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EVALUATION OF EUROPEAN MISTLETOE (*VISCUM ALBUM* L.) INFECTION IN THE CASTLE PARK IN LEDNICE

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Abstract

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This experiment focused on the evaluation of mistletoe infection (*Viscum album* L.) in main sections of the castle park in Lednice. The study evaluates the proportion of affected and unaffected individuals of host taxa and the intensity of their infestation. For *Acer campestre* and *Tilia cordata* one-way ANOVA was used to detect the difference among the number of mistletoe bushes and tree age, development stage, vitality and location. For the modelling of mistletoe infection probability also the dependence on these and other continuous explanatory variables (height and crown volume) was used for logistic regression with binomial distribution. Our results show that number of mistletoe on trees within same taxa increases with the tree age and with the lower tree vitality, but there is large difference between the hosts. Due to the results of logistic regression, the same factors also have strong impact on the probability of mistletoe infection, e.g. tree age and tree vitality. In this case no large differences were found between the hosts.

Viscum album, host woody species, mistletoe infection, probability of infection, incidence of mistletoe, logistic regression

Mistletoes are a polyphyletic and diverse group of flowering plants comprising over 1306 species from a broad range of habitats across all continents except for Antarctica. The group contains members of five families within the order *Santalales* which are mostly parasitic plants (Watson, 2001; Zuber, 2004). European or white berry mistletoe (*Viscum album* L.) from family *Viscaceae* (Nickrent *et al.*, 2010) is an evergreen, perennial, epiphytic, hemiparasitic shrub that lives on the wide range of woody species. It is native to Europe (Zuber, 2004).

Three widely distributed subspecies that differ in host specificity and a four subspecies only known from Crete have been recognised in Europe (Stopp, 1961; Ball, 1993; Böhling *et al.*, 2002): *V. album* subsp. *album* L. on dicotyledonous trees, *V. album* subsp. *abietis* (Wiesb.) Abromeit on *Abies* sp. div., *V. album* subsp. *austriacum* (Wiesb.) Vollmann on *Pinus* sp. div., rarely *Larix* sp. div. and *Picea* sp. div., *V. album* subsp. *creticum* N. Böhling, Greuter, Raus, B. Snogerup, Snogerup and Zuber on *Pinus brutia* Ten. subsp. *brutia* exclusive from Crete. Three subspecies can be found in the Czech Republic (Houfek, 1973; Kubát, 1974; Skalický, 1974).

The first overviews of host plants (e.g. *Acer* sp. div., *Populus* sp. div., *Malus* sp. div., *Pyrus* sp. div. and *Tilia* sp. div.) of *Viscum album* in the Czech Republic were published by Tubeuf (1923). Later Wangerin (1937) reported *Salix* sp. div. and *Sorbus aucuparia* L. as a host. Complex survey made by Unar *et al.* (1985) provide suitable basis for evaluating the frequency of host trees and shrubs over broader geographical areas.

According to Procházka (2004) 53 host taxa are recorded in the Czech Republic including five hybrid taxa; 26 are being native and 27 are alien species in the Czech flora. The range of hosts covers 13 families, among which *Salicaceae* (11 taxa), *Rosaceae* (11), *Aceraceae* (7), *Tiliaceae* (5) and *Oleaceae* (5) are more represented. Of the 22 genera harbouring mistletoe, *Populus* (7 taxa), *Acer* (7), *Tilia* (5), *Crataegus* (5) and *Fraxinus* (4) are most frequent in terms of host species numbers.

The highest diversity of host trees is in the locality of the Lednice castle park (Procházka, 2004). Total number of host species in all areas of the castle park in Lednice was 24 (Unar *et al.*, 1985), later it was supplemented with 73 taxa from 27 genera (Spálavský, 2001).

The distribution of *V. album* subsp. *album* L. in the Czech Republic is rather uneven. It cannot be found in large areas, e.g. central and western Bohemia, but it is common in other parts of the country, such as central and northeastern Moravia or the town of Břeclav in southern Moravia (Kubát, 1997). As to the phytogeographical regions (Skalický, 1988), the occurrence is concentrated in the Mesophyticum altitudinal floristic region and it is only sporadically found in the warmer Thermophyticum; such localities are mostly close to the boundary with the former region. It grows only rarely at higher altitudes of the Oreophyticum region.

