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The effect of white mistletoe (*Viscum album* subsp. *abietis* (Wiesb.) Abromerit) on diameter increment in Kazdağı fir stands

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Abstract

In this study, the effects of white mistletoe (*Viscum album* subsp. *abietis* (Wiesb.) Abromerit) on diameter increment in Kazdağı fir (*Abies nordmanniana* subsp. *equi-trojani* (Asc. & Sint. ex Boiss.) Coode & Cullen) stands distributed in Kastamonu region of Turkey were investigated. For this purpose, a total of 183 sample trees (77 healthy (uninfected) and 106 infected) were selected from mistletoe-infected stands. Mistletoe infected sample trees were classified according to the mistletoe intensity groups as lightly-, moderately- and heavily-infection levels. Increment cores were taken from the sampled trees, and annual ring widths were measured for evaluation period which is the last 30 years of sample trees. Underbark diameter increments were determined for the last 10, 20 and 30 years and for also last three 10-year periods. Mistletoe infected trees were compared to healthy trees according to the mean diameter increments. As a result, it was determined that there were statistically significant differences between underbark diameter increments of infected and uninfected trees. Increment losses of infected trees compared to uninfected trees were calculated as 21%, 28% and 33% for the last 30, 20 and 10 years, respectively. Similarly, significant differences were also observed for the last three 10-year periods and it was revealed that the underbark diameter increment losses were 11%, 24% and 33%, respectively. The results show that increment losses increase gradually with infection and the presence of white mistletoe negatively affects diameter increments with an increasing acceleration from the past to the present.

Keywords: Parasitic plants, Growth, *Abies nordmanniana* subsp. *equi-trojani*, Kastamonu

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1. Introduction

Growing stock, which is the main component of forest management activities, arises as a result of the growth and increment of trees in the stands. Various biotic and abiotic factors, which negatively affect the growth and increment of trees, also negatively affect the amount of growing stock of the stands. In addition, corruption in the wood quality of trees as a result of these factors is an undesirable situation in forest management.

Mistletoe (*Viscum album* L.) is a semi-parasitic plant that takes its water and nutrients from the host plant and can perform photosynthesis on its own (Üstüner & Düzenli, 2017). There are three subspecies of mistletoe in Turkey; *Viscum album* subsp. *album* L. (European mistletoe), *Viscum album* subsp. *abietis* (Wiesb.) Abromeit (white mistletoe) and *Viscum album* subsp. *austriacum* (Wiesb.) Volmann (pine mistletoe) (Miller, 1982; Eroğlu et al., 2006). Tutin et al. (1993) stated that *Viscum album* subsp. *album* infects deciduous tree species, while *Viscum album* subsp. *abietis* infects fir species and *Viscum album* subsp. *austriacum* infects pine, spruce and larch species. Barney et al. (1998) listed 452 plant species that host mistletoe.

Mistletoe, which damages the stands in which it spreads, negatively affects the diameter and height increment of the trees, reduces the wood quality, decreases the resistance of the trees to negative factors such as insects, fungi and diseases, and sometimes causes the death of the trees (Hawksworth, 1983; Tsopelas et al., 2004; Dobbertin & Rigling, 2006; Mathiasen et al., 2008; Barbu, 2009; Rigling et al., 2010).

Although there have been various studies examining the effect of white mistletoe on the diameter increment of trees (Noetzli et al., 2003; Barbu, 2009; Durand-Gillmann et al., 2014; Raftoyannis et al., 2015), no study has been found in this context in Turkey. In the studies on this subject in Turkey, the effects of pine mistletoe on Scots pine (Eroğlu, 1993; Eroğlu et al., 1995; Eroğlu & Başkaya, 1995; Bilgili et al., 2017; Bilgili et al., 2018; Coşkuner et al., 2018) and Crimean pine (Kanat et al., 2010; Çatal & Carus, 2011) stands were examined. In this study, it is aimed to reveal the effect of white mistletoe on diameter increment in Kazdağı fir stands of the Kastamonu region, Turkey.

