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Nutritional relationships between hemi-parasitic mistletoe and some of its deciduous hosts in different habitats

Cengiz Türe[1]*, Harun Böcük[1] & Zerrin Aşan[2]

[1]Anadolu University, Faculty of Science, Department of Biology, 26470, Eskişehir, Turkey; e-mail: cture@anadolu.edu.tr
[2]Anadolu University, Faculty of Science, Department of Statistics, 26470, Eskişehir, Turkey

Abstract: Parasitism of plants by other plants provides an exceptional opportunity for investigating correlative nutritional relationships. Because of lacking a usual plant-root sytem capable of active uptake, the best correlation for predicting the concentrations of elements in parasitic plants is often those in the host plants. This study, therefore, mainly focuses on determination of i) mineral nutrient partitioning between hemi-parasitic white berry mistletoe (*Viscum album* L. subsp. *album*) and four of its deciduous hosts growing in different habitats namely wetland and semi-arid and ii) effects of these habitat types on nutrient absorption. During the research, leaf samples of both hemi-parasites and their host plants were chemically analysed, mistletoes on each host plants were counted and the results were considered statistically. Concentrations of some elements (N, P, K, Na, S, Cu, Zn) were higher in mistletoe whereas some others (Ca, Mg, Fe, Mn and B) were higher in the hosts ($p < 0.05$). Habitat type was also determined to be effective in host-parasite systems. Revealing information about nutritional interactions between multi-host hemi-parasites and their host plants is a useful tool to understand their functions in ecosystems, population-community dynamics and their co-evolution process.

Key words: *Viscum album*; ecology; ecophysiology; mistletoe; nutrition; parasitism

Introduction

The earliest study about mistletoe was published in the 17th century in Europe (Clasius 1601). Ecological researches have changed markedly over the last 50 years, reflecting changing priorities and a gradual shift in overall attitudes toward these parasitic plants (Marvier 1996; Mathiasen et al. 2008). Building on these previous advances, current research on mistletoes is dominated by themes: mistletoes influence on wildlife habitat and mistletoe–ecosystem interactions. The studies that have started to examine the ecological roles of mistletoes indicate that they may qualify as keystone species in many forest ecosystems (Watson 2001; Devkota 2005; Press & Phoenix 2005). Because parasitic plants can alter the physical environment around them, including soil, water and nutrients, atmospheric CO_2 and temperature (Pegeau et al. 2003).

Viscum album L. subsp. *album*, white berry mistletoe (Loranthaceae), is one of the most important biological stress sources for host plants, and mostly, affects secondarily, as nutrient and water stresses (Fischer 1983; Ehleringer & Schulze 1985; Novacek 1985). Several studies have now clearly demonstrated that many mistletoes thought to be only water parasites actually derive some or most of their carbon requirements from their hosts as dissolved compounds in host xylem sap (Marshall & Ehleringer 1990; Schulze et al. 1984; Marshall et al. 1994; Richter et al. 1995; Norton et al. 1997). However, mechanisms of water and mineral movement from host to mistletoe still have a long way to go before they are fully comprehended (Glatzel 1983; Mathiasen et al. 2008).

Many ecological interactions among mistletoes, their host plants and organisms that depend on them for habitat have not yet been investigated in most ecosystems of the world (Watson 2001; Press & Phoenix 2005; Umucalilar 2007). Sustainable land use and conservation the habitats of hemi-parasitic mistletoes are based mostly on understanding their function in ecosystems. Thus, the objective of this research is to reveal information about (*i*) nutrional relationships between hemi-parasitic *V. album* subsp. *album* and its four deciduous host plants and, (*ii*) effects of habitat type on the nutritional relationships.

Material and methods

Study area

The study area covers a forest domain, densely infected by the hemi-parasitic mistletoe, at the northwest of Eskişehir (Turkey). It is located in semi-arid Mediterranean bioclimate level. The Porsuk river flows the area and generates to form wetland zone (Türe et al. 2004). Table 1 and 2 summarize the results of precipitation regime and bioclimatic analysis based on meteorological data of Eskişehir (Anonymous 2007) consistent with the Emberger method (1952).