Fruits and seeds of mistletoe are an important part of the food of many species of birds in winter. Among them is one group that spreads seeds and another group that destroys them (Grundmann *et al.*, 2011). The most important representatives of the first group are the mistle trush (*Turdus viscivorous* L.), a defecating vector, and blacksap (*Sylvia atricapilla* L.), a beak-wiping vector (Briggs, 2003; Watson, 2001; Zuber, 2004; Zuber and Widmer, 2000). Seed-destroying species are mainly coal tit (*Parus ater* L.), blue tit (*Parus caeruleus* L.), marsh tit (*Parus palustris* L.) and eurasian nuthatch (*Sitta europaea* L.). Coal tits and blue tits eat germinating mistletoe plants, as well (Grundmann *et al.*, 2011).

The birds usually feed on and digest the pulp of the berries, excreting the living seeds that stick tightly to any branch on which they land. In most cases, the initial infestation occurs on larger or older trees because birds prefer to perch in tops of taller trees (Briggs, 2003; Watson, 2001; Zuber, 2004). Grundmann *et al.* (2011) report that birds prefer solitary trees and trees standing on the edge of forests to rest and overnight, and therefore are often intensely infected with mistletoe. The limiting factor for the northern and eastern border of habitat of *V. album* L. is temperature (Luther and Becker, 1986).

According to Kartoolinejad *et al.* (2007), local distribution primarily depends on less important factors. Individual differences among host trees (especially diameter at breast height) play an important role in explaining local abundance and distribution of mistletoe plants. Some results showed that mistletoe abundance and infection intensity in *Parrotia persica* (DC.) C. A. Mey. were more linked than in the other host species. Further, positive significant relations were with diameter at breast height, distance to conspecific location in the stand edge, but no significant relation was observed with height of host trees.

Mistletoe removes water and minerals from host plants that may be significantly stressed in case of medium to heavy infestation (Nováček and Teterová, 1987; Grundmann *et al.*, 2011). Grundmann *et al.* (2011) further states that branches or trees with mistletoe may have a lower level of vitality than uninfected branches of the same tree, or uninfected trees. The complexity of this relationship is emphasized. The lower vitality of a tree (branch) may firstly lead to the increased infestation with mistletoe and the cause of worse vitality thus does not have to be infestation with mistletoe. This occurs only in the advanced stage of infection: severe infestation can lead to dieback of branches, in extreme case of the whole tree.

The aim of this study was to: (1) assess the extent of infestation with mistletoe of individual taxa of woody species (ratio of infected individuals and intensity of their infestation); (2) assess the relationship between selected characteristics of host trees (age, development stage, vitality and location) and their infestation with mistletoe; (3) predict the probability of infestation with mistletoe of host trees depending on their selected characteristics (age, development stage, height, crown volume, vitality, location).

MATERIAL AND METHODS

The research locality Lednice is situated in southern Moravia at an altitude of 165 m above the sea level, the most important centre of occurrence of the European Mistletoe in the Czech Republic (Procházka, 2004). It is located in the area thermophyticum, in the 18a phytogeographic sub-district – Dyjsko-svratecký úval (Skalický, 1988). According to Quitt's climate classification, the whole territory belongs to the warmest area of the Czech Republic labelled as T4 (Culek, 1996). Average annual temperature is about 9 °C. The warmest month is July with 19.2 °C and the coldest month is January with an average temperature of −1.7 °C. Vegetation period usually begins in middle-late March and ends in mid-November. The long-term precipitation amount in the vegetation period amounts to 300–350 mm (Culek, 1996).

This research focused on the spread of European mistletoe (*Viscum album* L.) in the dendrologically valuable castle park in Lednice na Moravě. The selected locality is an important heritage garden enlisted in the UNESCO World Heritage List. The area of this park is approximately 170 ha (without pond) and includes more than 10,000 trees. Among these woody plants we can also be found several rarities.

