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The Relationship among Infection Intensity of *Viscum album* with some Ecological Parameters of Host Trees

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ABSTRACT: We investigated the relations among infection intensity of European mistletoe (*Viscum album* L.) with host tree features in Nour Forest Park, located in Caspian Forests in North of Iran. The number of 30 circular plots with an area of 0.1 ha were sampled in all places have an aggregation of infested trees. Parameters including DBH, height, distance to stand edge, distance to conspecific tree, bark diameter and the number of adult mistletoe per tree for all infected individuals were recorded. Results showed that the mistletoe abundance and infection intensity in *Parrotia persica* was more than the other host species and also, have positive significant relation with DBH, distance to conspecific and locating in the stand edge, but no significant relation observed about height of host trees. Results of this study suggest that individual differences among host trees (specially DBH) play an important role in explaining local abundance and distribution of mistletoe plants.

Key words: Infection intensity, European mistletoe, Host trees, Caspian forests, Conspecific tree

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INTRODUCTION

Mistletoes are a polyphyletic and diverse group of flowering plants comprising over 1306 species from a broad range of habitats across all continents except Antarctica. The group contains members of five families within the Santalales order that are mostly parasitic plants (Watson, 2001; Zuber, 2004). *Viscum album* L. (European or White Berry mistletoe) from family Viscaceae is an evergreen, perennial, epiphytic, hemiparasitic shrub that lives on a wide range of woody plant species. The berries of female plant are small, sticky and whitish and are very attractive to birds. In Europe the main vectors are the mistle trush (*Turdus viscivorous*), a defecating vector, and blackcap (*Sylvia atricapilla*), a beak-wiping vector (Briggs, 2003; Watson, 2001; Zuber, 2004; Zuber and Widmer, 2000). Evergreen clumps of mistletoe are readily observed on deciduous trees in winter when leaves are off the trees (Fig. 1). Viscaceae family are predominantly arboreal xylem parasites dependent on their host for water and nutrients but producing their own sugars (López de Buen and Ornelas, 2002). European mistletoe have no real root, parasitize the stems of dicotyledonous trees and shrubs by means of parenchyma organs named haustoria, developing from the radicle of the seed (López de Buen, *et al.*, 2002; Tsopelas, *et al*., 2004; Watson, 2001; Zuber, 2004).

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; López de Buen and Ornelas, 2002; Watson, 2001; Zuber, 2004). In addition to, birds deposit more mistletoe seeds onto branches of some host individuals than other species. Preference of mistletoe-fruit eating birds for perching and consuming mistletoe fruits on some host tree species directly affects mistletoe seed dispersal (López de Buen and Ornelas, 2002). Whereas distribution process of *V. album* as other mistletoes, is a consequence of bird foraging behavior, this study was conducted to distinguish whether *V. album* infection intensity have any relations with host characteristic features as DBH,

height, distance to conspecific, locating in the stand edge, bark diameter and host species or not?

MATERIALS & METHODS

Caspian forests with an area of about 1/9 million ha located in north of Iran in southern coast of Caspian Sea. It is exclusive site of some alive fossil species such as *Populus caspica*, *Gleditsia caspica*, *Parrotia persica* and *Pterocaria fraxinifolia* and is dominant with *Fagus orientalis*, *Quercus castanifolia*, *Alnus glotinosa*, etc. The Caspian zone forests which also called the Hyrcanian forests are the most valuable forests in Iran, cover the northern slopes and foothills of Alborz mountain. Location of Alborz mountains between the Caspian Sea and Iran plateau results in mild climate and distinct vegetation cover. Forests of these zone stretch out from sea level up to an altitude of 2800 m and encompass different forest type thanks to 80 woody species i.e. trees and shrubs (Sagheb-Talebi, *et al.*, 2005; Hosseini, 2003).