* Corresponding author

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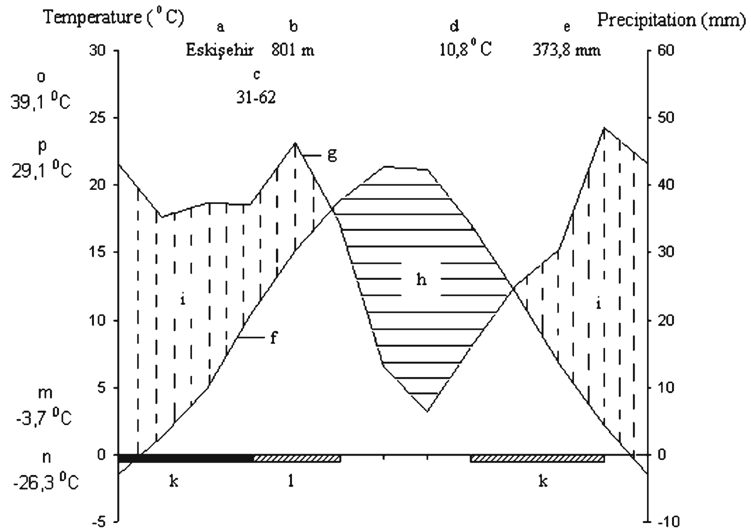

Fig. 1. Ombrothermic diagram of Eskişehir province. (a – city name; b – altitude; c – temperature and observation year number; d – mean annual temperature; e – mean annual precipitation; f – mean monthly temperature curve; g – mean monthly precipitation curve; h – dry period; i – rainy period; k – minumum temperature of the coldest month; l – annual absolute minumum temperature; m – absolute maximum temperature; n – maximum temperature of the hottest month).

Table 1. Annual precipitation (mm) and precipitation regime types of city Eskişehir.

Station	Spring (Sp)	Summer (S)	Fall (F)	Winter (W)	Annual	Precipitation Regime
Eskişehir	120.7	54.2	71.8	127.1	373.8	W.Sp.F.S.

Table 2. Bioclimatic zones of the study area according to Emberger method (1952).

Station	Altitude (m)	P (mm)	PE (mm)	M	m	S (PE/M)	Q	Bioclimate zone
Eskişehir	801	373.8	54.2	28.9	−3.7	1.8	51.9	Semi-Dry Mediterranean

P – Annual average precipitation (mm); PE – Annual summer precipitation mm/m^2); M – Average temperature of the hottest month (℃); m – Average temperature of the coldest month (℃); S – Value of dry season (PE/M); Q – Comparison of temperature-precipitation (2000.P.(M + m + 546.4) · (M – m)

The study area is in semi-dry Mediterranean climate Type 1 and precipitation regime type of the area is W.Sp.F.S. (Winter, Spring, Fall, Summer). In Fig. 1, ombrothermic diagram of Eskişehir is given according to Walter method (Walter 1960; Cireli et al. 1983). It can be seen that the dry period in Eskişehir starts in June and ends October.

Major soil types are red brown and alluvial soils (Anonymous 1994; Türe & Böcük 2007). In terms of geological characteristics, the stratigraphic ranging of the formations in the area and its environment experience three different structures, namely, slope rubble (Quaternary), alluvion (Quaternary) and conglomerate (Neogen), (Erdir & Türe 2003).

Plant material

Female individuals of *Viscum album* subsp. *album* and its four deciduous hosts are the plant materials of this study. The mistletoe, hemi-parasitic evergreen shrub, shows great variance with respect to host, 452 different host species in 96 genera of 44 families (Barney et al. 1998), and habitat diversity (Zuber 2004; Umucalilar 2007). It is propagated exclusively by seed, which is carried distantly with the aid of birds (Amico & Aizen 2000; de Buen & Ornelas 2001; Soto-Gamboa & Bozinovic 2002).

Decidious host plant species are *Crataegus monogyna* Jacq. subsp. *monogyna* (wild hawthom-Rosaceae), *Robinia pseudoacacia* L. (black locust-Fabaceae) growing in semi-arid habitat, *Salix alba* L. (white willow-Salicaceae), *Populus alba* L. (white poplar-Salicaceae) growing in wetland habitat.

General vegetation structure

The study area is mainly consist of forest vegetation distributing into two different habitats, wetland and semi-arid. Forests in wetland habitats are adjacent to the Porsuk river. Since it distributes mostly along the river, it is also called as "flood-plain forests". It has to be underlined that a significant part of the research area is located in semi-arid zone.

