Türk. entomol. derg., 2011, 35 (3): 423-435
ISSN 1010-6960

Orijinal araştırma (Original article)

Impacts of *Neodiprion sertifer* (Geoff., 1785) (Hymenoptera: Diprionidae) on growth and increment loss in young *Pinus brutia* (Ten.) generations

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Summary

Pinus brutia (Ten.) is affected by various biotic and abiotic factors during its lifetime. Insect damage undoubtedly is the most important biotic factor for the tree. The European pine sawfly (EPS), *Neodiprion sertifer* (Geoff., 1785) (Hymenoptera: Diprionidae), eats the needles of P. brutia trees and damages their assimilation organs. In this study, as a result of leaf eating of EPS on the trees of young *P.brutia*; its effect on increment of diameter, height and volume and growth loss was studied from 2000 to 2004. For this purpose, three different pure young *P. brutia* generations in the districts of Aziziye, Burdur were chosen as the study area. EPS has caused an epidemic which continued for 5 years in the seedlings in that young generations. In the 5 aged young *P. brutia* generations, 45 non-infested and 45 infested groups were chosen and cut in three different areas. At the choosen seedlings stem analysis was made to compare the increment and growth of infested and non-infested groups. Discs for stem analysis were taken from 0.0 m and each 0.25 m of the seedlings which were cut. Annual rings in the discs were measured with the sensitivity of 0.01 and diameter, height and volume development were set for each sample seedling according to age. In the sample seedling which were in non-infested and infested groups, annual increments were compared with ANOVA Statistical Test. In the sample seedling which were in the non-infested and infested groups; diameter ($F_{1;88}$=39.415***), height ($F_{1;88}$=50.212***) and volume ($F_{1;88}$=58.378***) growths were statistically different. Substantial decreases were identified in the growth of diameter, height and volume in the seedling which were in the non-infested group. These decreases on average were 39%, 28% and 71% successively.

Keywords: European pine sawfly, *Pinus brutia*, increment and growth loss, defoliation

Anahtar sözcükler: Çam yaprak arısı, *Pinus brutia*, artım ve büyüme kaybı, yapraksızlaşma

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Alınış (Received): 01.07.2010 Kabul ediliş (Accepted): 02.11.2010

Introduction

Pinus brutia (Ten.) is climax tree of the Mediterranean region and one of the most important forest trees of Turkey. It usually grows in pure stands and is valuable for its timber products as well as for soil stabilization and wildlife habitats. This species accounts for 26% of Turkey's total forest area, where it covers 5.4 million hectares. Of this, 3 million hectares are productive while 2.4 million hectares are degraded (Anonymous, 2006). *P. brutia* has been used for many different products in the forest products industry, including timber, furniture, pulp and board products, fuel wood, window and door framing, flooring, structural material in home construction, package, etc. (Bektaş et.al., 2003).

The annual and mean volume increment of natural forest of *P. brutia* are 19.0 and 14.4 m^3ha^{-1}, respectively (Çatal, 2009). These annual increments can be promoted in an order by 27.8 and 15.4 m^3ha^{-1} in plantation areas at site class I. According to The Food and Agriculture Organization of the United Nations's definition for fast growing species, *P. brutia* can be considered as fast growing species (Usta, 1991). In Turkey, 0.26 million hectare areas are regenerated in *P. brutia* stands last decade (Anonymous, 2006). Thus, young *P. brutia* stands are cover wide areas.

P. brutia is negatively affected by various abiotic and biotic factors during its lifetime. Insect damage is undoubtedly the most important biotic factor (Çanakçıoğlu, 1989). The European pine sawfly (EPS), *Neodiprion sertifer* (Geoff., 1785) (Hymenoptera:Diprionidae), feeds on the *P. brutia* needles and damages assimilation organs. Defoliation of conifers by insects can have a substantial impact on tree growth (Piene, 1989; Miller & Wagner, 1989; Piene & Little, 1990; Carroll et al., 1993; Chung & Shin, 1994; Karsh, 1996; Piene & MacLean, 1999; Carus & Avcı, 2005; Carus, 2009).

