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SMALL RODENTS AS THE CAUSE OF DECREASE IN YOUNG NARROW-LEAVED ASH TREE GROWTH (*Fraxinus angustifolia* V a h l)

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Abstract

Margaletić J., Božić M., Jazbec A., Čavlović J., Lukić N.: Small rodents as the cause of decrease in young narrow-leaved ash tree growth (*Fraxinus angustifolia* V a h l)**.** Ekológia (Bratislava), Vol. 26, No. 4, p. 372–381, 2007.

The paper deals with the results of a six-year investigation on the influence of small rodents in the process of recovery (sanation process) and renovation of pedunculate oak forest stands (*Genisto elatae-Quercetum roboris caricetosum brizoides* H t. 1938.) by narrow-leaved ash seedling plants (*Fraxinus angustifolia* V a h l). In the Spring of 1996, damage by small rodents in the form of bites of various intensity on a sample of 2580 two-year old narrow-leaved ash seedling plants was recorded in the lower parts of the stalk of 2197 seedling plants (85.16%). According to the intensity of the damage, the plants were divided into three categories. In December 2000, the increment of 31 trees was analysed.
Having analysed the variance of diameter ($F = 117.14$; $df = 2$; $p < 0.0001$) and height ($F = 128.41$; $df = 2$; $p < 0.0001$) of trees, significant difference between damage categories was established. Scheffe's post-hoc test showed statistically significant difference between damage categories, annual radial growth and their interaction.

Key words: reforestation, narrow-leaved ash (*Fraxinus angustifolia* V a h l), small rodents, increment, ANOVA with repeated measurements

Introduction

The lowland region of Croatia extends along the valleys of the rivers Sava, Drava, Kupa and Danube. This region presents 16% of the total area of Croatia amounting to 56,538 square kilometres. 31% of the lowland area is covered by forests consisting of approximately twenty forest associations, among which are the most represented valuable forests of pedunculate oak and narrow-leaved ash. As this is 16% of the total forested area in Croatia, or 19% of the total growing stock, the attention and importance paid to this part of the Croatian forests is understandable (Čavlović, 1999).

In the last hundred years, the stability of the lowland forest ecosystem has been disturbed and site conditions changed under the adverse influence of harmful pests, climatic changes, and hydromeliorative activities. In this respect, for several decades degradation and decay of stands has occurred in pedunculate oak sites. Biological melioration and regeneration of these stands by narrow-leaved ash plants was investigated by Matić, Skenderović (1993). The research results showed that narrow-leaved ash successfully regenerate these sites and can prepare the sites in processes of biological melioration. Maintenance and protection of natural and optimal conditions for the survival of pedunculate oak and narrow-leaved ash stands as main forest systems in lowland regions, is the priority and an important goal in forest management. Thus, establishment of quality and productive forest stands is based on the maintenance of a sufficient number of young plants per area unit (Dreyer et al., 1991; Matić et al., 2000).

During artificial stand regeneration, damage to young plants caused by small rodents has been noticed. The bark of young plants is an important food source during the winter months for small rodents from subfamilies Murinae and Arvicolinae, as polyphagian animals (Schneider, 2000; Carey, Harrington, 2001; Heroldová, 2002; Miklos, Žiak, 2002). The increased number of these mammals was noticed in Croatian forests in the period from 1995 to 2003 in a great number of sites (Margaletić et al., 2005). The highest intensity of damage to young plants in the form of various intensity bites in the lower part of the stem, was recorded on narrow-leaved ash (*Fraxinus angustifolia* V a h l) by voles (*Microtus* spp. or *Clethrionomys glareolus* S c h r.) (see Margaletić, 1998). The aim of the investigation was to determine to what extent small rodents influenced the radial increment and growth of young narrow-leaved ash plants by biting the bark.

Material and methods

The investigation was carried out in department 58a of the management unit "Turopoljski lug" (Forest office Velika Gorica) which is located about 30 kilometres south-east of Zagreb (Fig. 1).