2. Material and Methods

2.1. Study area

The total area of Kastamonu, which has an important place throughout the country in terms of forestry activities, is more than 1.3 million hectares and approximately two-thirds (0.9 million hectares) are covered with forests (General Directorate of Forestry, 2021). Kastamonu forests correspond to approximately 6% of the total forests in Turkey. The forests in the study area consist of pure and mixed stands of Crimean pine (*Pinus nigra* subsp. *pallasiana*), Scots pine (*Pinus sylvestris*), Brutian pine (*Pinus brutia*), Kazdağı fir (*Abies nordmanniana* subsp. *equi-trojani*), beech (*Fagus orientalis*), oak (*Quercus* spp.) and hornbeam (*Carpinus betulus*) species. Kazdağı fir (*Abies nordmanniana* subsp. *equi-trojani*) is one of the main forest tree species of the Kastamonu region. Its distribution area in the region is 0.1 million hectares and its rate of total forests is 12% (General Directorate of Forestry, 2006). The study was carried out in white mistletoe infected Kazdağı fir stands in Kastamonu. The distribution of Kazdağı fir in Turkey and the study area are given in Figure 1.

2.2. Field measurements

Kazdağı fir stands which were exposed to white mistletoe in the Kastamonu region were determined by interviews with the Kastamonu Regional Directorate of Forestry staff and the local people, and by carrying out preliminary field studies, firstly. Then, the study data were obtained by measurements made on 183 sample trees (77 uninfected (healthy) and 106 infected) taken in the summer season of 2013 from the stands, which were determined to be infected with white mistletoe.

