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PHYSIOLOGICAL ASPECTS IN TWO *ANGELICA* L. TAXA (APIACEAE)

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Abstract: Two of the species of the *Angelica* L. genus present in Romania possess therapeutic qualities. *A. archangelica* is listed in several pharmacopoeias, while *A. sylvestris* is used in folk therapies, with in vitro research confirming its values. Although numerous compounds have been isolated from the two species and many bioactivities have been ascribed to them, physiological attributes of the above taxa are known to a much lesser extent. The current paper presents measurements of the intensity of photosynthesis, respiration and transpiration at different growth stages for *A. archangelica* and *A. sylvestris*. In the same time, values for chlorophyll and carotenoid pigments content and moisture in leaves are given for each growth stage considered.
Keywords: *Angelica archangelica* L., *Angelica sylvestris* L., photosynthesis, transpiration, respiration, water content.

Introduction

The genus *Angelica* L. is comprised of over 90 species spread throughout most areas of the globe (Feng et al., 2009). More than half of these species are used in traditional therapies, while some of them are included in several national and European pharmacopoeias. Bioactive constituents in different *Angelica* species include coumarins, essential oils, polysaccharides, organic acids and acetylenic compounds (Sarker and Nahar, 2004). In vitro testing confirmed cytotoxic (Lee et al., 2003; Thanh et al., 2004), antiinflamatory (Shin et al., 2010), antibacterial (Widelski et al., 2009), antifungic (Wedge et al., 2009), neuroprotective (Kang and Kim, 2007), serotonergic (Deng et al., 2006) activities for extracts obtained from a range of *Angelica* species.

Although the chemical composition of the different species constituted the object of numerous studies so far, a survey of the literature reveals little data regarding physiological processes in these plants (though see Popescu et al., 2012). This holds true especially for less studied species such as *A. sylvestris*.

In Romania, the genus *Angelica* is represented by *A. archangelica* L., *A. sylvestris* L. and *A. palustris* (Besser) Hoffm. *A. archangelica* posseses compounds with antimicrobial (Bojor, 2003), antiproliferative (Sigurdsson et al., 2005), insecticidal (Pavela, 2010) and cytotoxic (Gawron and Glowniak, 1987) activities. It is also a cultivated species in several european countries, including in our country for the pharmaceutical and the food industry (Păun et al., 1986). For *A. sylvestris,* an antimicrobial activity was in vitro proved (Sarker et al., 2005). Moreover, the species is held useful in the ecological reconstruction of some habitats, being considered a magnet-species (Zych et al., 2007).

Both species are biennial, with only a basal stalk of leaves in the first year and with the flowering stem developing in the second year. *A. archangelica* has a limited distribution in Romania, with populations occuring from 500 to 1,500 m altitude, in the mountains (Crăciun, 1976), while *A. sylvestris* is much more widespread, frequent in the entire country

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(Pârvu, 2003). We consider the data presented in the current paper, measurements of intensity of photosynthesis, transpiration and respiration, as well as data upon the quantity of assimilating pigments, water content and intensity of the photosynthetic active radiation (P.A.R.), useful for a better cultivation or introduction of these taxa in certain habitats.

Materials and methods

Analyses upon individuals of the two species were carried out for plants in the vegetative phase of the first year of vegetation and in the flowering and fruiting phases of the second year of vegetation. The plants in the vegetative phase and the ones in the flowering phase were analyzed in the same time (April 2012), while the fruiting ones in August 2012. For *A. archangelica*, individuals were collected and analyzed from Gura Haitei (Suceava county), while *A. sylvestris* individuals were collected and analyzed from Gura Haitei and Miclăuşeni (Iaşi county).

For each species, the intensity of photosynthesis, transpiration and respiration were analyzed *in situ* with the aid of an Lci portable apparatus (ADC BioScientific), which also recorded the intensity of P. A. R. at the surface of the leaves. Each parameter was measured on 5 mature leaves from the main stem, facing the sun, for each individual. Determinations were carried on at approximately 10:00 AM. Values are expressed as mean ± standard error (n=5) of the recorded measurements.

A thermohigrometer (Testo 651) was used to record the temperature and relative humidity around the analyzed plants. Values are expresses as mean ± standard error (n=4) of recorded values.

For assimilating pigments quantification, a colorimetric method was used. 1 g of fresh material (mature leaves from the main stem), was extracted in 80% acetone (25 ml). A Shimadzu spectrophotometer was used to record the extinctions of the extracts at 663, 646 and 470 nm. Actual values for the quantity of pigments were calculated using formulas described by Lichtenthaler and Wellburn (1983).

The amount of dry matter and water content were calculated by weighing the material prior to and after drying the material at 105°C until constant weight.

Results and discussions

Values for the intensity of photosynthesis, transpiration, respiration are given in Table 1. The recorded abiotic parameters are given in Table 2. The amounts of assimilating pigments are given in Figs. 1-3, while the amounts of dry matter and water content are shown in Table 2.