This project, carried out (November and December of 2004) in Nour Forest Park located between 5 Km east of Nour city and 25 Km west of Mahmoud-Abad in Mazandaran province (36° 34´ N, 51° 41´ E; at -10 m a.s.l.) The mean annual precipitation of the region is 1040 mm and mean annual temperature is 17 °C. The mean maximum and minimum monthly air temperature are 26 °C (in Jun.) and 7.5 °C (in Jan.) and the mean maximum and minimum monthly rainfall are 212 mm (in Dec.) and 19 mm (in Jun.) respectively. We selected thirty circular plots with an area of 0/1 in places have an aggregation of infested trees inattentive host species, through the study region. For each plot, we recorded and identified features as diameter at breast height (DBH) of >10 cm (because trees <10 cm DBH, were not infected to *V. album*), height, distance to nearest conspecific (Co specific tree is the nearest infected tree of the same species), distance to stand edge, number of mistletoe adult plants per tree, bark diameter and species name for all the trees. Finally all collected data were analyzed using SPSS 12.0 for windows software.

RESULTS & DISCUSSIONS

As mentioned above, all thirty 1000 m^2 plots were sampled in places have some infected trees in a manner that surround maximum infected species. Table 1, shows the number of each species sampled in plots. In this study, only three species of *Parrotia persica* (Ironwood tree), *Carpinus betulus* and *Populus caspica* were infected and occurred in sample plots. Because, other species, either have fewer infected individual or were very scattered through the study region.

Fig. 1. Clumps of mistletoe on *Parrotia persica* trees in Nour forest park (Photoe by Kartoolinejad, Winter 2004)

Thus, the most statistical analysis, applied only for *P. persica* host species.

Abundance of the infected species was compared with Chi-Square test. Results, revealed significant difference in 99% confidence level (Fig. 2) ($X^2 = 517.614$; d.f.= 2 ; $P = 0.000$).Number of mistletoe per tree (infection intensity), have bean examined among host species, by Mann-Whitney U test. Results showed, the infection intensity of *P. persica* in comparison with *Populus caspica* have significant difference in 99 % (U = 555.5; Z = -2.519; $P = 0.008$) and with *C. betulus*, in 95% confidence level (U =1781.5; Z = -2.519 ; $P = 0.012$). Figure 3 shows the number of infected Ironwood trees per each 5 cm diameter classes. As considered, there are maximum number of infected individuals into classes 30 and 35; but 80 and 85 have no individual member. Figure 4 also, shows the number of infected individuals of Ironwood trees per each 2 m height classes. The maximum number of infected individuals in this graph, belong respectively to four middle height classes of 21, 17, 15 and 19.

Relationship among individual characteristics (Diameter of Breast height, height and bark diameter at breast height) of *P. persica* and *C. betulus* with infection intensity (adult mistletoe shrubs per each tree), was tested by correlation analysis. Tables 2 and 3, show their results for these species respectively. The relation of DBH-height for infected and healthy trees of *P. persica* also, shown in Fig 5. In this graph, height of infected host as a same diameter is lower than the healthy trees.

Fig. 6 compares the correlation of DBH-*Viscum* number (per each tree), for host species of *P. persica* and *C. betulus*. In this graph, the number of *Viscum* per each individuals of *P. persica* (with specific diameter) is more than the amount of *C. betulus*. We recorded infected trees in which their nearest tree was another infected individual. This parameter examined by Chi-Square test. The result showed, infected *P. persica* which had another infected tree near itself, was more frequent than the others. ($X^2 = 81.582$; d.f.= 1; $P = 0.000$).

Table 1. The number of infected and healthy individual species in all plots

Species	Individuals	Infected individuals	% of occurrence in plots
Parrotia persica	403	306	66/5 %
Carpinus betulus	65	18	10/7 %
Populus caspica	14	8	2/3 %
Alnus glutinosa	43	0	7/1 %
Acer velutinum	35	0	5/8 %
Ulmus carpinifulia	20	0	3/3 %
other species	26	0	4/.3 %
Total	606	332	100

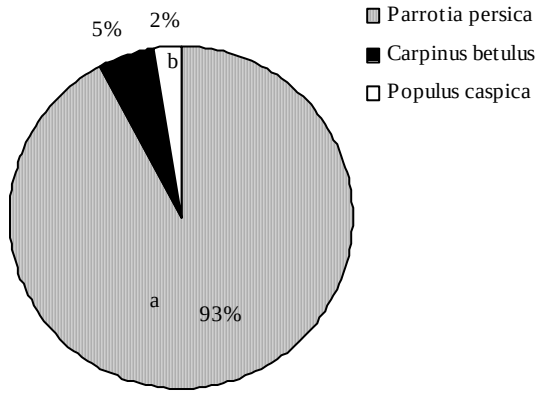

Fig. 2. Comparison of host abundance of *V. album* in study region with Chi-Square test