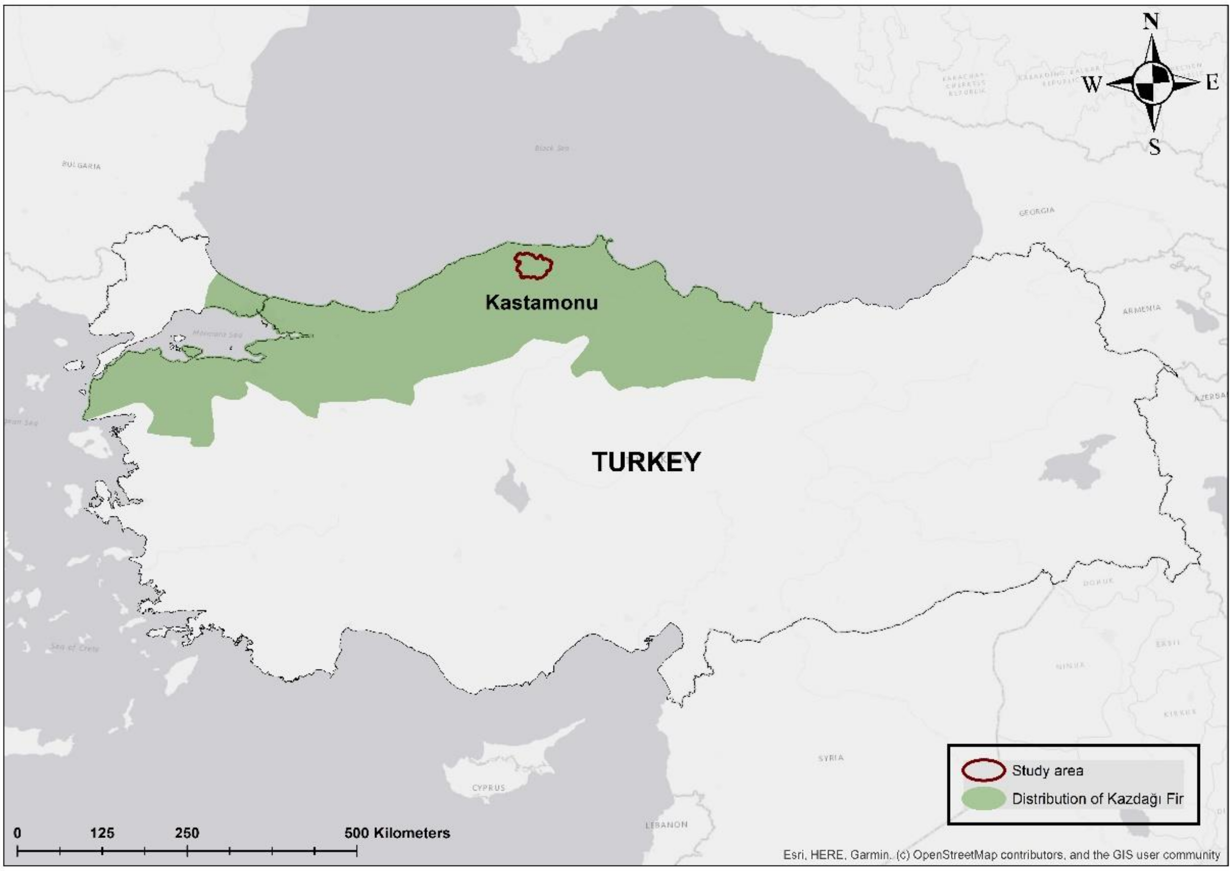

Figure 1. Natural distribution of Kazdağı fir and the study area

When examining the effect of any biotic or abiotic factor on growth and increment, it is necessary to standardize the effects of other climatic, edaphic and physiographic factors and stand characteristics. Shaw et al. (2008) stated that the effect of climatic and ecological factors on the growth and increment of the trees can be eliminated by selecting the infected and uninfected trees from the same stands and site conditions. Therefore, within the scope of the study, sample trees with two different structures, infected and uninfected (healthy), were selected in the same stands. During the selection of the sample trees, care was taken to ensure that the healthy trees were close to the infected trees and had similar diameters and to ensure that the selected sample trees did not grow under suppression.

Diameter at breast height and age measurements of the sample trees were made during the field studies. The diameters at breast height of the sample trees were measured with calipers to the nearest 0.1 cm. In order to determine the ages of the trees and to make increment calculations, increment cores were taken from the breast heights of the sample trees using increment borers.

Infected trees were classified according to their white mistletoe infection degrees using “The 6-Class Dwarf Mistletoe Rating System” proposed by Hawksworth (1977). According to this system, the living top of each sample tree was divided into three equal sections and each section was defined separately with a value of 0 (no visible infection), 1 (lightly infected, i.e. the rate of infected branches is 50% or less) or 2 (heavily infected, i.e. the rate of infected branches is more than 50%) according to the mistletoe infection density of the branches in the respective section. The mistletoe infection degree of each tree was obtained by summing the values given for the three sections. Finally, the sample trees were separated into four infection degree groups; *(i)* Healthy (uninfected), *(ii)* Low infection (trees with a total infection degree of 1 or 2), *(iii)* Moderate infection (trees with a total infection degree of 3 or 4), and *(iv)* High infection (trees with a total infection degree of 5 or 6). The distribution of sample trees by infection degrees was 77 healthy, 36 lowly infected, 58 moderately infected, and 12 highly infected. Figure 2 shows two sample trees that are healthy and heavily infected with white mistletoe.

2.3. Diameter increment calculations

To determine the diameter increments of the sample trees, the ring widths of the last 30 years were measured on the increment cores taken from the sample trees, starting from the annual ring of one year before the measurement year. During this stage, scaled digital photographs of the increment cores were taken, and the width of each annual ring for the last 30 years was measured by the trial version of Digimizer Image Analysis Software to the nearest 0.01 mm. In each sample tree, the underbark diameter increments (mm) for the respective year were determined by multiplying the measured annual ring widths with 2, and mean underbark diameter increments were calculated for the last 10 years (10-year period back from the measurement year), last 20 years (20-year period back from the measurement year) and last 30 years (30-year period back from the measurement year). In addition, to determine the consecutive periodic mean increments of the sample trees, the mean periodic underbark diameter increments for the last three 10-year periods were also calculated.