The insect damage on various main tree species in Turkey for wood lost averaged 221909 m^3, 3% of the annual wood harvest. The estimated reduction in growth was valued at per year $6.9 million. EPS has a significant influence on stand dynamics by reducing tree growth (Anonymous, 2009).

In Turkey, EPS attacks pine forests of all ages. But EPS prefers relatively young stands, growing on barren sites. The host plants include all pine species in the range of the insect, *P. brutia* is the main hostal (Smith, 1993). EPS has recently become an important insect pest in Burdur, on the South of Turkey, where many young, precommercially thinned, high-investment *P. brutia* stands have been defoliated. When insects defoliate a tree, they remove not only a portion of the photosynthetic material but also the sites where chemicals such as growth hormones are produced, and this affects many vital functions.

EPS is a widespread and economically important forest insect. In this study first objective was to analyze the impact of EPS on the diameter, height and volume growth of the infested *P. brutia* that survived the most recent outbreak. Our second objective was to provide approximate estimates of this decrease and estimates of growth losses of the diameter, height and volume.

Material and Methods

Description of study site and EPS

This study was carried out approximately 9.3 km west of Aziziye, Burdur, Turkey (38°25′ north latitude, 29°11′ east longitude) in 2005 (Figure 1). The study was carried out in a 5 year-old, pure, natural regeneration, unthinned young *P. brutia* generations. This area, damage of EPS were detected from 2000 to 2004 along the spring seasons since natural regeneration.

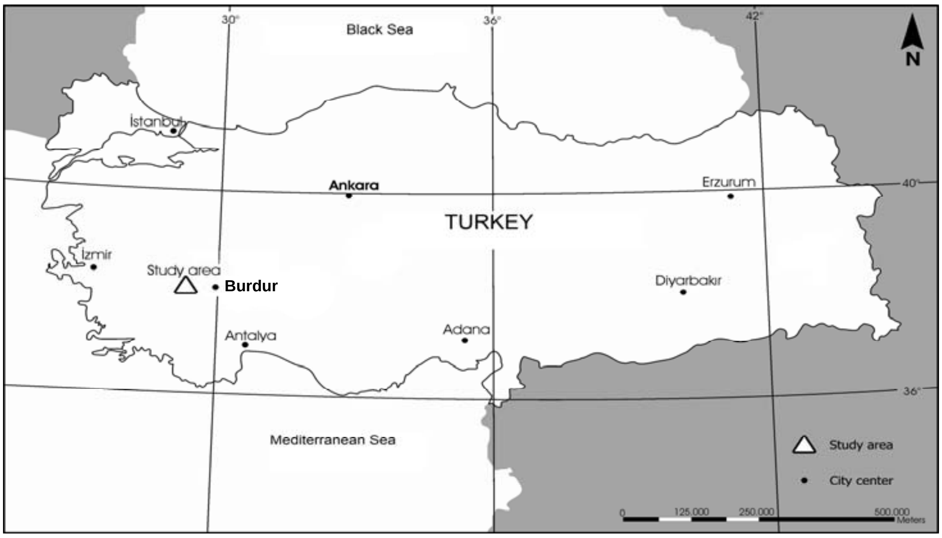

Figure 1. Location of study area in Burdur region.

This study has been done in 3-4 hectares homogeneous parts of young *P. brutia* generation in the 150 hectare of the district of Aziziye and Kemer in Burdur of Turkey. It was known that EPS caused epidemic in this district for 5 years with an increasing or decreasing intensity. Diameter, height and volume increments and growth amounts were analyzed by the way of stem analysis in 90 sample seedlings from infested and non-infested groups in a total of three study areas.

In 2005, the average density was 6500 seedligs per hectare, mean bottom diameter at seedling 2.1 cm and mean height 62 cm. The *P. brutia* stands was approximately total 150 hectare (each 50 hectares, three sample plots) in size, 1210 meter altitude. The stands consist of dominated by opengrown, 1.08 m height *P.brutia*, with small numbers of macchia. In the stands, site quality was poor.