The field investigation was carried out in winter periods (usually from mid-December to mid-March) of the year 2011 and 2012. The territory of the park was divided to 13 sections and each of them was further divided to departments whose total number was 129 (Pejchal and Šimek, 1996). The surveyed area included sections 1 to 11 which contain more than 9 000 trees, among them were approximately 6 000 deciduous trees. Total number of taxa is more than 360 (including cultivars and varieties). First, tree inventory was drawn up and all trees were individually evaluated. The following data was recorded:

a) Identification, which included: serial section number, serial department number, serial number of the element in a department, element type, taxon (for this purpose we used the nomenclature according to Kubát (2010) and Erhardt *et al.* (2008).
b) Basic dendrometric quantities: tree height, crown width, diameter of breast height. Measured in practice by common methods (Machovec, 1982).
c) Additional dendrometric quantities: height to crown base, ideal crown volume (calculated as regular ellipsoid), real crown volume (based on a geometric shape, the possible damage of crown was deducted) (Pejchal and Šimek, 1996).
d) Age and development stage. Age category: 7-point scale (I. older than 205 years, II. 205–155 years, III. 155–95 years, IV. 95–75 years, V. 75–50 years, VI. 50–30 years, VII. younger than 30 years – corrected by Pejchal and Šimek, 1996). Development stage (DS): 5-point scale (newly planted/germinating individual, rooted individual, stabilized maturating individual, mature individual and superannuated individual – Pejchal and Šimek, 1996).
e) Vitality indicators. Distinguished a physiological and biomechanical vitality aspect. Used a following scale: 0 – vitality optimum, 1 – mildly decreased, 2 – middle decreased, 3 – strongly decreased, 4 – very strongly decreased to none (Pejchal, 1995; Roloff, 2001). This feature was evaluated pre-eminently with help of phase models of apical shoot architecture proposed by Roloff (2001).
f) Location of individuals: 10-point grading (S – solitary plant, OCG – open canopy group, CCG – closed canopy group, MOCG – margin of open canopy group, MCCG – margin of closed canopy group, OCS – open canopy stand, CCS – closed canopy stand, MOCS – margin of open canopy stand, MCCS – margin of closed canopy stand, A – alley; Pejchal and Šimek, 1996).
g) Incidence of mistletoe: two categories – uninfected individuals (0) and infected individuals (1).

The infection degree of host plants was the ratio of the volume of each mistletoe individual to foliage crown. The following scale was used (Spálavský, 2001): 0 – No infection: no mistletoe was found on the tree (0 %), 1 – Rare occurrence: the tree is partially infected, completely overriding branches of the host trees, mistletoe takes up one-tenth of the active assimilative crown volume (1–10 %), 2 – Scattered occurrence: the tree is infected uniformly or in clusters, which occupy about one-tenth to one-third of the active assimilative crown volume (11–40 %), 3 – Abundant occurrence: the tree is infected with a mild, mistletoe volume is higher or approximately equalled to the volume of the active assimilative part of the crown (41–70 %), 4 – Mass occurrence: The tree is infected strongly; mistletoe takes up a substantial part of the crown (71–100 %). Besides, the exact number of mistletoe bushes was counted on each infected taxa and was used later in the data analysis.

Data analysis

The data processing was carried out in Microsoft Office Excel 2010 and all statistical analyses were performed using the statistical program R version 3.0.1. (R Core Team, 2013), for editing R scripts we used Tinn-R code editor (Faria, 2011). For best result we used only the data of the largest host trees (*Acer campestre* L. and *Tilia cordata* Mill.) which were analysed separately. The following data was added for further analyses: age, development stage (DS), location of individuals (LOC), vitality (VIT) as a categorical explanatory variable; and tree height, crown volume as a continuous explanatory variable. The aim of this data analysis was to find which above-mentioned variables have the strongest effect to infection intensity.

At first, from the collected data were selected the samples by means of simple random sampling. These samples were of the same size in all levels of each individual factor; each factor had different sample size. Non-infected trees were excluded from the analysis. In this case the exact number of mistletoe bushes on the tree was used as continuous response variable. For this purpose one-way analysis of variance (ANOVA) type I (sequential) sum of squares was used. The Dunnett-Tukey-Kramer pairwise multiple comparison test was used from the package "DTK" (Lau, 2011) for multiple comparisons. The treatment contrast was used to estimate factor level means with 95% confidence intervals (CI).

In the second case all data was used (only some factor levels was omitted), the incidence of mistletoe (infected or non-infected) was used as a dichotomous response variable. For modelling of this relationship logistic regression (generalised linear model – GLM, binomial family) was used choosing the backward elimination method (Faraway, 2005) and starting with the richest model (all predictors was added). To compare the new model with null model Chi-square test was used at significance level 0.05, but this comparison was also performed with Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). If these tests gave different results, primarily the results of the AIC and BIC were accepted against the Chi-square test. To estimate the logistic regression coefficient, a maximum likelihood (ML) estimation process was implemented. From the regression coefficients odds ratio (OR) was calculated to predict the probability of mistletoe infection. The 95% confidence interval (CI) was used to estimate the precision of the OR. For this purpose the "rms" package (Frank and Harrell, 2013) and "epicalc" (Chongsuvivatwong, 2012) was used. After the analysis all accepted statistical models were checked pre-eminently with the help of diagnostics plots.