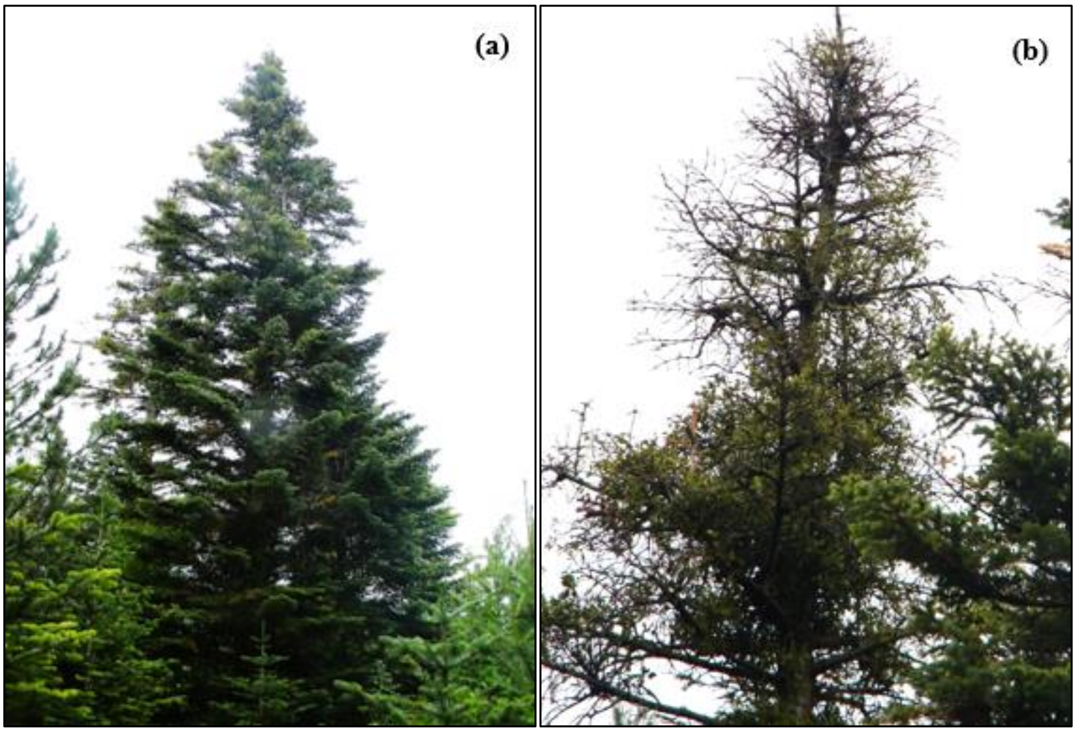

Figure 2. Healthy (a) and heavily infected (b) sample trees

2.4. Evaluation methods

Annual rings of trees for a given year are formed as a function of various factors such as biological, physical, stand characteristics, and climatic characteristics. In order to reveal the extraordinary effects that affect the increase such as mistletoe infection, the effects of these factors affecting the natural growth process should be eliminated and only the effects of extraordinary factors should be examined (Swetnam et al., 1985; Çatal & Carus, 2011). Dendrochronological analysis is one of the most preferred methods to reveal the effects of biotic and abiotic factors affecting annual ring development (Niklasson, 2002; Stephens et al., 2018). In this study, dendrochronological analyzes were performed using underbark diameter increment values of the sample trees. For dendrochronological analyzes, dendrochronological graphs for the last 30-year periods were prepared with underbark diameter increments of the last 30 years with the measurements made. These graphs were drawn separately for the healthy and infected sample trees, and for trees in mistletoe infection degrees. In the preparation of each graph, the averages of the underbark diameter increments determined for the relevant years of the sample trees were taken into account.

Independent samples *t*-test was used to ascertain differences between healthy and infected trees in terms of mean underbark diameter increment for the last 10, 20 and 30 years, and for the last three 10-year periods. To determine differences between infection degree groups for the same periods, Analysis of Variance (ANOVA) was performed. Within ANOVA, pairwise comparisons between groups were revealed using Duncan test. Separately for infection groups (healthy and infected) and infection degree groups (healthy, low, moderate and high), Repeated Measures ANOVA was used to determine differences among the periodic mean underbark diameter increments of the periods as the last 10, last 20 and last 30 years, and of the last three 10-year periods, and pairwise comparisons were conducted with Bonferroni test. Statistical analyzes within the scope of the study were performed at 95% confidence level, and IBM SPSS 23 package was used for these analyzes.

3. Results

Descriptive statistics regarding age (*t*) and diameter at breast height (*dbh*) measurements on sample trees are given in Table 1. Summary statistics on the mean periodic underbark diameter increments of the sample trees for the last 10, 20 and 30 years, and for the last three 10-year periods are given in Table 2.

The dendrochronological graphs created to observe the change in the mean underbark diameter increments of the sample trees for the last 30 years are given in Figure 3 according to the mistletoe infection status and in Figure 4 according to the mistletoe infection degrees. When Figure 3 is examined, it is seen that healthy trees and mistletoe infected trees show a similar trend, but the underbark diameter increments of infected trees are lower since the beginning of the examined period. In Figure 4, it is seen that the underbark diameter increments of all infection degree groups have decreased over the years, and the healthy group has higher underbark diameter increments from the first years compared to the other groups.