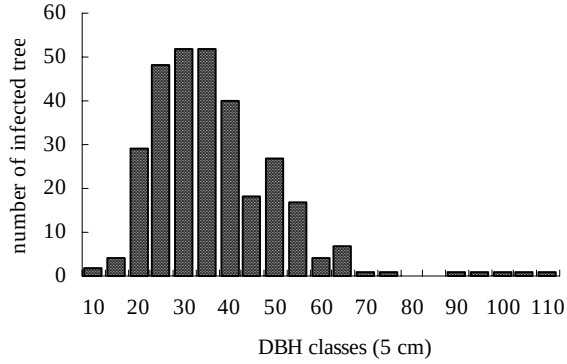

Fig. 3. Number of infected individuals of *P. persica* per 5 cm diameter classes

Table 2. The relationship among mistletoe infection intensity with bark diameter at breast height, DBH and height of *P. persica* (n=306)

	Measured parameters	*P*- value	r
Spearman correlation	Bark diameter	0.011	0.146 *
Pearson correlation	DBH	0.000	0.356 **
	Height	0.264	- 0.064 ns

The symbols ** and * state respectively the significant differences in 99% and 95% confidence level and also **ns** sign, shows no significant differences between groups.

Table 3. The relationship among mistletoe infection intensity with bark diameter at breast height, DBH and height of *C. betulus* (n=18)

	Measured parameters	*P*- value	r
Pearson correlation	Bark diameter	0.156	0.349 ns
	DBH	0.013	0.575 *
	Height	0.312	0.253 ns

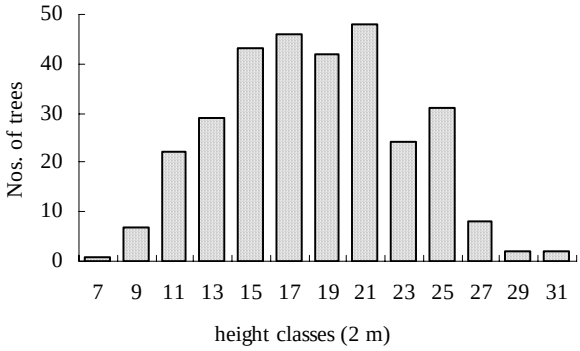

Fig. 4. Number of infected individuals of *P. persica* per 2 m height classes

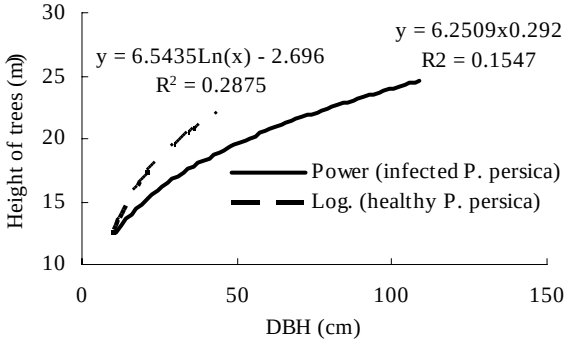

Fig. 5. Relation of DBH-height for infected and healthy trees of *P. persica*

Mistletoe infection intensity, examined for tree location (at two situations of edge and interior) in *P. persica* species by Mann-Whitney U test. Results showed that, the Ironwood trees located at the edge of forest or near roads and borders were more infected to *V. album* (U = 1780.5; Z = -2.534; *P* = 0.011).

Moreover, we analyzed the relationship between intensity of infection in trees located on forest (or road) edges or interiors, and the individual tree features (height, DBH, distance to conspecific and bark diameter at breast height) using ANCOVA. Because tree height, DBH, distance to conspecific and bark diameter factors might obscure the importance on the infection intensity of tree location in the fragment, it was necessary to control these factors in the analyses. Tree features were used as covariate to control for this variability. In this model, tree location was fix factor and the number of mistletoes per tree was the dependent variable.