In semi-arid habitats, three layers can be distinguished vertically: tree, shrub and herb. The tree layer is dominated by *Robinia pseudoacacia*. Average age of this population is 20. Some neddle-leaved taxa namely *Pinus nigra* Arn. subsp. *pallasiana* (Lamb.) Holmboe and *Cedrus libani* L. accompany with the *R. pseudoacacia* locally. Canopy coverage of the tree layer is 60%, its height reaches to 10 m. LAI value is 3.2. Shrub layer in this habitat is dominated by *Crataegus monogyna* (average age 15) and *Juniperus oxycedrus* L. associations. Canopy coverage of this layer is 40%, its height varies between 0.6 and 3 m. The most common plant species of herb layer are *Nigella arvensis* L. var. *glauca* (Boiss.) N. Terracc., *Alyssum borzaeanum* E. I. Nayardy, *Helianthemum nummularium* (L.) Miller subsp. *nummularium*, *Poylgala supina* Schreb., *Minuartia anatolica* (Boiss.) Woron. var. *anatolica*, *Hypericum perforatum* L., *Linum hirsutum* L. var. *anatolicum* (Boiss.) Hayek, *Ononis spinosa* L. subsp. *leiosperma* (Boiss.) Širj., *Eryngium campestre* L. var. *campestre*, *Xanthium spinosum* L., *Centaurea solstitialis* L. subsp. *solstitialis*, *Centaurea virgata* Lam., *Xeranthemum annuum* L., *Convolvulus arvensis* L., *Teucrium polium* L., *Sideritis montana* L. subsp. *montana*, *Aegilops geniculata* Roth, *Hordeum bulbosum* L., *Bromus tectorum* L., *Koeleria cristata* Pers., *Poa bulbosa* L., *Stipa lessingiana* Trin & Rupr, *Dactylis glomerata* L. subsp. *glomerata*, *Acantholimon acerosum* L. var. *acerosum*. Canopy coverage of the herb layer is 20% and its height is up to 30 cm.

In wetland habitats, three layers can be distinguished vertically: tree, shrub and herb. The common tree species include *Salix alba* (average age 25), *Populus alba* (average age 30). *Platanus orientalis* L. (average age 30) accompanies with these species. Canopy coverage of the tree layer is 70%, its height reaches to 15 m. Shrub species in this habitat incorporate *Rubus sanctus* Schreb., *Rosa canina* L., *Tamarix smyrensis* L. LAI value is 3.4. Canopy coverage of this layer is 40%, its height reaches to 1.5 m. Common herb species of this habitat are*Ranunculus constantinopolitanus* (DC.) d'Urv., *Stellaria media* (L.) Vill. subsp. *media*, *Rumex acetosella* L., *Potentilla reptans* L., *Agrimonia eupatoria* L., *Lythrum salicaria* L., *Epilobium hirsutum* L., *Dipsacus laciniatus* L., *Anagallis arvensis* L. ssp. *arvensis*, *Veronica anagallis-aquatica* L., *Mentha longifolia* (L.) Huds. subsp. *thyphoides* (Briq.) Harley var. *thyphoides*, *Plantago major* L. subsp. *major*, *Typha angustifolia* L., *Phragmites australis* (Cav.) Trin. ex Steud., *Lemna minor* L., *Potamogeton crispus* L. Canopy coverage of this layer is 20% and its height reaches to 1.5 m.

Plant analyses

Sampling of the plants were made on October 2005, the most stable period in terms of mineral movements in plants in Eskişehir, Turkey. Deciduous host plant species were selected from the dominant plant taxa of canopy layer. 10 individuals were chosen from each host plants in the study area. Leaf samples of these host plants and healthy mistletoes, at least 8 mistletoes from each individual host plant (2 from each direction (north, south, east, west)), were collected randomly. The leaf samples of the each individual host plant and its hemi-parasitic mistletoe were taken from the same branch for each direction. After packaging samples seperately and taking to laboratory, they were immediately dried at 65 °C for 24 hours, ground and dried again at 65 °C for 12 hours. These dried samples were used for the analyses (Black 1965; Gülçur 1974; Anonymous 1994). Each individual and its hemi-parasite were analysed separetely. Each nutrient analysis produced 3 replicates from the same sample and the mean values of the results were used.