Table 1. Descriptive statistics for the sample trees

Infection status	Infection degree		Mean	Std. Dev.	Min	Max
Healthy (n=77)		*t* (years)	65.7	15.6	34	100
		dbh (cm)	31.5	5.2	19.0	46.3
Infected (n=106)		*t* (years)	74.2	17.7	36	133
		dbh (cm)	37.2	6.3	25.0	60.1
	Low (n=36)	*t* (years)	72.0	18.3	36	124
		dbh (cm)	35.8	5.4	25.0	47.5
	Moderate (n=58)	*t* (years)	76.2	18.5	37	133
		dbh (cm)	37.8	7.1	26.0	60.1
	High (n=12)	*t* (years)	71.5	11.0	52	90
		dbh (cm)	38.9	3.8	32.5	44.0

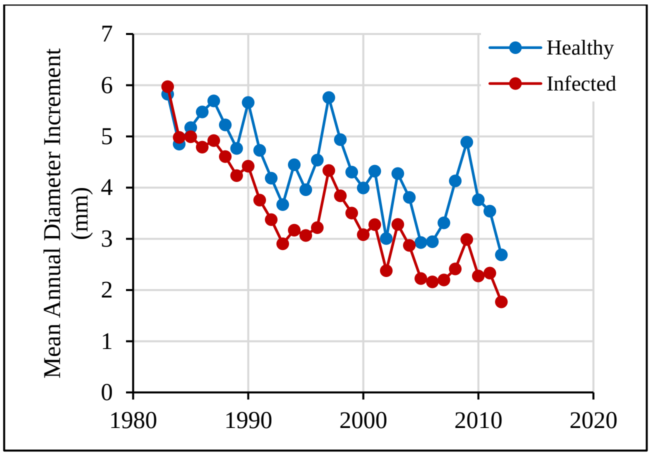

Figure 3. Underbark diameter increment dendrochronology for healthy and infected groups

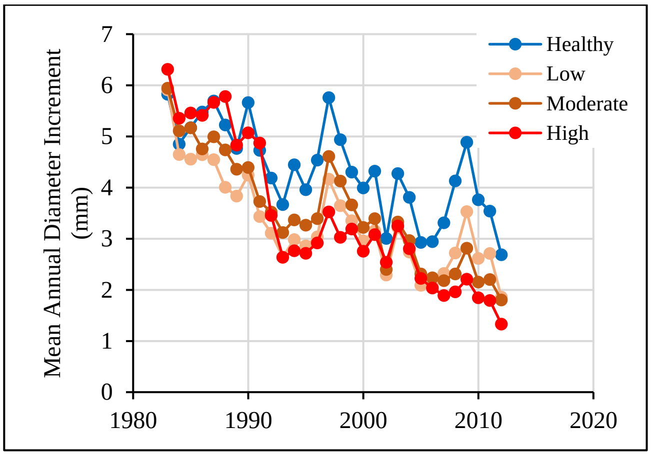

Figure 4. Underbark diameter increment dendrochronology for infection degree groups

Table 2. Descriptive statistics for the mean periodic underbark diameter increment

Infection status	Infection degree	Period	Mean	Std. Dev.	Min	Max	Period (10-year)	Mean	Std. Dev.	Min	Max
Healthy (n=77)		2003-2012	3.63	1.51	0.97	7.87	2003-2012	3.63	1.51	0.97	7.87
		1993-2012	3.96	1.48	0.96	7.98	1993-2002	4.29	1.55	0.95	8.09
		1983-2012	4.36	1.43	1.23	8.14	1983-1992	5.16	1.57	1.32	8.48
Infected (n=106)		2003-2012	2.45	1.24	0.43	5.89	2003-2012	2.45	1.24	0.43	5.89
		1993-2012	2.86	1.30	0.67	6.51	1993-2002	3.28	1.55	0.75	7.98
		1983-2012	3.45	1.39	0.80	7.37	1983-1992	4.61	1.87	1.05	10.25
	Low (n=36)	2003-2012	2.59	1.44	0.51	5.89	2003-2012	2.59	1.44	0.51	5.89
		1993-2012	2.85	1.29	0.80	6.05	1993-2002	3.11	1.38	1.10	7.98
		1983-2012	3.33	1.28	1.15	7.37	1983-1992	4.29	1.57	1.84	10.01
	Moderate (n=58)	2003-2012	2.43	1.22	0.43	5.38	2003-2012	2.43	1.22	0.43	5.38
		1993-2012	2.94	1.40	0.67	6.51	1993-2002	3.46	1.73	0.75	7.63
		1983-2012	3.52	1.54	0.80	7.00	1983-1992	4.67	2.05	1.05	10.25
	High (n=12)	2003-2012	2.14	0.60	1.12	2.75	2003-2012	2.14	0.60	1.12	2.75
		1993-2012	2.53	0.66	1.44	3.81	1993-2002	2.92	1.00	1.56	5.11
		1983-2012	3.42	0.84	1.73	5.38	1983-1992	5.22	1.74	1.93	8.52