RESULTS

Although *Viscum album* subsp. *austriacum* (Wiesb.) Vollmann was found near Lednice and *V. album* subsp. *abietis* (Wiesb.) Abromeit was discovered in southern Moravia (Kubát, 1997), no mistletoe shrub was found on coniferous trees during our field experiments. There is only one subspecies (subsp. *album*) living in the main section of the castle park. Out of the 6000 studied deciduous individuals, 1350 (22.5 %) are already infected with mistletoe. Tab. I and Tab. II show that the main host woody species (with the largest absolute number of infected individuals) are *Acer campestre* L., *Tilia cordata* Mill., *T. platyphyllos* Scop., *A. platanoides* L., *Juglans nigra* L. and *Crataegus monogyna* Jacq.

The intensity of infestation in individual taxa is very different (see Tab. I). The low level (the 1st mistletoe infection category) substantially prevails in *Acer campestre* L., *T. platyphyllos* Scop., *A. platanoides* L.,*Crataegus pedicellata* Sarg., Malus sp. div., *Robinia pseudoacacia* L. and *Carpinus betulus* L. From the host

I: *Evaluation of infection intensity of the most common host taxa*

Taxon	Number of all individuals	Infected individuals (number and %)	Mistletoe infection category (number of individuals and %)			
			1.	2.	3.	4.
Acer campestre	1043	422	299	96	26	1
		40	71	23	6	0
Tilia cordata	446	253	69	91	65	28
		57	27	36	26	11
Tilia platyphyllos	378	128	88	23	12	5
		34	69	18	9	4
Acer platanoides	116	69	44	15	10	0
		59	64	22	14	0
Juglans nigra	92	53	13	17	20	3
		58	25	32	38	6
Crataegus monogyna	83	51	28	17	5	1
		61	55	33	10	2
Acer pseudoplatanus	118	46	26	9	8	3
		39	57	20	17	7
Crataegus pedicellata	78	32	27	4	1	0
		41	84	13	3	0
Malus sp. div.	64	32	24	7	0	1
		50	75	22	0	3
Robinia pseudoacacia	74	29	19	9	1	0
		39	66	31	3	0
Carpinus betulus	306	28	22	5	1	0
		9	79	18	4	0
Celtis occidentalis	36	20	11	6	3	0
		56	55	30	15	0
Prunus padus	81	16	14	2	0	0
		20	14	13	0	0
Acer saccharum	16	9	1	5	3	0
		56	11	56	33	0
Total	**2931**	**1188**	**685**	**306**	**155**	**42**
		41	**58**	**26**	**13**	**4**

II: *Number of evaluated and infected individuals of the most commonly occurring host taxa*

Taxon	Number of all individuals	%	Number of infected individuals	%
Acer campestre	1043	36	422	36
Tilia cordata	446	15	253	21
Tilia platyphyllos	378	13	128	11
Acer platanoides	116	4	69	6
Juglans nigra	92	3	53	4
Crataegus monogyna	83	3	51	4
Acer pseudoplatanus	118	4	46	4
Crataegus pedicellata	78	3	32	3
Malus sp. div.	64	2	32	3
Robinia pseudoacacia	74	3	29	2
Carpinus betulus	306	10	28	2
Celtis occidentalis	36	1	20	2
Prunus padus	81	3	16	1
Acer saccharum	16	1	9	1
Total	**2931**	**100**	**1188**	**100**

trees, not listed in Tab. I, have low level of infection *Aesculus hippocastanum* L., *Alnus glutinosa* (L.) Gaertn. and *Fraxinus excelsior* L. The increased intensity of infection (the 2nd and higher mistletoe infection category) prevails especially in *Tilia cordata* Mill., *Juglans nigra* L. and *Acer saccharum* Marshall. From the less frequent host taxa that are not mentioned in Tab. I are heavily infected all the individuals of *Quercus palustris* Münchh.