Plant materials were analysed according to the following methods: The Kjeldahl method for nitrogen (N) determination, the vanadamolybdophosphoric acid for phosphorus (P), the flame photometer method for potassium (K) and sodium (Na), the curcumin method for boron (B), the turbidimetric barium chloride method for sulphur (S), the atomic adsorption method for calcium (Ca), magnesium (Mg), ferro (Fe), zinc (Zn), copper (Cu), manganese (Mn) and molybdenum (Mo) (Black 1965; Gülçur 1974; Anonymous 1994).

Table 3. The Mood's Median test results of the mistletoe number on the hosts.

Plants	N	Median	Chi-Square	df	Sig.
Populus alba	10	11.5	27.88	3	.000*
Salix alba	10	19.5			
Robinia pseudoacacia	10	7			
Crataegus monogyna ssp. *monogyna*	10	3.5			
Total	40	9			

* significant at $p < 0.05$

Mistletoe density on host plants

Mistletoes were counted from randomly selected 30 individuals belonging to each host plant species to determine the density of hemi-parasites. Median values of hemi-parasite density on each host are given in Fig. 3 and Table 3.

Data Analysis

Data obtained from laboratory analyses were considered statistically by using SPSS 11.5 Statistic Program. Two Way ANOVA test was performed to determine whether there were any relationships between the hemi-parasitic mistletoe and its four different deciduous hosts in term of nutrient constituents. Statistical analyses were applied for each nutrient independently. Gabriel test was applied to determine which species were statistically correlated with its host and whether there was any relationship between host plants and their hemi-parasites. In addition, the Mood's Median test was applied to determine whether there were any differences among the host plants in terms of mistletoe number which emerge.

Results

Differences in all nutrient concentrations except Mo between the mistletoes and their hosts are statistically significant ($p < 0.05$). However, concentrations of some elements (N, P, K, Na, S, Cu, Zn) are higher in mistletoe than its hosts whereas the others (Ca, Mg, Fe, Mn and B) are higher in the hosts (Fig. 2, Table 4).

In host plants; concentrations of Na, Ca, Zn and Mo in *P. alba*; P, K, S, Mg, Cu, Mn and B in *S. alba*; N in *R. pseudoacacia* and Fe in *C. monogyna* subsp. *monogyna* are the highest. Concentrations of P, K, Na, Zn and Mo in the mistletoes on *P. alba*; S, Ca, Mg, Mn and B in the mistletoes on *S. alba*; N in the mistletoes on *R. pseudoacacia*; Fe and Cu in the mistletoes on *C. monogyna* subsp. *monogyna* are the highest (Fig. 2).

Mean nutrients concentrations of the hosts-their parasites and homogen host plant groups according to nutrient concentrations are given in Fig. 2 and Table 5, respectively. These host plants are clustered in 3 homogenous groups for N and Mn concentrations, and 2