The results of the Independent samples *t*-test conducted to determine the mean underbark diameter increment differences between healthy and infected trees for the last 10, 20 and 30 years and for the last three 10-year periods are given in Table 3. According to the test results, significant differences were found between the healthy and infected trees in terms of mean underbark diameter increments for the last 10, the last 20 and the last 30 years ($p<0.05$). When the mean increments determined for the three different periods for the infected trees were compared with the means of the healthy trees for the same periods, the diameter increment losses of the infected trees were calculated as 21% for the last 30 years, 28% for the last 20 years and 33% for the last 10 years. Similarly, significant differences were also found for 10-year periods ($p<0.05$). The underbark diameter increments loss values were 11% for the last 3rd 10-year, 24% for the last 2nd 10-year, and 33% for the last 1st 10-year periods. The results show that the presence of mistletoe negatively affects the increments with an increasing acceleration from the past years to the present. Therefore, it can be said that the increment losses gradually increase with the increase in the effect of infection.

Table 4 shows the results of ANOVA conducted to determine whether there are significant differences between infection degree groups in terms of mean underbark diameter increments for the last 10, 20 and 30 years and for the last three 10-year periods. Significant differences were found between the healthy group and the infection degree groups for the last 10, 20 and 30 years ($p<0.05$). It was determined that mean underbark diameter increments decreased in all infection degree groups, including the healthy group, from the last 30 years to the last 10 years. When the mean increments of infection degree groups for three different periods were compared to the means of the healthy group, diameter increment losses of low infected group were 24% for the last 30 years, 28% for the last 20 years and 29% for the last 10 years. Increment losses were 19%, 26% and 33% for moderately infected group for the last 30, 20 and 10 years, respectively, while 22%, 36% and 41% for high infected group. When the 10-year mean periodic diameter increments were examined, it was determined that there were significant differences between the healthy group and the infection degree groups during the 3rd and 2nd 10-year periods ($p<0.05$).

Table 3. Comparison of mean underbark diameter increments according to infection status

Period	Infection status	Id_{mean}[1] (mm)	*p*
Last 10 years (2003-2012)	Healthy (n=77)	3.63	<0.001**
	Infected (n=106)	2.45	
Last 20 years (1993-2012)	Healthy (n=77)	3.96	<0.001**
	Infected (n=106)	2.86	
Last 30 years (1983-2012)	Healthy (n=77)	4.36	<0.001**
	Infected (n=106)	3.45	
3rd 10-year (2003-2012)	Healthy (n=77)	3.63	<0.001**
	Infected (n=106)	2.45	
2nd 10-year (1993-2002)	Healthy (n=77)	4.29	<0.001**
	Infected (n=106)	3.28	
1st 10-year (1983-1992)	Healthy (n=77)	5.16	0.036*
	Infected (n=106)	4.61	

[1]*Id_{mean}: Mean underbark diameter increment.* **Significant at 0.05 level, and ** Significant at 0.001 level.*

To determine differences among the periodic mean underbark diameter increments of the periods as the last 10, last 20 and the last 30 years, and of the last three 10-

year periods, Repeated Measures ANOVA was performed separately for infection status and infection degree groups (Table 5). As a result, significant differences were found between the infection status groups and between infection degree groups for the last 10, 20 and 30 years and for the last three 10-year periods ($p<0.05$). According to the results, it was observed that the mean underbark diameter increments gradually decreased from the beginning to the end of the 30-year evaluation period in all of the groups.

Table 4. Comparison of mean underbark diameter increments according to infection degrees

Period	Infection degree	Id_{mean}[1] (mm)	F	p
Last 10 years (2003-2012)	Healthy (n=77)	3.63^a	11.373	<0.001*
	Low (n=36)	2.59^b		
	Moderate (n=58)	2.43^b		
	High (n=12)	2.14^b		
Last 20 years (1993-2012)	Healthy (n=77)	3.96^a	9.667	<0.001*
	Low (n=36)	2.85^b		
	Moderate (n=58)	2.94^b		
	High (n=12)	2.53^b		
Last 30 years (1983-2012)	Healthy (n=77)	4.36^a	6.408	<0.001*
	Low (n=36)	3.33^b		
	Moderate (n=58)	3.52^b		
	High (n=12)	3.42^b		
3rd 10-year (2003-2012)	Healthy (n=77)	3.63^a	11.373	<0.001*
	Low (n=36)	2.59^b		
	Moderate (n=58)	2.43^b		
	High (n=12)	2.14^b		
2nd 10-year (1993-2002)	Healthy (n=77)	4.29^a	6.979	<0.001*
	Low (n=36)	3.11^b		
	Moderate (n=58)	3.46^b		
	High (n=12)	2.92^b		
1st 10-year (1983-1992)	Healthy (n=77)	5.16	2.398	0.070^{ns}
	Low (n=36)	4.29		
	Moderate (n=58)	4.67		
	High (n=12)	5.22		