The study areas is a slope of approximately 15% and main aspect of the study areas is south. The study areas is found on calcareous formations and is moderately well drained. The soil is generally shallow or medium-deep, and stony, with a predominantly sandy-clay texture.

Mean monthly and annual temperature and rainfall data for the period 1940-2004 were obtained from the Burdur Meteorological Station. In the study area, the mean annual precipitation is 735 mm and falls mainly from October through May, with great deviations in the distribution and amount of precipitation during the study period. The region is in a transitional zone between the Mediterranean climate and the continental climate with its colder winters and hotter summers. Mean annual temperature is 9.8ºC. In accordance with De Martonne's dryness coeficient, the study area is identifed as semi-humid.

EPS, family Diprionidae, belong to the most harmful insects to forestry in Europe. The larvae of most species feed on pine needles, and mostly young trees are damaged or killed, either directly or due to following secondary pests. The adult insects communicate chemically and the females release a sex pheromone that attracts males. After mating the females oviposit on the pine needles (Östrand et al., 1999).The principal infests of EPS are pines. It is an insect defoliator that normally feeds foliage of pines. EPS is a serious defoliator of young pines (Çanakçıoğlu, 1989). The old foliage is totally consumed on heavily infested trees giving the tree a bottle brush appearance.

The infested plants include all pine species in the range of the insect, but in Burdur, *P. brutia* is the main host. Although EPS attacks pine forests of all ages in general, it prefers relatively young stands, growing on barren sites in the study area. However, no exact cyclicity has been proven. Local outbreaks may occur almost every year, and high population densities can continue for several years in the same stand (Larsson & Tenow, 1984).

A build-up phase may be released by a combination of dry summers, poor soils, physiological state of the host plant, nutritive value of the needles and the absence of predators and parasites (Hanski, 1987; Larsson et al., 1993). This buildup phase often occurs in a seemingly unpredictable manner. The subsequent epidemics may cover tens of thousands of hectares, causing considerable economic losses to forestry; reducing tree growth (Austara et al., 1987), predisposing trees to secondary pests, and under extreme circumstances, even killing the host trees. EPS occurs in Europe, Asia, and eastern North America, and is one of the major defoliators at the pine forests (Larsson & Tenow, 1984). EPS populations fuctuate abruptly between epidemic and endemic levels, having local outbreaks every 5±6 years and extensive regional epidemics every 20±30 years in Finland (Juutinen & Varama, 1986).

Methods

Previous studies have demonstrated positive relationships between tree growth and foliar amount (Long et al., 1981; Waring, 1983; Kollenberg & O'Hara, 1999), but less information exists to document such relationships following defoliation (Piene & MacLean, 1999). As a result of needles eating of EPS on the seedling of *P.brutia*; its effect on diameter, height and volume and growth loss sould revealed.

Stem analysis refers to a technique of examining the growth rings of sections from a tree stem. It enables the past growth history of a tree stem to be reconstructed (Avery & Burkhart, 1994). Thus, dendroecological methods (Swetnam, et.al., 1988) enable one to account for abiotic and biotic conditions that affect annual radial growth in trees, such as climate and tree age, and then isolate the contribution of a single factor, such as insect defoliation, to radial growth. Annual ring width is substantially reduced, to the point that radial increment data can be used to identify and index the severity of past outbreaks (Carlson & Mc Caughey, 1982; Swetnam & Lynch, 1989; Ryerson, et al., 2003; Carus, 2009). Several recent studies have used dendroecological analysis to investigate the effects of defoliating insects on radial growth (Piene, 1989; Piene & Little, 1990; Krause, 1997; Muzika & Leibhold, 1999; Zhang et al., 1999; Colbert & Fekedulegn, 2001; Speer et al., 2001; Naidoo & Lechowicz, 2001; Carolyn & Marc, 2003).