Analyzing the data in Table 1, it can be noted that the peak of photosynthesis is recorded in the flowering phase for both species considered. The same observation stands for the peak of respiration. For *A. archangelica* and *A. sylvestris* from Gura Haitei the maximum of the transpiration is recorded in the flowering phase, while for *A. sylvestris* from Miclăuşeni, in the fruiting phase. Such photosynthetic performances conform with those observed in other herbaceous plants and are assigned to the increased content of pigments in leaves as well as to the age of the leaves (Murariu, 2002; Burzo et al., 1999). The respiration rates are also considered to decrease with the age of the organ, besides the influences exerted by other factors, internal or external to the plant (Jeanrenaud, 1969; Boldor et al., 1981). The transpiration rates are, generally, thought to increase during the flowering period and are influenced by some climatic as well as by internal factors (Peterfi and Sălăgeanu, 1973).

Table 1. The intensity of some physiological processes in the analyzed species

Species (phase)/Process	**Photosynthesis (μmol $CO_2/m^2/s$)**	**Transpiration (mmol $H_2O/m^2/s$)**	**Respiration (μmol $CO_2/m^2/s$)**
A. archangelica 1st year	2.314±0.62	1.492±0.07	1.278±0.71
flowering	3.97±0.85	2.244±0.02	2.102±0.74
fruiting	0.68±0.28	0.482±0.05	1.068±0.41
A. sylvestris Gura Haitei 1st year	3.09±0.69	0.688±0.01	1.608±0.23
flowering	5.206±0.71	2.554±0.02	2.408±1.31
fruiting	2.34±0.22	1.902±0.30	0.78±0.17
A. sylvestris Miclăuşeni 1st year	1.518±0.39	0.746±0.07	0.77±0.14
flowering	2.854±0.41	1.818±0.07	1.618±0.41
fruiting	2.452±0.24	1.982±0.05	1.306±0.25

Table 2. Some abiotic parameters recorded at different stages

Species/Parameter	**P. A. R. (μmol/m^2/s)**	**Relative humidity (%)**	**Temperature (°C)**
A. archangelica 1st year	79±0.00	56.00±0.00	21±0.00
flowering	65±0.00	38.80±0.00	28.8±0.00
fruiting	58.6±0.40	38.50±0.00	28.9±0.00
A. sylvestris 1st year Gura Haitei	63.4±1.83	45.00±0.00	23.8±0.45
flowering	124.6±2.50	44.00±0.018	26.6±0.00
fruiting	464.6±16.31	41.55±0.055	27.7±0.00
A. sylvestris 1st year Miclăuşeni	36.6±0.98	51.20±0.00	24.2±0.00
flowering	71.2±3.31	50.40±0.00	27.4±0.00
fruiting	213±48.97	44.20±0.004	29.5±0.35

Table 3. The amount of dry matter and water content in leaves of analyzed species

Species/Parameter	**D. M. %**	**Water content %**
A. archangelica 1st year	19.59	80.41
flowering	16.79	83.21
fruiting	25.04	74.96
A. sylvestris 1st year Gura Haitei	21.11	78.89
flowering	24.75	75.25
fruiting	34.08	65.92
A. sylvestris 1st year Miclăuşeni	20.55	79.45
flowering	26.36	73.64
fruiting	27.35	72.65

Table 4. ANOVA results for photosynthesis variation among phenophases in *A. archangelica*

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	27.06065	2	13.53033	6.867977	0.010277	3.885294
Within Groups	23.64072	12	1.97006			

Table 5. ANOVA results for photosynthesis variation among phenophases in *A. sylvestris* – Gura Haitei

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	22.08985	2	11.04493	6.467367	0.012424	3.885294
Within Groups	20.49352	12	1.707793			

Table 6. ANOVA results for transpiration variation among phenophases in *A. archangelica*

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.968093	2	4.484047	29.87572	2.19E-05	12.97367
Within Groups	1.80108	12	0.15009			

Table 7. ANOVA results for transpiration variation among phenophases in *A. sylvestris* – Gura Haitei

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4.506293	2	2.253147	106.7505	2.27E-08	12.97367
Within Groups	0.25328	12	0.021107			

Table 8. ANOVA results for transpiration variation among phenophases in *A. sylvestris* – Miclăuşeni

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	7.81708	2	3.90854	283.4329	7.94E-11	12.97367
Within Groups	0.16548	12	0.01379			

Table 9. Correlation coefficients transpiration – P. A. R.

Species/Phase	1st year	flowering	fruiting
A. sylvestris Gura Haitei	0.686477	0.033372	0.228239
A. sylvestris Miclăuşeni	-0.18178	0.375405	0.753223

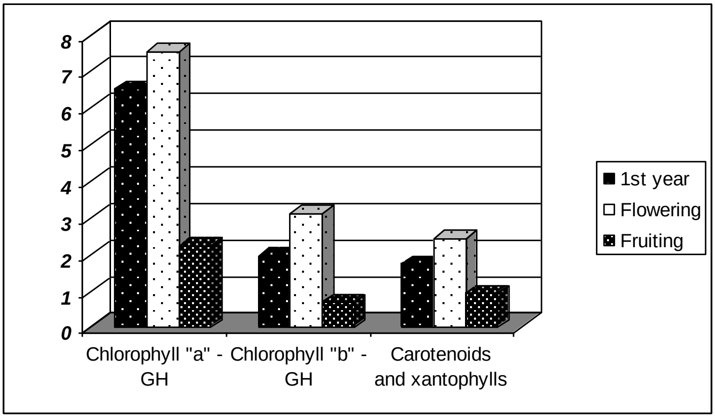

Figure 1. The variation of the content of assimilating pigments in *A. archangelica* (µg/ml)