[1]*Id_{mean}: Mean underbark diameter increment. *Significant at 0.001 level, and ^{ns}Non-significant at 0.05 level. Superscripts indicate homogenous groups according to Duncan test.*

4. Discussion

According to the results of the study, the mistletoe infection affects the diameter growth and increment of Kazdağı fir trees negatively. When healthy and infected trees were compared in terms of mean underbark diameter increments for the last 10, 20, and 30 years, and the last three 10-year periods, it was revealed that infected trees had lower increments for all periods. When trees are evaluated depending on the infection degrees, it can be said that the diameter increment trends of the infected trees decrease faster than the healthy trees with the increase in mistletoe density, and the group whose increments are the most affected by this situation is the trees with high infection. Although there are no significant differences between infection groups (i.e., low, moderate and high), these groups have lower increments, especially in the last years of the investigation period, compared to healthy trees with the effect of white mistletoe. Another important result is that the increments of the trees in high infection group at the beginning of the investigation period showed a similar trend to the healthy trees, but in parallel with the effect of the mistletoe, increments were considerably lower than the healthy group in last years.

For silver fir (*Abies alba* Mill.) stands in Switzerland and Romania, it was determined that the mistletoe infection degree affected the diameter increment negatively, and the diameter increment decreased with the increase in the mistletoe density (Noetzli et al., 2003; Barbu, 2009). In our study, similar results were obtained for Kazdağı fir (*Abies nordmanniana* subsp. *equi-trojani*) stands in Kastamonu region of Turkey, and the diameter increment decreased in all mistletoe infection degrees with the effect of white mistletoe compared to healthy trees, and this decrease was higher as the mistletoe density increased. Durand-Gillmann et al. (2014) investigated the effects of mistletoe on basal area increment in silver fir stands of France. According to the results of the study, basal area increment is negatively affected by mistletoe. Even though the basal area increment was not examined in our study, given that the basal area increment is a function of diameter and diameter increment, the results obtained in their study are comparable to the results of our study.

Although there is no study investigating the effects of white mistletoe (*Viscum album* subsp. *abietis*) on growth and increment in fir stands in Turkey, there are some researches on the effects of pine mistletoe (*Viscum album* subsp. *austriacum*) on diameter increment in Scots pine (*Pinus sylvestris*) and Crimean pine (*Pinus nigra* subsp. *pallasiana*) stands. Eroğlu (1993) investigated the effect of mistletoe on the diameter increment of Scots pine stands in Trabzon province for 5- and 15-year periods. The results of the study revealed that mistletoe affected the diameter increments negatively and this effect caused 56% increment losses for the 5-year period and 39% for the 15-year period. Similarly, Bilgili et al. (2017) stated that mistletoe infection causes diameter increment losses up to 60% in the Scots pine stands of the Eastern Black Sea region of Turkey. Although these results are higher than the values obtained in our study, the increment losses obtained in our study are also quite high. In another study conducted in the Eastern Black Sea region, it was determined that mistletoe caused diameter increment losses are 17% for low, 38% for moderate, and 45% for high infection degrees in Scots pine stands for a period of 15 years (Coşkuner et al., 2018). In our study, diameter increment losses of Kazdağı fir stands for the last 20 years are 28, 26 and 36% for low, moderate and high infection