In this study, observations and measurements were carried out in the infested and non-infested seedlings. In these young generations, *P. brutia* seedlings were chosen as infested and non-infested groups, in terms of features such as slope, aspect, altitude in similar place and taken from the places which have the same density and crown closure. It was seen that EPS ate the needles in the young generations where sample areas were taken between 2000-2004 every year in spring months (late april-early may) and that there were colour changes in neddles. In the young generations which were in the district, it was seen that EPS damaged 25-30% of the seedlings.

In order to learn the amount of EPS*'s* damage occured in the spring of 2005, in the young generation three similar areas were chosen. Study plots display many similarities in terms of site conditions (climate, soil, altitude, relief and exposure) site quality and stand features. Fourtyfive sample seedlings were measured in the infested areas and 45 sample seedlings were measured in the noninfested areas. In each of these sample areas, 15 seedlings were chosen representing in the non-infested and infested groups. Thus, a total of 90 sample seedlings were chosen from the non-infested and infested groups in sample areas. The size of the sample which was chosen for our study was found sufficient (Kalıpsız, 1981).

The increment amounts of the seedlins chosen from the infested and non-infested groups in the past were found by the way of stem analysis. In this way, sample the seedlings were cut having been successively numbered on ground level. The seedlings which were cut were separated in the lenghts of 25 cm sections (0, 25, 50, 75, ….. cm). From the beginning and end of each section, discs cuttings in the thickness of 3 cm were taken. Stem sections that were taken from each seedling were put into special bags. They were given sequence numbers increasingly from bottom to up. The same processes was repeated for all sample seedlings.

The annual ring widths in the discs were measured individually in four directions with the sensitivity of 0.01 mm with the help of a stereomicroscope as spring and summer wood annual rings. Used to annual rings, the annual stem volume amounts were found out. Smalian's formula (V) used to find the volume (Avery & Burkhart, 1994).

$$V= \frac{(B + b)}{2} L$$

V=Volume of stem (dm^3)

B=Cross-sectional area at large end of stem piece (cm^2)

b=Cross-sectional area at small end of stem piece (cm^2)

L=stem piece lenght (cm)

Diameter increment of non-infested group *P. brutia* sample seedlings were compared to diameter increments of infested seedlings. Annual height increments were found out from the annual ring numbers on the discs. Also, height increments were checked on the seedling in order to prevent the mistakes such as the encountering of annual height growth to the first or last. With annual ring numbers in the sections and thicknesses, volumes were calculated. Thus, with the help of stem analysis for the sample seedlings in the infested and non-infested groups; diameter, height and volume growths which belonged to the growth till the last age and increments of each age step were found out. Also, diameter, height and volume graphics were drawn according to age in consideration of groups in order to examine if there is any difference in the infested and non-infested seedlings.

Statistical analysis

Differences in height, diameter and volume between the non-infested and infested groups for all the years 2000 to 2004 were tested using ANOVA.

Differences between main effects were assumed to be significant at $p<0.001$. All analyses were conducted with SPSS for Windows Ver. 17.0 statistical package on computer.

Results and Discussion

Some statistics about annual increments and growths in the non-infested and infested sample seedlings chosen from sample areas are given in Table 1 and 2.

Table 1. Summary of sample tseedlings used in the incremenet

Age	Number of used seedling	Non-infested Group			Infested Group		
		Avarege diameter (cm)	Average height (cm)	Average volume (dm^3)	Avarege diameter (cm)	Average height (cm)	Average volume (dm^3)
1	45	0.46	19.21	2.15	0.29	15.16	0.97
2	45	0.55	21.13	13.15	0.38	19.12	6.52
3	45	0.71	31.84	51.51	0.49	19.98	21.12
4	45	0.85	30.18	115.18	0.53	19.40	28.12
5	45	0.73	19.25	141.12	0.31	15.11	51.15

