values of respiration.

## The suction force of leaves

Plants have a vascular system that contains a column of water under constant tension. Water moves from the roots to the leaves through a series of interconnected vessels known as xylem. As water evaporates from the leaves through small stomata, the vascular system produces or suction force as the plant continuously draws water from the roots through the xylem, creating tension. This process is affected by environmental factors such as air temperature, humidity, wind and soil water availability. As soils become dry, the tension within the plant increases as it becomes more difficult for the roots to draw water from the soil. Under such conditions, the water in the leaves will be collected; the amount of stress required to move from the leaves corresponds to the availability of soil moisture.

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Measuring water potential can provide information on the soil moisture content for a particular plant by determining the amount of effort, or pressure, the plant is exhibiting while pulling water from the soil. Plants under higher turgor pressure (osmotic flow of water) indicate low soil moisture content, while low pressure indicates higher soil moisture content.

For hemiparasitic plants, this suction force has another value. It ensures the absorption of raw sap from the xylem vessels of the host plant. Therefore, this force must overcome the water retention force in the conducting vessels of the host plant.

The determinations confirm this fact. In *Rhinanthus rumelicus* the suction force of the leaves had the maximum value of 19.34 atm, and in *Medicago minima* the maximum value recorded was 11.23 atm ( figure 4).

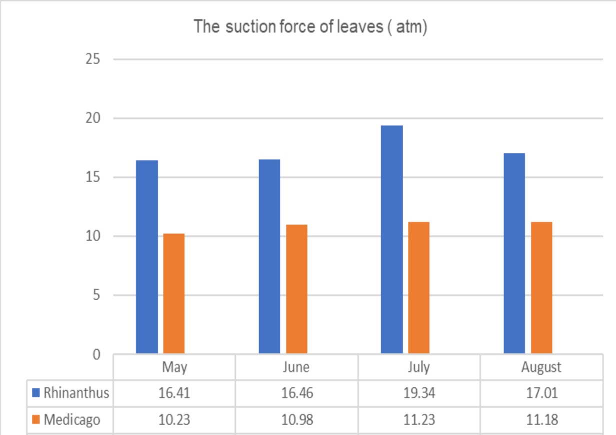

**Figure 4. The suction force of leaves (atm)**

All parasitic plants have adapted physiologically to ensure access to host resources once attached. By transpiring at a rate consistently higher than that of the host, parasites create a "sink" effect and siphon the xylem sap toward the haustorium. To do this, parasites maintain a water potential less than that of the host by keeping their stomata open except under the most severe water stress (Phoenix and Press 2005, Světlíková et al. 2018).

In addition, parasitic plants tend to have higher mineral nutrient concentrations in their dry tissue than their hosts. Although some of this may be because xylem is unidirectional and therefore materials are not translocated back to the host, some mineral nutrients accumulate in such high amounts that suggest a parasitic plant may have differential selectivity in nutrient uptake than the host. Most notably, parasitic plants have been shown to accumulate up to 20 times more potassium in their tissue than the host (Press and Graves 1995).

## The total water content of leaves

During the determinations, the percentage of water in the leaves showed insignificant variations in *Rhinanthus rumelicus* (figure 5). In the host plant *Medicago minima*, in the months of July and August, the amount of water was less. One reason may be the extraction of a larger amount of water by the hemiparasitic plant as the drought settled in the soil.

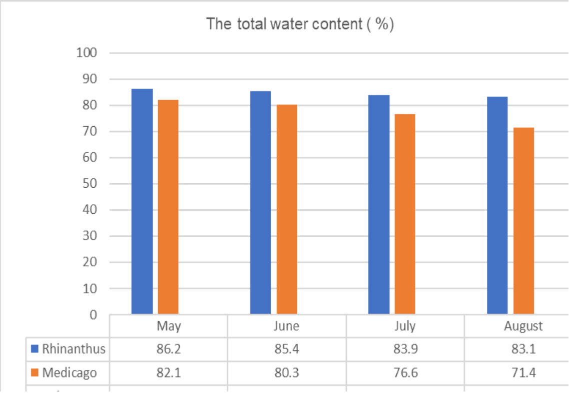

**Figure 5. The total water content of leaves (%)**

## The chlorophyll content of leaves

The average values of the chlorophyll content of the leaves of the species *Rhinanthus rumelicus* were approximately equal to those of the host species. No significant differences were recorded during the determination period (figure 6). In August, in *Rhinanthus rumelicus*, the decrease in the content of chlorophyll is related to the entry into the senescence period of the plants.

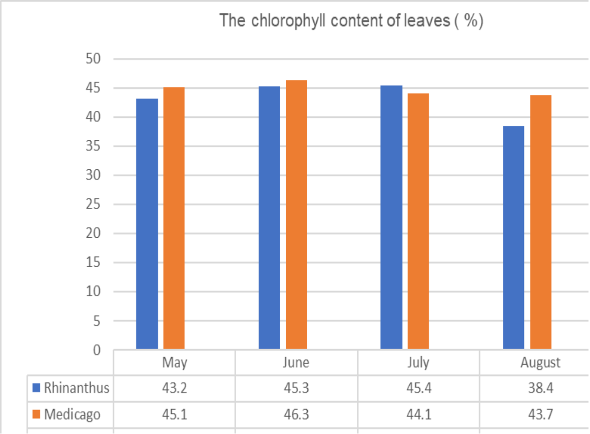

**Figure 6. The chlorophyll content of leaves ( SPAD unities)**

## CONCLUSIONS

In the meadows from the south-west area of Mehedinti County - Romania, the trophic relationship between the hemiparasitic species *Rhinanthus rumelicus* and its host from the Fabaceae family, *Medicago minima,* is manifested by the exclusive use of water and minerals. Photosynthesis is carried out with values comparable to those of autotrophic plants, but respiration has much higher values.

An interesting aspect is related to the high values of the intensity of transpiration in the hemiparasitic plant. These values favour the creation of a suction force strong enough to extract the raw sap from the conducting vessels of the host plant. As a result of this fact, the amount of water in the leaves of the hemiparasitic plant remains relatively constant and is not influenced by the amount of water in the environment.

The normal chlorophyll content also confirms the photosynthetic assimilation capacity of the hemiparasitic plants.

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