Table 5. Repeated measures ANOVA results for underbark diameter increments

Infection status	Infection degree	Period	Id_{mean}[1] (mm)	p	Period (10-year)	Id_{mean}[1] (mm)	p
Healthy (n=77)		Last 10 years (2003-2012)	3.63[c]	<0.001[*]	3[rd] 10-year (2003-2012)	3.63[c]	<0.001[*]
		Last 20 years (1993-2012)	3.96[b]		2[nd] 10-year (1993-2002)	4.29[b]	
		Last 30 years (1983-2012)	4.36[a]		1[st] 10-year (1983-1992)	5.16[a]	
Infected (n=106)		Last 10 years (2003-2012)	2.45[c]	<0.001[*]	3[rd] 10-year (2003-2012)	2.45[c]	<0.001[*]
		Last 20 years (1993-2012)	2.86[b]		2[nd] 10-year (1993-2002)	3.28[b]	
		Last 30 years (1983-2012)	3.45[a]		1[st] 10-year (1983-1992)	4.61[a]	
	Low (n=36)	Last 10 years (2003-2012)	2.59[c]	<0.001[*]	3[rd] 10-year (2003-2012)	2.59[c]	<0.001[*]
		Last 20 years (1993-2012)	2.85[b]		2[nd] 10-year (1993-2002)	3.11[b]	
		Last 30 years (1983-2012)	3.33[a]		1[st] 10-year (1983-1992)	4.29[a]	
	Moderate (n=58)	Last 10 years (2003-2012)	2.43[c]	<0.001[*]	3[rd] 10-year (2003-2012)	2.43[c]	<0.001[*]
		Last 20 years (1993-2012)	2.94[b]		2[nd] 10-year (1993-2002)	3.46[b]	
		Last 30 years (1983-2012)	3.52[a]		1[st] 10-year (1983-1992)	4.67[a]	
	High (n=12)	Last 10 years (2003-2012)	2.14[b]	<0.001[*]	3[rd] 10-year (2003-2012)	2.14[b]	<0.001[*]
		Last 20 years (1993-2012)	2.53[b]		2[nd] 10-year (1993-2002)	2.92[b]	
		Last 30 years (1983-2012)	3.42[a]		1[st] 10-year (1983-1992)	5.22[a]	

[1]*Id_{mean}: Mean underbark diameter increment, Superscripts indicate homogenous groups according to Bonferroni test.*
[*]*Significant at 0.001 level.*

degrees, respectively. Sönmez (2014) determined that mistletoe infection in Scots pine stands in Erzurum province caused 40% diameter increment loss in 10 years. In our study, the increment loss of infected trees for the last 10 years is 33%.

Kanat et al. (2010) investigated the effect of pine mistletoe on annual diameter increment in Crimean pine stands of Kahramanmaraş region, Turkey. The results of the study showed that mistletoe affected the annual diameter increment negatively and according to the data for 9 years (from 1992 to 2000), the annual diameter increment of infected trees was 41% lower than healthy trees. In our study, the mean increment loss of infected trees for the last 10 years is 33%, and has a lower value than Kanat et al. (2010). Çatal & Carus (2011) studied the effect of mistletoe density on diameter increment in Crimean pine stands of Isparta region, Turkey. In this study, the mistletoe infection levels were classified into 3 groups (low, moderate and high) as our study, and healthy sample trees were taken as the control group. It was observed that the diameter increment of infected trees showed a significant decrease compared to the control group for the period from 1998 to 2005. This decrease rate was found as 26%, 39% and 63% for low, moderate and high infection levels, respectively. When these results are compared with the diameter increment losses for the last 10 years in our study (29%, 33% and 41% for low, moderate and high infection levels, respectively), similar results were obtained for low and moderate degrees.

5. Conclusion

According to the results of the study, pine mistletoe (*Viscum album* subsp. *abietis*) had an important negative effect on underbark diameter increments of Kazdağı fir (*Abies nordmanniana* subsp. *equi-trojani*) trees and caused increment losses. It was also observed that the increment losses increased gradually with infection level, and the highest losses were observed in intensely infected trees.

In silvicultural treatments for mistletoe infected stands, it is necessary to remove the infected trees from the stands, especially starting from heavily infected trees. This application is appropriate to prevent the spread of mistletoe to other trees and to reduce the negative effects of mistletoe on growth and increment. However, silvicultural treatments should be applied carefully, since there is a risk of increased mistletoe infection due to the interruption of stand cover. Besides, the mistletoe on the trees can meet their light needs easily due to the open stand cover, and they can grow more easily and cause more damage to the host tree. The presence of mistletoe in the stands also reduces the resistance of trees against other primary factors such as drought, insects, and fungi, and may cause drying of the trees. For this reason, fighting applications should be done without delay. Considering the negative effects of mistletoe, stands with potential risk should be monitored regularly and continuously in terms of mistletoe infection.

Pruning the infected branches, especially for newly infected trees, is another effective traditional fighting method for mistletoe. When applying this method, care should be taken not to prune healthy branches and not to damage the terminal shoots. Therefore, only infected branches should be treated and this intervention should be applied in a way that does not affect the vitality of the host tree.

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Conflict of interest

The authors declare that there is no conflict of interest.

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