Table 2. Summary of sample seedlings used in the growth

Age	Number of used seedling	Non-infested Group			Infested Group		
		Avarege diameter (cm)	Average height (cm)	Average volume (dm^3)	Avarege diameter (cm)	Average height (cm)	Average volume (dm^3)
1	45	0.46	19.21	2.15	0.29	15.16	0.97
2	45	1.01	40.34	15.30	0.67	34.28	7.49
3	45	1.72	72.18	66.81	1.16	54.26	28.61
4	45	2.57	102.36	181.99	1.69	73.66	56.73
5	45	3.30	121.61	323.11	2.00	88.77	107.88

Substantial decreases have been identified in the increment quantities in the years of infested. After the analysis of increment amounts in the groups, between the year 2000-2004, twice evident increment decline 4 (2003) and 5 (2004) ages were seen. Defoliation in *P. brutia* caused a decrease mostly in volume increment, partially in diameter and perhaps in height successively.

Considerable growth differences have been seen in infested and non-infested groups. Serious decreases have been found out in the growth of diameter, height and volume in the sampling which are in the infested group and these decreases have been found as average percentage values as 39%, 28% and 71% successively.

Also, the change in bottom diameter, height and volume have been analysed graphically in the infested and non-infested groups (Figure 2). After the analysis of growth curves between the years 2000-2004, twice growth decline were seen in the years 2003 and 2004 (at the ages of 3^{th} and 4^{th}).