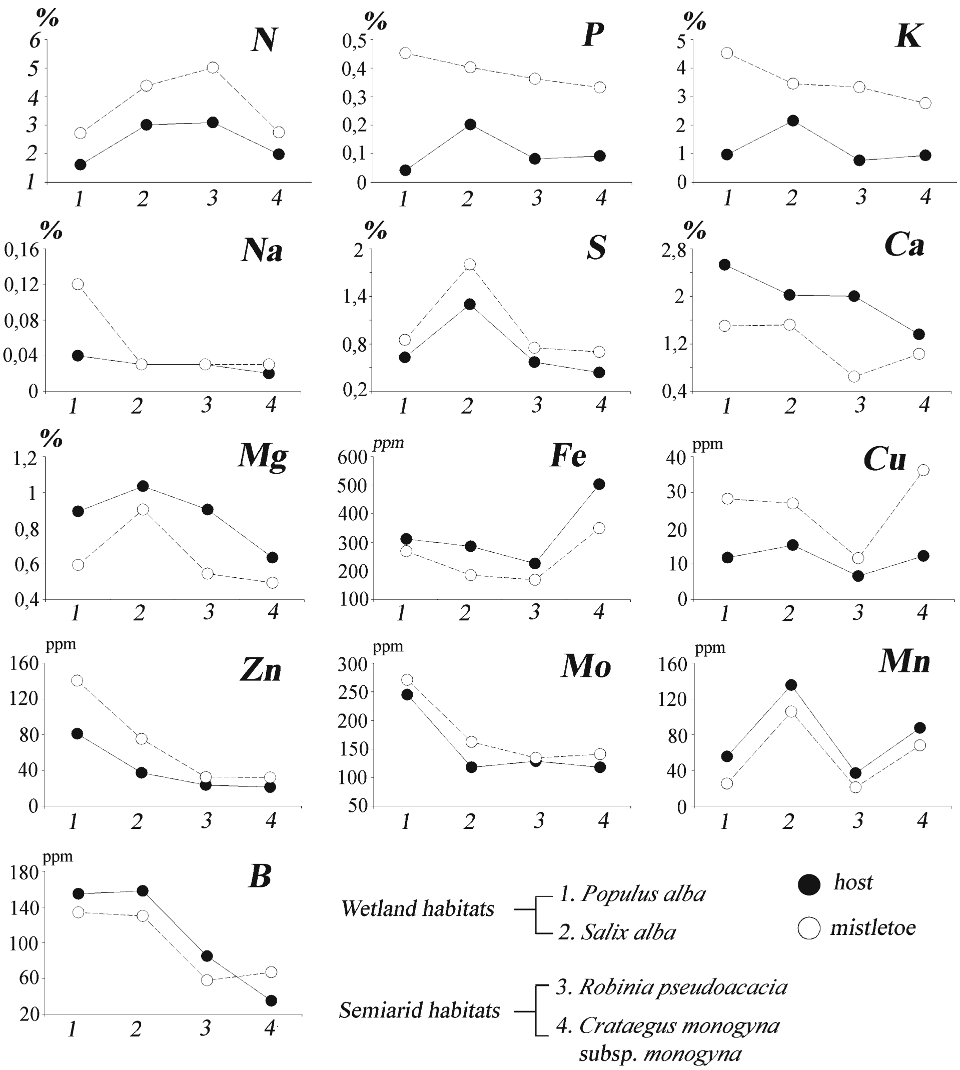

Fig. 2. Mean concentration values for 13 nutrients in all host plants and the mistletoes.

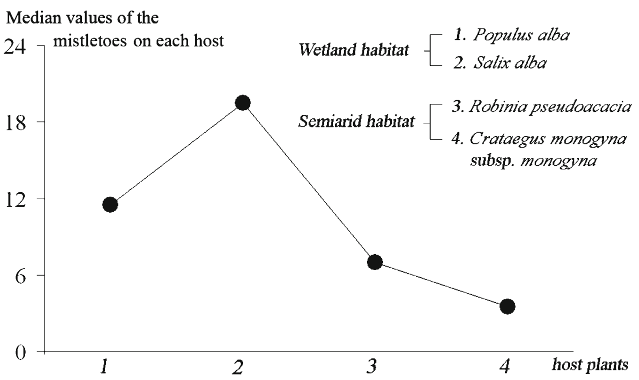

Fig. 3. Median values for densities of the mistletoes on each host.

homogenous groups for P, K, Na, Zn, Mg, S, Fe, Ca, B and Cu.

Differences in mistletoe number on the selected host plants in different habitats are statistically important ($p < 0.05$). Median values of hemi-parasites differ from general median values, and *P. alba* -*S. alba* and *C. monogyna* subsp. *monogyna* -*R. pseudoacacia* form two homogenous groups. Because the median values of *P. alba* and *S. alba* is higher than the general median value, it is noted that the hemi-parasitic mistletoe number on these host plants is higher on *C. monogyna* subsp. *monogyna* and *R. pseudoacacia* which have less median values than the general median value (Table 3, Fig. 3).

The results show that nutrient concentrations in the host plants are not correlated with the habitat types. However, nutrient absorption by mistletoes runs in accordance with nutrient concentrations in the host plants. It seems that nutrient concentration in the host plants is related to the species of them and mistletoes in wetland habitats adsorb nutrients more than those in semi-arid habitats (Fig. 2, Table 4).

Discussion

Parasitism of plants by other plants provides an exceptional opportunity for investigating correlative nutritional relationships (Yoder 2001). Mistletoes are perennial flowering parasitic plants attached to branches of trees and shrubs and affect host viability by withdrawing essential resources (Devkota 2005). Because mistle-

Table 4. Results of Two-Way ANOVA tests related to difference between the host and the mistletoe for each nutrient.