European mistletoe is an evergreen epiphytic phanerophyte, respectively an epiphytic hemiparasitic shoot parasite. The maximum age of a shrub is about 27-30 years. The patchy distribution of this plant depends on available hosts, birds and humans (Zuber, 2004). It parasitizes several host tree species in northern forest of Iran such as *Carpinus betulus*, *Ulmus glabra* and *carpinifolia*, *Tilia begonifolia*, *Populus spp.*, *Acer velutinum*, *Prunus divaricata*, *Alnus glutinosa*, *Quercus castanifolia* and even *Fagus orientalis*, etc.

In this study, the number of infected Ironwood individuals per diameter and height classes, the maximum number of infected individuals are approximately related to middle classes of the tree species. This is as a result of preference of mistletoe-fruit eating birds for perching and eating mistletoe fruits on such host trees and consequently through *endozoochory* process, deposit more mistletoe seeds onto branches of the host individuals than the others (Brigs, 2003; López de Buen *et al*., 2002; López de Buen and Ornelas, 2002). The relation of DBH-height for infected and healthy *P. persica* showed, in a same diameter, infested trees has lower height than the healthy ones (with no mistletoe) (Fig. 5). This may be because of the decreasing in host growth as a consequence of mistletoe damages. Because, they take water and dissolved inorganic compounds

directly form the xylem of their host (Zuber, 2004; Tennakoon and Pate, 1996). Also, based on Fig. 6, the number of *Viscum* per each individuals of *P. persica* (with specific diameter) was more than the amount of *C. betulus*, indicating that *P. persica* comprises suitable and compatible host species for the mistletoe in the study region (LÓpez de Buen and Ornelas, 2002). From the different nutritional modes displayed by flowering plants, parasitism represents one of the most successful (Nickrent, 2001; LÓpez de Buen and Ornelas, 2002). Mistletoe parasitism constitutes a continuum of host specificity that range from specialized to generalized.

Specialist mistletoes are typically restricted to single host species (although they can infest other host), whereas generalist mistletoes use various host species with no apparent preference for any of them. Although, most parasitic mistletoe have bean described to behave as host generalist, they can show host specialization at a regional scale (Norton and Carpenter, 1998; López de Buen and Ornelas, 2002). Thus, *Viscum album* L. may be considered as host specialist in the study area.

Table 4. Results for *P. persica* tree features (a) DBH, (b) bark diameter and (c) distance to conspecific in relation to tree location at forest edge or interior. *

Source of variation	d.f.	S.S.	M.S.	*F* - value	*P* - value
(a) DBH					
Tree location	20995.722	2	10497.861	11.697	.000
DBH	8030.523	1	8030.523	8.948	.003
Tree location×DBH	41.421	1	41.421	.046	.830
Residual	271046.779	302	897.506		
Tree location	25656.510	2	12828.255	14.338	.000
DBH	38824.949	1	38824.949	43.395	.000
Residual	271088.199	303	894.681		
(b) Bark diameter					
Tree location	66942.497	2	33471.248	32.725	.000
Bark diameter	932.538	1	932.538	.912	.340
Tree location×Bark diameter	838.444	1	838.444	.820	.366
Residual	308882.924	302	1022.791		
Tree location	66964.887	2	33482.444	32.756	.000
Bark diameter	191.781	1	191.781	.188	.665
Residual	309721.367	303	1022.183		
(c) Distance to conspecific					
Tree location	5035.065	2	2517.533	2.473	.086
Distance to conspecific	334.676	1	334.676	.329	.567
Tree location×Distance to conspecific	71.204	1	71.204	.070	.792
Residual	307427.446	302	1017.972		
Tree location	9375.727	2	4687.864	4.619	.011
Distance to conspecific	2414.498	1	2414.498	2.379	.124
Residual	307498.650	303	1014.847		

*In the model, tree location was a fixed factor, tree DBH, bark diameter and distance to conspecific were covariates, and intensity of infection (number of mistletoe per tree) the dependent variable. Non-significant interaction were removed from the ANOVA models.