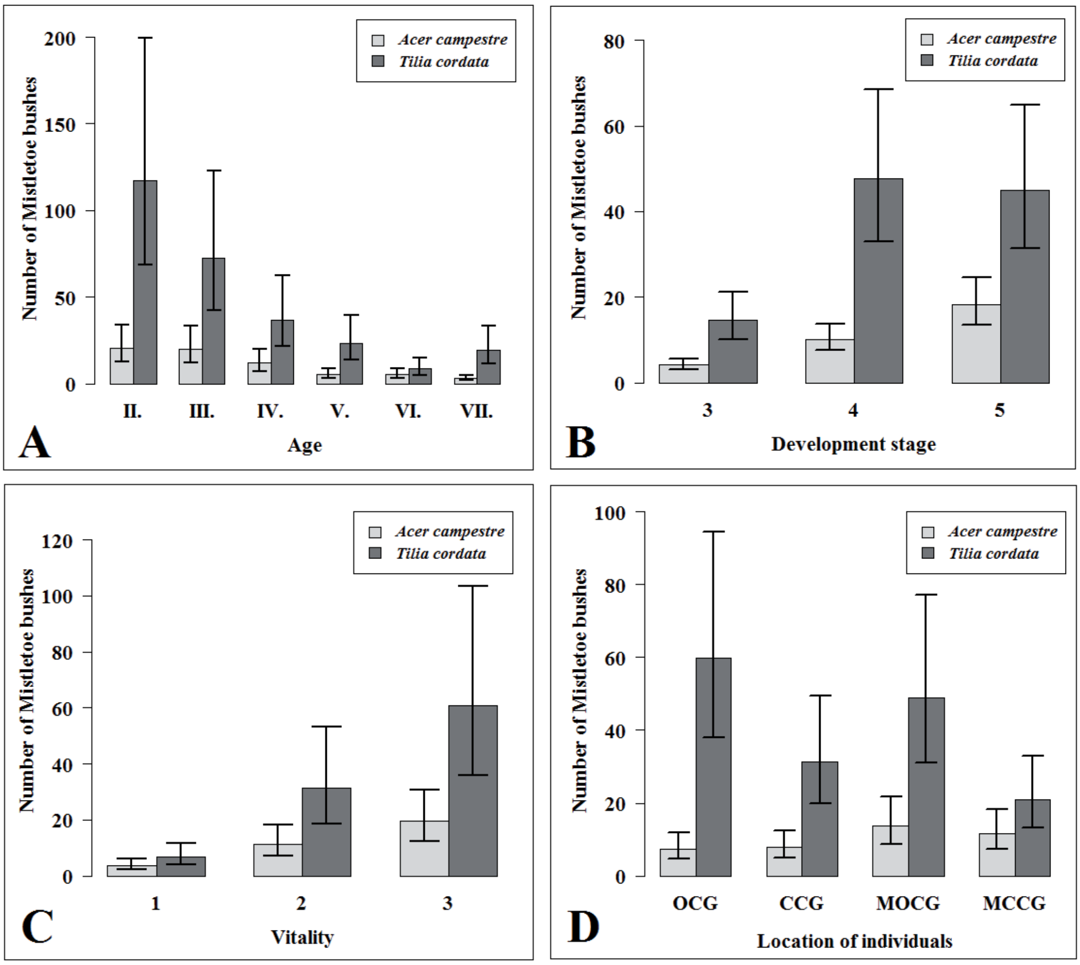
Tab. II represents the number of evaluated individuals and out of them infected individuals of the most commonly occurring host taxa, expressed in both absolute and percentage values.

RESULT OF DATA ANALYSIS

Because the data was not normally distributed and variance was not constant, logarithmic transformation was applied to the data prior to analysis. The one-way ANOVA (Tab. III, Fig. 1) showed significant difference between the number of mistletoe bushes and tree age (*Acer campestre* L.: $F_{5,114} = 9.96$, $p < 0.001$; *Tilia cordata* Mill.: $F_{5,54} = 12.52$, $p < 0.001$), between the mistletoe bushes and development stage (*A. campestre*: $F_{2,207} = 23.887$, $p < 0.001$; *T. cordata*: $F_{2,117} = 13.055$, $p < 0.001$), between the mistletoe bushes and tree vitality (*A. campestre*: $F_{2,87} = 13.049$, $p < 0.001$; *T. cordata*:

III: *Average number (CI 95 %) of mistletoe bushes with dependence of several factors*