	Source	Sum of Squares	df	Mean Square	F	Sig.
N	1	17.116	3	5.705	11.608	0.000*
	2	16.657	1	16.657	33.892	0.000*
	Error	12.287	25	0.491		
	Total	46.061	29			
P	1	0.648	3	0.216	2.506	0.082
	2	1.494	1	1.494	17.346	0.000*
	Error	2.153	25	8.613E-02		
	Total	4.295	29			
K	1	16.090	3	5.363	18.805	0.000*
	2	25.73	1	25.273	88.610	0.000*
	Error	7.130	25	0.285		
	Total	48.493	29			
Na	1	1.173E-02	3	3.912E-03	10.015	0.000*
	2	2.424E-03	1	2.424E-03	6.207	0.020*
	Error	9.764E-03	25	3.906E-04		
	Total	2.392E-02	29			
S	1	5.075	3	1.692	33.676	0.000*
	2	0.644	1	0.644	12.816	0.001*
	Error	1.256	25	5.024E-02		
	Total	6.975	29			
Ca	1	3.673	3	1.224	10.921	0.000*
	2	5.344	1	5.344	47.664	0.000*
	Error	2.803	25	0.112		
	Total	11.820	29			
Mg	1	0.705	3	0.235	14.640	0.000*
	2	0.399	1	0.399	24.863	0.000*
	Error	0.401	25	1.605E-02		
	Total	1.505	29			
Fe	1	217317.999	3	72439.333	11.885	0.000*
	2	92845.391	1	92845.391	15.233	0.001*
	Error	152375.889	25	6095.036		
	Total	462539.279	29			
Cu	1	988.490	3	329.497	5.238	0.006*
	2	1695.008	1	1695.008	26.947	0.000*
	Error	1572.533	25	62.901		
	Total	4256.032	29			
Zn	1	30371.825	3	10123.942	27.708	0.000*
	2	7089.145	1	7089.145	19.402	0.000*
	Error	9134.380	25	365.375		
	Total	46595.350	29			
Mo	1	74481.772	3	24827.257	2.779	0.062
	2	4240.378	1	4240.378	0.475	0.497
	Error	223307.414	25	8932.297		
	Total	302029.565	29			
Mn	1	42950.402	3	14316.801	21.507	0.000*
	2	5005.224	1	5005.224	7.519	0.011*
	Error	16641.772	25	665.671		
	Total	64597.398	29			
B	1	50681.469	3	16893.823	40.079	0.000*
	2	857.780	1	857.780	2.035	0.166
	Error	10537.958	25	421.518		
	Total	62077.207	29			

1 – Host plant, 2 – Parasite, * – significant at $p < 0.05$

toes lack a usual plant root sysytem capable of active uptake they rely completely upon a host connection through the haustorium for water, nitrogen and mineral nutrients (Watson 2001; Garkoti et al. 2002; Glatzel & Geils 2009). Therefore, the best correlation for predicting the concentrations of elements in the mistletoe is

Table 5. Results of Multiple Comparisons Gabriel Test related to homogenous groups among all plants for each nutrient.

		Subset		
N		1	2	3
	Populus alba	2.1630		
	Crataegus monogyna subsp. *monogyna*	2.3645	2.3645	
	Salix alba		3.3457	3.3457
	Robinia pseudoacacia			4.0465
P		1	2	
	Populus alba	0.1717		
	Crataegus monogyna subsp. *monogyna*	0.2067	0.2067	
	Robinia pseudoacacia	0.2167	0.2167	
	Salix alba		0.3825	
K		1	2	
	Populus alba	0.2425		
	Crataegus monogyna subsp. *monogyna*		1.7983	
	Robinia pseudoacacia		1.9933	
	Salix alba		2.2717	
Na		1	2	
	Robinia pseudoacacia	2.700E-02		
	Crataegus monogyna subsp. *monogyna*	2.700E-02		
	Salix alba	2.717E-02		
	Populus alba		7.6502	
S		1	2	
	Crataegus monogyna subsp. *monogyna*	0.5700		
	Robinia pseudoacacia	0.6567		
	Populus alba	0.7375		
	Salix alba		1.5683	
Ca		1	2	
	Crataegus monogyna subsp. *monogyna*	1.1733		
	Robinia pseudoacacia	1.3033		
	Salix alba		1.8817	
	Populus alba		1.9925	
Mg		1	2	
	Crataegus monogyna subsp. *monogyna*	0.5567		
	Robinia pseudoacacia	0.7233		
	Populus alba	0.7350		
	Salix alba		0.9733	
Fe		1	2	
	Robinia pseudoacacia	195.1667		
	Salix alba	270.3333		
	Populus alba	288.0000		
	Crataegus monogyna subsp. *monogyna*		423.6592	
Cu		1	2	
	Robinia pseudoacacia	8.8333		
	Salix alba	19.1667	19.1667	
	Populus alba	19.7500	19.7500	
	Crataegus monogyna subsp. *monogyna*		24.0000	