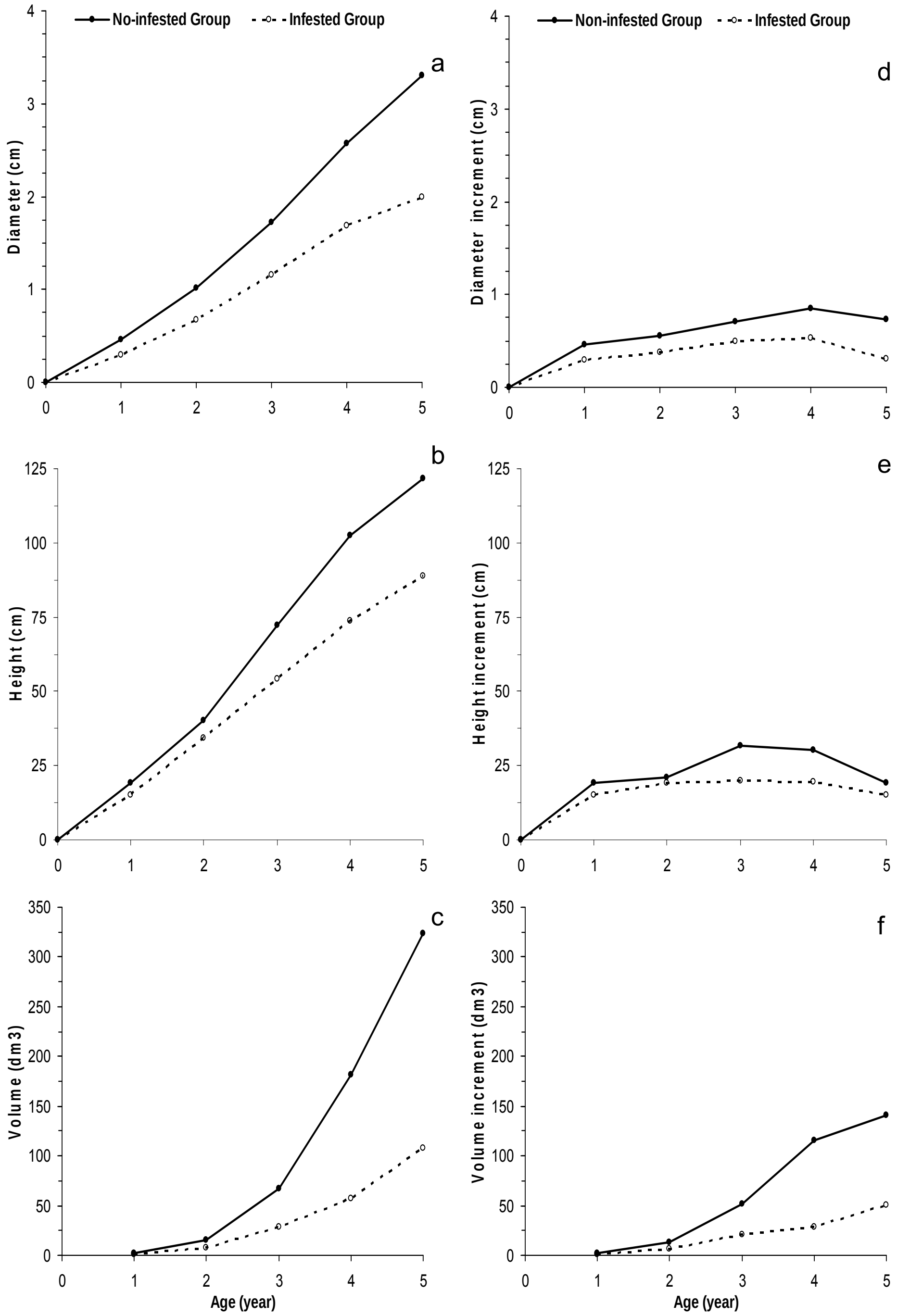

Figure 2. Development trend of diameter (a), height (b), volume (c) and increment of diameter (d), height (e), volume (f) as a function of age of non-infested and infested groups at the *P. brutia* sample seedlings, respectively.

According to results of ANOVA, defoliation EPS made on *P. brutia* samplings caused decrease firstly in stem volume secondly in diameter and last height increment thus in growth amounts (Table 3).

Table 3. Results of ANOVA for increment and growth loss at bottom diameter, height and volume (non-infested=45 seedlings; infested=45 seedlings)

Age	Increment (F values)			Growth (F values)		
	Avarege diameter (cm)	Average height (cm)	Average volume (dm^3)	Avarege diameter (cm)	Average height (cm)	Average volume (dm^3)
1	5.91**	1.13^{ns}	3.41*	5.91**	1.13^{ns}	3.41*
2	10.25**	1.05^{ns}	4.45*	12.82**	3.45^{ns}	5.48*
3	4.59*	9.16**	6.74*	9.75**	6.42**	7.03*
4	35.15***	8.15*	25.41***	13.52***	18.15***	21.18***
5	55.86***	16.01**	31.12***	21.59**	33.33***	33.25***
Total				39.415***	50.212***	58.378***

ns:non-significant, *:p<0.05; **:p<0.01;***:p<0.001

Differences between dimeter of non-infested and infested group were significantly different in all ages (F=39.415, p<0.001). And differences between height of non-infested and infested group were significantly different in all ages (F=50.212, p<0.001), but not in age 1 (F=1.13, p>0.05) and age 2 (F=3.45, p>0.05). The difference of stem volume at all age were also statistically significant (F=58.378, p<0.001) (Table 3). It has been understood that the effect of insect damage at height growth is less important.

Other insects that feed primarily on older foliage age classes have produced similar negative effects on growth in various host species. Two years of severe defoliation in Pinus echinata, by Neodiprion pratti caused a 32% reduction in volume growth (Morris et al., 1964).

After 2 years of severe defoliation of *Pinus sylvestris* L., by *Neodiprion sertifier,* volume growth was reduced by 33% (Austara et al., 1987). Thus, insects that defoliate only old foliage can cause growth losses as quickly and as severely as those reported for defoliators of current-year foliage (Piene, 1989; Karsh, 1996).

Conclusions

In this study, to be investigated the effects of defoliation on the development of diameter, height and volume growth of *P. brutia* seedligs infested by EPS.

This study has been done in 3-4 hectares homogeneous parts of young *P. brutia* generation in the 150 hectare of the district of Aziziye in Burdur of

Turkey (Figure 1). It was known that EPS caused epidemic in this district for 5 years with an increasing or decreasing intensity. Diameter, height and volume increments and growth amounts were analyzed by the way of stem analysis in 90 sample seedlings from infested and non-infested groups. ESP causes significant defoliation and growth loss in the first 5 years of an outbreak on *P.brutia*. This was especially evident in age 2 and age 3 seedlings, when percent defoliation decreased with foliage age. In the study area, it was seen that EPS severely caused an epidemic with a sudden growth decrease at the ages of 4 and 5 of sample seedlings.