Factor	Level	Acer campestre			Tilia cordata		
		Mean	CI (95 %)	Sample size	Mean	CI (95 %)	Sample size
Age	II.	20.56	12.39–34.13	20	117.10	68.70–199.50	10
	III.	20.17	12.15–33.49	20	72.23	42.39–123.10	10
	IV.	12.08	7.27–20.05	20	36.51	21.43–62.22	10
	V.	5.14	3.09–8.54	20	23.10	13.56–39.36	10
	VI.	5.09	3.07–8.46	20	8.64	5.07–14.72	10
	VII.	3	1.8–4.96	20	19.57	11.48–33.34	10
Development stage	3	4.13	3.05–5.58	70	14.63	10.16–21.08	40
	4	10.15	7.51–13.72	70	47.61	33.05–68.58	40
	5	18.17	13.45–24.56	70	45.05	31.28–65	40
Vitality	1	3.79	2.40–6	30	6.84	4.03–11.62	15
	2	11.44	7.23–18.11	30	31.32	18.44–53.20	15
	3	19.47	12.30–30.82	30	60.92	35.87–103.47	15
	4	–	–	30	55.71	32.80–94.63	15
Location	OCG	7.44	4.68–11.83	30	59.86	37.97–94.38	30
	CCG	7.86	4.94–12.49	30	31.36	19.89–49.45	30
	MOCG	13.65	8.59–21.71	30	48.89	31.01–77.08	30
	MCCG	11.55	7.27–18.36	30	20.96	13.29–33.04	30



1: *Average number (CI 95 %) of mistletoe bushes with dependence of different age of hosts (A), development stages (B), vitality (C) and location of individuals (D)*

$F_{3,56} = 14.63$; $p < 0.001$). We got different results for the location of individuals. There was no significant difference between the mistletoe bush and location of *A. campestre* individuals ($F_{3,116} = 1.59$, $p = 0.20$), while there was statistically significant difference in case of *T. cordata* ($F_{3,116} = 4.161$, $p=0.007$). The largest difference was found in age and development categories. In case of *A. campestre* the age category II. and VII. ($p < 0.001$), while in case of *T. cordata* the age category II. and VI. ($p < 0.001$) were significantly different. The development category 3 and 5 ($p < 0.001$) of *A. campestre* and the development stage 3 and 4 ($p < 0.001$) of *T. cordata* showed to be significantly different. The vitality category 1 and 3 ($p < 0.001$) were statistically different in both species. In case of location of individuals, the largest difference was found only in *T. cordata* between the margin of closed canopy group and closed canopy group ($p = 0.002$).

The results of logistic regression indicate that neither development stage nor tree volume has an effect to the mistletoe infection probability, therefore they were omitted from the logistic model. Tab. IV and Tab. V show the probability of mistletoe infection due to impact of explanatory variables. There are no large difference between the species. The mistletoe infection probability is five times higher in the tree age category III. (95–155 years), than in the category VII. (< 30 years) in both hosts. In case of vitality, the mistletoe infection probability is 4.5 times higher in tree vitality 3 than in tree vitality 1, also in both cases.

In case of *Acer campestre* L. the probability of mistletoe infection will be counted by the following logit model: $\ln \pi/(1-\pi) = -2.28 + 0.38 \times (\text{Age VI.}) + 1.06 \times (\text{Age V.}) + 1.33 \times (\text{Age IV.}) + 1.65 \times (\text{Age III.}) + 1.27 \times (\text{Age II.}) + 0.57 \times (\text{VIT 2.}) + 1.57 \times (\text{VIT 3.}) - 0.79 \times (\text{VIT 4.}) - 0.02 \times (\text{MCCG}) - 0.01 \times (\text{OCG}) + 0.33 \times (\text{S}) - 0.64 \times (\text{CCG}) + 0.05 \times \text{height}$. Example: The probability of mistletoe infection of 15 m tall, age category V., tree vitality 3, *A. campestre* in closed canopy group is 61 %.