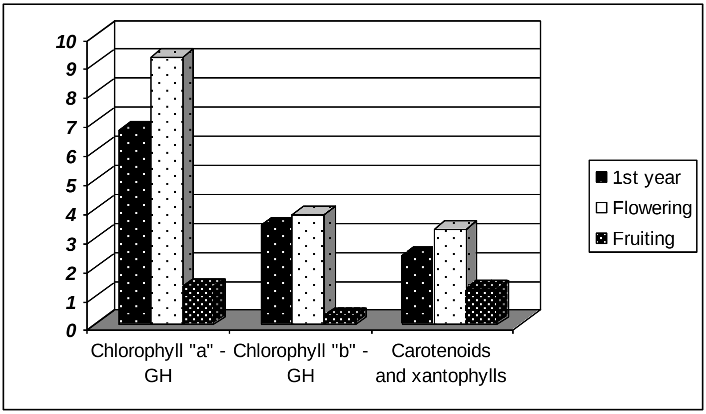

Figure 2. The variation of the content of assimilating pigments in *A. sylvestris* – Gura Haitei (μg/ml)

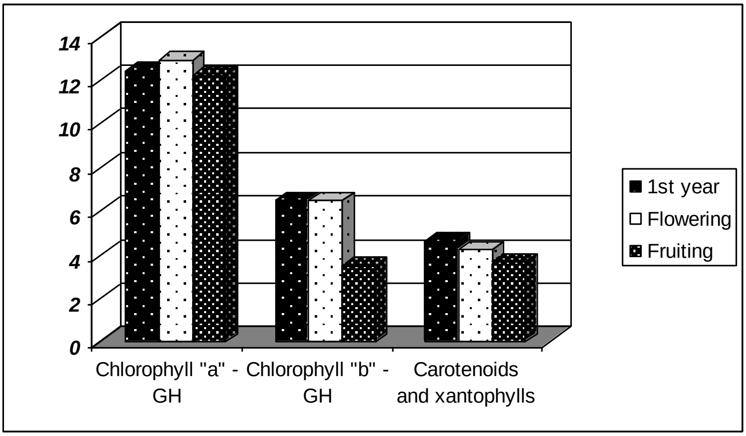

Figure 3. The variation of the content of assimilating pigments in *A. sylvestris* – Miclăușeni (μg/ml)

From a statistical standpoint, the photosynthesis process displays significant variation (P>95%) among phenophases in *A. archangelica* and *A. sylvestris* (Gura Haitei), as shown in Tables 4 and 5, respectively. The transpiration intensity is significantly variable (P>99%) in both species, and in both locations for *A. sylvestris* (Tables 6, 7, 8). The respiratory process, however, does not display significant variation among phases.

The transpiration process can be correlated with the amount of P. A. R. reaching the surface of the leaves. Thus, in *A. sylvestris*, the correlation coefficients show a weak to strong correlation of the two variables (Table 9). In the case of 1st year Miclăușeni individuals, the negative values owe to the relative constant light flow recorded. The effect of light upon transpiration rates is well-known, since the degree of opening of stomata is light mediated (Burzo et al., 1999).

The content of assimilating pigments in leaves decreases in the fruiting stage and is at the highest level during the first stages of vegetation (Figs. 1, 2, 3). This observation agrees with that of Burzo et al. (1999), that the content of assimilating pigments is higher before the leaves mature. Our results also confirm data recorded for other herbaceous species in forest ecosystems (Păucă-Comănescu and Tăcină, 1979).

Some authors (Šesták, 1966; Draskovits and Fekete, 1976; Okubo and Kawanabe, 1978) quoted by Masarovičová and Eliáš (1980), state that one of the indicators of photosynthetic capacity might be the amount of chlorophyll. Although a direct correlation between the amount of pigments and the intensity of photosynthesis couldn't be established (Peterfi and Sălăgeanu, 1973; Murariu, 2002), we might note that, for *A. sylvestris*, individuals from Gura Haitei are more photosynthetically active than individuals from Miclăuşeni in the first phases, although with smaller amounts of pigments in leaves.

Regarding the content of water in leaves, the highest percentage of water content is recorded in the first stages of vegetation, and decreases in the fruiting stage (Table 2). A similar trend was described for other herbaceous species (Jeanrenaud et al., 1969; Murariu, 2002). However, *A. archangelica* presents a higher content of water in leaves than *A. sylvestris*, fact that might be attributed to the wetter habitat preferred by the former species.

Conclusions

The current paper presents data regarding some physiological aspects in two *Angelica* species. The values obtained for the intensity of photosynthesis, transpiration and respiration as well as for the content of assimilating pigments and water content in leaves fit within trends depicted in the literature for the growth phases considered in herbaceous plants.

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