In the seedlings which are in the infested group; severe decreases were seen in the growth of bottom diameter, height and volume. These decreases are successively 39%, 28% and 71% as average percentage values. Although the similarity of these different values indicates that growth loss estimates in this study are accurate, the small number of seedlings examined in this intensive study could limit its applicability to other areas. Activities of EPS have periodically been seen. Although growth decrease was seen in the seedlings in infested groups in the 4 and 5 aged (Table 1), it was found out that damage rate in the year 2004 was in low levels.

According to ANOVA results, between seedlings in the infested and non-infested groups have a significant difference, according to diameter ($F_{1;88}$=39.415***); height ($F_{1;88}$=50.212***) and volume ($F_{1;88}$=58.378***). The immediate and severe reduction in growth due to defoliation by EPS is a direct result of larval preference for young foliage, which is an important source of carbohydrates.

Developing accurately dated long-term infested and non-infested stem analyses also could identify trends in frequency, extent, duration and severity of outbreaks. This information might prove useful in refining simulations and models, as well as providing date for ecological studies of the relations between EPS outbreaks, stand density, species diversity, site history (fire control and logging) and climatic events.

Özet

Kızılçam [*Pinus brutia* (Ten.)] Gençliklerinde *Neodiprion sertifer* (Geoff., 1785) (Hymenoptera: Diprionidae)'in artım ve büyüme kaybı üzerine etkisi

Kızılçam [(*Pinus brutia)* (Ten.)] yaşamı boyunca değişik biyotik ve abiyotik zararlıların etkisinde kalmaktadır. *Neodiprion sertifer*'(Geoff., 1785) (Hymenoptera: Diprionidae)'de kızılçamın asimilasyon organı olan yapraklarını yiyerek zarar vermektedir. Bu çalışmada, *N. sertifer*'in kızılçam gençliklerindeki fidanlarda yaptığı yaprak yemesi sonucunda; çap, boy ve hacimdeki artım ve büyüme kaybı üzerindeki etkisi araştırılmıştır. Çalışma, 2000-2004 yılları arasında 5 yıl böceğin etkisinin sürekli gözlendiği Burdur ili Aziziye yöresinde

yapılmıştır. Çalışma alanında, 3 farklı yörede kontrol ve zarar grubundan 45'er örnek fidan alınmıştır. Böylelikle toplam 90 örnek fidan seçilmiştir. Seçilen fidanlarda zarar ve kontrol grubundaki artım ve büyüme miktarlarını karşılaştırmak için gövde analizleri yapılmıştır. Seçilen fidanlar kesilmiş, 25 cm aralıklarla dipten tepeye doğru gövde kesitleri alınmıştır. Kesitlerdeki yıllık halkalar arası ölçülmüş ve her bir fidan için yaşa göre çap, boy ve hacim artım ve büyümesi belirlenmiştir. Kontrol ve zarar grubu örnek ağaçlarda yıllık artımlarının istatistik açıdan aynı olup olmadığı ANOVA ile test edilmiştir. Sonuç olarak, kontrol ve zarar grubundaki fidanlarda çap ($F_{1;88}$=39.415***), boy ($F_{1;88}$=50.512***) ve hacim ($F_{1;88}$=58.378***) artımları istatistik açıdan farklı bulunmuştur. Zarar grubundaki ağaçlarda çap, boy ve hacim büyümelerinde önemli miktarda azalmalar belirlenmiş ve bu azalmalar kontrole göre ortalama yüzde değerler sırasıyla %39, %28 ve %71 olarak bulunmuştur.

Acknowledgements

I am grateful to Lecturer Mustafa KORKMAZ, Suleyman Demirel University, High School of Foreign Languages, for reviewing the final version of the English manuscript. Also, I would like to thank Prof. Dr. Serdar CARUS for his help.

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