Table 5. (continued)

		Subset		
Zn		1	2	
	Crataegus monogyna subsp. *monogyna*	24.6666		
	Robinia pseudoacacia	26.0000		
	Salix alba	47.6666		
	Populus alba		108.7500	
Mn		1	2	3
	Robinia pseudoacacia	28.3333		
	Populus alba	39.7500	39.7500	
	Crataegus monogyna subsp. *monogyna*		77.1666	
	Salix alba			123.8333
B		1	2	
	Crataegus monogyna subsp. *monogyna*	50.8333		
	Robinia pseudoacacia	70.4167		
	Salix alba		141.6666	
	Populus alba		141.8750	

* p is significant at the 0.05 level, 1 – *Crataegus monogyna*, 2 – *Robinia pseudoacacia* 3 – *Salix alba*, 4 – *Populus alba*

often (but not always) the concentrations of elements in the host (Glatzel & Geils 2009).

Hemi-parasitic mistletoes characteristically occur in low-nutrient habitats (Davis & Graves 2000). However, they are commonly characterized by a higher nutrient contents than their hosts (Mehrotra 1978; Ehleringer & Schulze 1985; Malicki & Berbeciowa 1986; Kutbay et al. 1996) notably in terms of N, P and K concentrations (Fig. 2). The hydrostatic pressure in the cells of the two parts of haustorial connection (between host and parasite) is in favor of the parasite. Besides, mistletoes have lower water potential and higher transpiration rate than their hosts (Schulze et al. 1984; Gauslaa & Odasz 1990; Garkoti et al. 2002). Therefore, in general, for mistletoes, nutrient flow through the transpiration stream is predominantly one-way, from host to parasite and not to opposite direction (Zuber 2004; Hosseini et al. 2008; Glatzel & Geils 2009). Furthermore, mistletoes do not share the nutrients with their hosts to avoid mineral deficiency and cope with excess and imbalance (Glatzel & Geils 2009). These are the possible reasons why many mobile nutrients are higher concentrations in mistletoes than their host plants (Fig. 2).

Parasitism is suggested as a strategy for enhancing N acquisition (Lamont 1983; Kutbay et al., 1996; Pageau et al. 2003; Doi et al., 2008), a macronutrient most limiting mistletoe growth (Schulze et al. 1984). High N supply increases the severity of infection by parasites (Marschner 1995). However, according to Hosseini et al. (2008), the host plant cannot absorb and compensate N supply quickly. Therefore, N amount in host plant is generally lower than its mistletoe. This situation has frequently been documented (Puustinen & Mutikainen 2001; Barberaki & Kintzios 2002; Bowie & Ward 2004; Lamien et al. 2006) although a few studies have also found N concentrations in leaves of mistletoes to be lower than those of their hosts (Ehleringer & Schulze 1985; Bannister 1989). In this study, all mistletoes have also higher N content than their hosts (Fig. 2) but *R. pseudoacacia* and the mistletoe on this species have the highest N concentrations among them. This is probably because of the fact that legume plants generally receive N in large amounts by the help of nitrogen-fixing root symbionts (Bowie & Ward 2004).