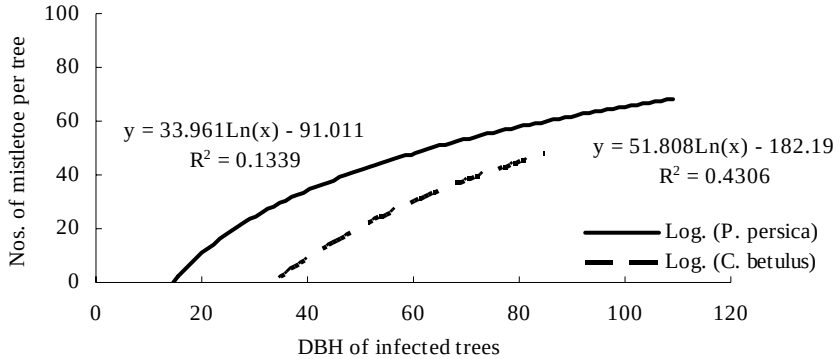

Fig. 6. Correlation of DBH- *Viscum* number per tree, for *P. persica* and *C. betulus* host species

Because, its special host i.e. *P. persica* have exhibited the most infection intensity and also, prevalence in Nour Forest Park (Fig. 2 and Table 1). However, this pattern may change over the geographical range of the interaction among seed dispersing bird, mistletoe and host tree, like incidence of *Carpinus betulus* as another special host of the mistletoe in higher altitude of Hyrcanian Forests.

Frugivorous birds show preference for perching and foraging in some infested host species during winter (Zuber, 2004). They go to infested trees to eat, and visit the nearest trees (infested or not), to rest. This behavioral pattern is expected to promote a higher probability of infection and re-infection of trees near infested trees, because the birds defecate or regurgitate the viable mistletoe seeds that adhere to the tree branches (López de Buen *et al*., 2002). In this case, results of Chi-Square test showed the significant difference among infested *P. persica* individuals ($X^2 = 81.582$; $P = 0.000$).

One of the important factor in the post-dispersal establishment of heliophyte mistletoes is light incidence, which are opportunistic plants in disturbance-dependent high light environments, such as human-modified tree communities and incremented edges of forest (López de Buen *et al*., 2002). Our relevant results, will be confirmed by this declarations. Since, locating in the edge of forest, open area or near roads had an impressive effect on both infection intensity and prevalence of *V. album* on host (*P. persica*) in the study area.

Explaining local abundance and distribution (prevalence and intensity of infection) of mistletoe plants, individual differences among host trees play an important role (López de Buen *et al*., 2002). The ANCOVA showed that the intensity of *V. album* infection in the study area, was affected by some individual tree characteristics as DBH (but not distance to Conspecific and height; table 4). In ANCOVA analyses, since interaction between distance to nonspecific and tree location, interaction between DBH and location and either interaction between bark diameter and location were not significant, they were removed from the model. After removing such effects, the ANOVA values for tree location were significant in all three cases (Table 4). The significant value of these tree features ($P < 0.05$) indicated that these variables served a purpose in the analyses by controlling for differences among trees. Then significant differences in intensity of mistletoe infection among the trees located at stand edge or interior, are due to differences in tree diameter at breast height and not distance to conspecific or bark diameter at breast height. Since height of infected trees have no significant effect on infection (by correlation coefficient), was not applied in ANCOVA test. Bark diameter at breast height, although have shown significant correlation with infection intensity about *P. persica* (Table 2), these variables were only weakly correlated ($r_s = 0.146$) and either is not a good parameter for intensity recognition of *Viscum*.

CONCLUSION

The interaction among mistletoes and their dispersal birds and hosts may play an important role for some of the host tree species. Mistletoe species can be serious pests in natural forests and plantations or they can be threatened species themselves in their limited natural areas of distribution. Host compatibility and habit quality are important regulators of mistletoe abundance and distribution as we see about *P. persica* in Nour Forest park. However, forest fragmentation and logging may increase light, nutrient and water available for remaining trees. These factors may change the dynamics and condition the outcomes of mutualistic interaction between mistletoe and their pollinators and seed dispersers, and as a consequence, the number and spread of mistletoe species living on these trees. In general, we can briefly state, the most infected trees in Nour Forest park were *P. persica* species located at the edge of stand, roads and open area places. On the other hand, human impact strongly affects the dynamics of *Viscum* populations.

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