In case of *Tilia cordata* Mill. the probability of mistletoe infection will be counted by the following logit model: $\ln \pi/(1-\pi) = -2.38 + 0{,}73 \times (\text{Age VI.}) + 1.01 \times (\text{Age V.}) + 1.08 \times (\text{Age IV.}) + 1.71 \times (\text{Age III.}) + 0.91 \times (\text{VIT 2.}) + 1.46 \times (\text{VIT 3.}) + 0.51 \times (\text{VIT 4.}) - 0.09 \times (\text{MCCG}) - 0.80 \times (\text{OCG}) + 0.26 \times (\text{S}) - 0.85 \times (\text{CCG}) + 0.09 \times \text{height}$. Example: The probability of

IV: *Logistic regression summary table to predict mistletoe infection with dependence of several factors: Acer campestre*

Variable	Total	Infected	Coefficient	Wald Z	P	OR (95 % CI)
	Individuals		(S.E.)			
Intercept	110	16	–2.23 (0.44)	–5.11	< 0.001[a]	0.10 (0.04–0.24)
Age VII.	110	16	–	–	–	1.00
Age VI.	291	68	0.38 (0.31)	1.22	0.222	1.47 (0.81–2.80)
Age V.	209	92	1.06 (0.33)	3.24	0.001	2.89 (1.55–5.63)[b]
Age IV.	178	105	1.33 (0.35)	3.81	< 0.001	3.79 (1.94–7.68)
Age III.	165	117	1.65 (0.38)	4.35	< 0.001	5.21 (2.51–11.20)
Age II.	37	22	1.27 (0.50)	2.57	0.01	3.56 (1.37–9.60)
VIT 1	201	34	–	–	–	1.00
VIT 2	585	249	0.57 (0.23)	2.48	0.013	1.76 (1.13–2.78)
VIT 3	188	134	1.57 (0.27)	5.76	< 0.001	4.81 (2.84–8.28)
VIT 4	16	3	–0.79 (0.70)	–1.13	0.258	0.45 (0.10–1.61)
MOCG	73	42	–	–	–	1.00
MCCG	396	206	–0.02 (0.28)	–0.06	0.950	0.98 (0.56–1.71)
OCG	67	35	–0.10 (0.38)	–0.25	0.801	0.91 (0.43–1.93)
CCG	442	130	–0.64 (0.29)	–2.20	0.028	0.53 (0.30–0.93)
S	12	7	0.33 (0.72)	0.46	0.645	1.40 (0.34–5.76)
Height	990	420	0.05 (0.02)	2.30	0.021	1.05 (1.01–1.10)[c]

Log-likelihood = –554.9986
AIC value = 1137.9972
[a] Significance cases in the model (shaded lines).
[b] Interpretation: Likelihood of mistletoe infection increases 2.89 (95% CI: 1.55–5.63) times in age category V. (if other variables remain unchanged), statistically significant ($p < 0.001$).
[c] Interpretation: If the tree height will increase of 1 m, the mistletoe infection probability increases 1.05 (95 % CI: 1.01–1.10) times (if other variables remain unchanged). Statistically significant only at 5 % significance level ($p = 0.021$).

V: *Logistic regression summary table to predict mistletoe infection with dependence of several factors: Tilia cordata*

Variable	Total	Infected	Coefficient	Wald Z	P	OR (95 % CI)
	Individuals		(S.E.)			
Intercept	55	10	–2.38 (0.57)	–4.20	<0.001[a]	0.10 (0.03–0.28)
Age VII.	55	10	–	–	–	1.00
Age VI.	90	29	0.73 (0.45)	1.62	0.105	2.07 (0.86–5.01)
Age V.	95	53	1.01 (0.46)	2.18	0.029	2.74 (1.11–6.77)[b]
Age IV.	95	69	1.08 (0.52)	2.09	0.036	2.96 (1.07–8.17)
Age III.	90	79	1.71 (0.59)	2.89	0.004	5.53 (1.74–17.65)
VIT 1	130	31	–	–	–	1.00
VIT 2	187	121	0.91 (0.32)	2.87	0.004	2.48 (1.33–4.6)
VIT 3	88	74	1.46 (0.44)	3.32	<0.001	4.32 (1.82–10.25)
VIT 4	20	14	0.51 (0.64)	0.80	0.426	1.66 (0.48–5.78)
MOCG	42	28	–	–	–	1.00
MCCG	160	101	–0.09 (0.44)	–0.20	0.838	0.91 (0.38–2.17)
OCG	28	23	0.80 (0.74)	1.08	0.281	2.22 (0.52–9.51)
CCG	177	77	–0.85 (0.45)	–1.88	0.06	0.43 (0.18–1.03)
S	18	11	0.26 (0.80)	0.32	0.749	1.29 (0.27–6.25)
Height	425	240	0.09 (0.03)	3.07	0.002	0.43 (0.18–1.03)