The mistletoes on each host plants have higher P concentrations than their hosts and the host plant *S. alba* and the mistletoe on *P. alba* have the highest P concentrations (Fig. 2). Similar results were also declared by some other researchers (Glatzel 1983; Davies & Graves 2000; Hosseini et al., 2008; Glatzel & Geils 2009). The reason of high P concentration in mistletoe leaves is possibly due to the absence of a phloem connection between host and hemi-parasite, high transpiration rates and the lack of a retranslocation system (Smith & Stewart 1990; Glatzel & Geils 2009). Davies and Graves (2000) reported that increasing P amount in host tissues had a positive effect on the host, with the negative impact of parasitism being greatly reduced at the higher P level.

K content of mistletoe tissue in this (Fig. 2) and many other studies (Glatzel 1983; Hosseini et al. 2007, 2008) is disproportionately higher than the content of other major nutrients (Glatzel & Geils 2009). In the host plant, K is cycled between leaves and sites of photosynthate utilization in the wake of photosynthate transport in the phloem. However, it cannot cycle beyond the host-parasite interface in the hemi-parasite and K imported with the xylem sap. Thus, it is trapped in the hemi-parasite phytomass (Glatzel 1983; Smith & Stewart 1990). In the present study, the host plant *S. alba* and the mistletoe on *P. alba* have the highest K concentrations (Fig. 2).

Not only N, P and K, but also some other nutrient concentrations like Na, Zn, S and Cu are higher in mistletoe tissues than their host plants (Fig. 2) as confirmed by some other studies (Devkota 2005; Hosseini et al. 2008; Glatzel & Geils 2009). Higher concentrations of some elements in leaves of host plants such as Ca and B (Fig. 2) are not surprising because of their immobile or limited mobile characteristics (Brown & Shelp 1997; Malone et al. 2002).

Except the nutritional partitioning characteristics, mistletoe numbers on host plants reveals important data to evaluate their distributional characteristics. Because their distribution in natural plant communities is not uniform, being affected by many local environmental factors (Devkota 2005). The hypothesis of this study was that habitat type could one of the most important limiting factors of mistletoe distribution. *P. alba* – *S. alba* and *C. monogyna* subsp. *monogyna* – *R. pseudoacacia* form two different groups according to mistletoe number of each host plants. These groups match the plant couple in different habitats, wetland (*P. alba*, *S. alba*) and semi-arid habitats (*C. monogyna* subsp. *monogyna*, *R. pseudoacacia*). Moreover, higher amounts of many elements are available in both mistletoes and their host plants growing in wetland areas (Fig. 2). These results confirm the hypothesis.

The extent to which the host is affected depends not only how much of the resource is diverted by parasite, but also on the overall supply available to the host (Devkota 2005). Therefore, improvement of mistletoes vary considerably depending on their ability to obtain water and minerals from their hosts (Mathiasen et al. 2008). It is clear that nutrient absorption by mistletoes and mistletoe numbers on each host plant are closely related to habitat types (Figs 2, 3). Recently, parasites have been shown to modify the feeding patterns of their hosts. Hosts may attempt to compensate for the increased nutritional demands caused by parasites by increasing their foraging effort (Miura et al. 2006; Hosseini et al. 2007). In high water balanced habitats, it is easier to take nutrient by host plants because of availability of enough water. Therefore, we can easily hypothesize that nutrition potential of a mistletoe from its hosts is mostly affected from any habitat type. Some paleoecological studies show that mistletoe pollen grains are present in relatively large amount in floodplain areas during geological ages (especially Holocene), (Kroll 1998; Brayshay & Dinnin 1999). The fact that coevolution of host and its parasite appears from wetland habitats shows further adaptation of mistletoes to the wetland species. The literatures which focus on physiological productivities like photsynthesis, respiration, transpiration, water deficit, osmotic potential and phytomass in hemi-parasitic plants in high water balanced habitats could reach up to 5 times greater than the ones in arid and semi-arid areas (Hellmuth 1971; Rödl & Ward 2002). Besides, as a consequence of capturing enough water and nutrients, it is reported that hosts growing in high water-balanced habitats are less affected by damage of mistletoes (Hellmuth 1971; Tsopelas 2004; Gathumbi et al. 2005; Yüksel et al. 2005; Dobbertin & Rigling 2006). This information also overlaps our assesment in this study. Indeed, habitats with high water balance could advance the ecological success of mistletoes, and the same adaptation can also be the ease for resistance to parasite. It can be reasonable to argue this study hopefully will contribute to understand nutritional relationships of parasitic plant life and their roles in ecosystems.

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