Log-likelihood = –215.6719
AIC value = 457.3437
[a] Significance cases in the model (shaded lines).
[b] Interpretation: Likelihood of mistletoe infection increases 4.32 (95 % CI: 1.82–10.25) times in vitality category 3 (if other variables remain unchanged), statistically significant ($p < 0.001$).
[c] Interpretation: If the tree height will increase of 1 m, the mistletoe infection probability increases 0.43 (95 % CI: 0.18–1.03) times (if other variables remain unchanged). Statistically significant ($p = 0.002$).

mistletoe infection of 15 m tall, age category V., tree vitality 3, *T. cordata* in closed canopy group is 41%.

DISCUSSION AND CONCLUSION

The main hosts of mistletoe, that we found in the castle park in Lednice, also rank among the main host taxa in the Czech Republic, stated by Procházka (2004), Unar *et al.* (1985) and Houfek (1973).

Based on our results there is large difference between the mistletoe number and the host trees. In case of *Tilia cordata* Mill. the mistletoe number was averagely 5 times higher than in case of *Acer campestre* L. Similar results published Kartoolinejad *et al.* (2007) and Baltazár (2011).

The discovered significant difference among the number of bushes on host individuals of both examined taxa, depending on their age, development stage and vitality, can be explained by the gradually increasing size of host individuals as well as by reducing their vitality with increasing age. Massive trees are probably also attractive to birds' rest and overnighting. The results thus confirm the opinions of some authors (Kartoolinejad *et al.*, 2007; Grundmann *et al.*, 2011). Our single research does not answer the question, what role plays the vitality of host tree in its initial infestation with mistletoe. The statement that the location of host trees of *Parrotia persica* (DC.) C.A. Mey. has a significant effect on the number of mistletoe bush individuals (Kartoolinejad *et al.*, 2007), we confirmed only in case of *Tilia cordata* Mill. The highest number of mistletoe individuals was on trees in open canopy groups and in their edges.

The determined probability of mistletoe infection increases with a decrease in vitality from the 1st to the 3rd degree, however clearly decreases in the 4th degree. This illogicality is likely due to the used scale of vitality, in which the 4th degree involves dying trees with strongly reduced lively part of the crown.

The role of the tree height to probability of infection was statistically significant in both cases. These results are consistent with findings (Baltazár, 2011), that among the height of infected and uninfected individuals of *Acer campestre* L., *Tilia cordata* Mill. and *T. platyphyllos* Scop. were statistically significant differences. The average height of uninfected trees was 10 to 12 m and of infected trees was approximately 16 to 20 m. Other results were obtained by Kartoolinejad *et al.* (2007), who found no relationship between the infection intensity and tree height.

SUMMARY

Approximately 1350 individuals from the 6000 surveyed deciduous trees in the castle park in Lednice are already infected with mistletoe. Among the most frequently infected taxa are currently: *Acer campestre* L., *Tilia cordata* Mill., *Tilia platyphyllos* Scop., *Acer platanoides* L., *Juglans nigra* L. and *Crataegus monogyna* Jacq. The intensity of infestation in individual taxa is very different. The low level substantially prevails mainly in *Acer campestre* L., *T. platyphyllos* Scop., *A. platanoides* L., *Crataegus pedicellata* Sarg., Malus sp. div., *Robinia pseudoacacia* L. and *Carpinus betulus* L. The increased intensity of infection prevails especially in *Tilia cordata* Mill., *Juglans nigra* L. and *Acer saccharum* Marshall.

The one-way ANOVA for *Acer campestre* L. and *Tilia cordata* Mill. showed significant difference between the number of mistletoe bushes and tree age, development stage and tree vitality. We got different results for the location of individuals. Significant influence of the location of host individuals on the number of mistletoe bushes was confirmed only in *Tilia cordata* Mill. The highest number of mistletoe individuals was on trees in open canopy groups and in their edges. There are large differences between hosts. In case of *Tilia cordata* Mill., the number of mistletoe bushes was approximately 5 times higher than in case of *Acer campestre* L.

The results of logistic regression show that the tree age has the largest impact to the infection; the probability of this with the oldest trees is five times higher than with younger trees. Tree vitality has also great impact; in case of trees with worse vitality, the probability of infection is 4.5 times higher than with trees which have high vitality. There was also no difference between *Acer campestre* L. and *Tilia cordata* Mill.

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