Analysis of the dynamics and intensity of the narrow-leaved ash damage started in May, 1996 on seven experimental plots of 5x5 m each. The sample consisted of a total number of 2580 plants. In the period from May until November, 1996, plants were examined six times (Margaletić, 1998), while in the period from 1997 to 2000 they were examined every six months. 99.4% of damage to the plants was recorded in the first examination in 1996. The plants were then grouped into three categories: category 1 – undamaged; category 2 – partly damaged (only a superficial part of the bark was damaged and the remaining area was not continuous affected); category 3 – heavily damaged (deep and continuous damage). 2197 trees were classified in categories 2 and 3 (85.16% of the total number of plants). All 2580 plants in the experiment were numbered.

In December 2000, 31 trees, which had also been damaged during the winter months of 1994/95 and during the period up until 2000 had not been additionally damaged by rodents, were selected and cut by a random sample method. 10 trees were sampled from categories 1 and 2 and 11 trees from category 3. Trees from category 1 were used in the investigation as a control sample. Samples of cross-sections were taken at stem base (0.00 m). Ring-widths were measured on two opposite radii per cross section. The annual radial growth of each radii was measured to the nearest 0.01 mm with a tree-ring measuring device (*Digitalpositiometer Lega SMIL3*) and recorded in the database. The total height of felled trees was measured with the precision of 0.01 m.

Descriptive statistics were carried out for the analysed variable ring width (radial growth), bark and height. The level of significance of 0.05 was regarded as statistically significant in all tests. Differences between damage

Fig. 1. Locality of the research site.

categories for tree diameter with bark and height were tested by variance analysis, and differences for individual ring-width by variance analysis with repeated measurements among damage categories, year and their interaction. We considered a tree effect as a random effect, while the effect of a damage category and year were considered as fixed effect (Davis, 2002).

If any of the factors in a variance analysis were statistically significant, multiple Post-hoc test (Schefee) was used to determine the difference (Sokal, Rohlf, 1995). If the interaction between the ring width and damage category was statistically significant, the differences for important years were targetedly tested. All analyses and graphical surveys were done by statistical package STATISTICA 6.0.

Results

Diameters and heights of sampled trees were measured and the results of these measurements are shown according to damage category in Fig. 2.

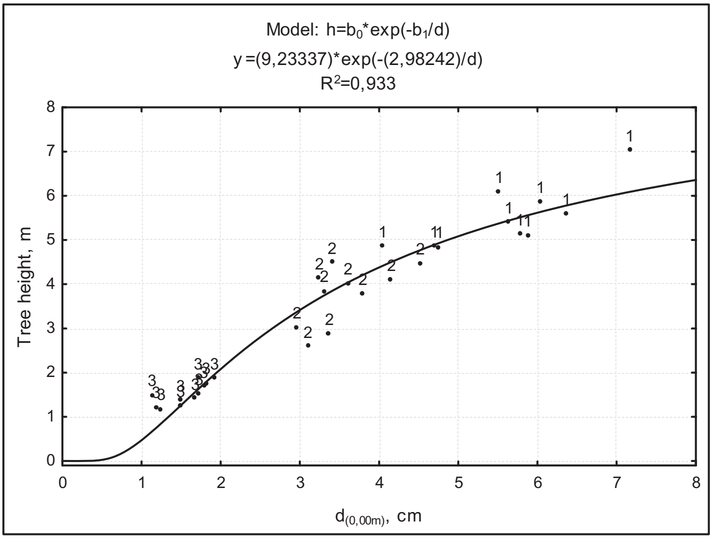

Fig. 2. Relationship between diameter and height of the analysed young trees grouped in three damage categories (category 1 – undamaged; category 2 – partially damaged; category 3 – heavily damaged). Observed data were fitted with the Mihailov's function.

In 1996 the diameters of all trees were classified as category 3. At the time of sampling (the end of 2000) they were several times smaller (Mean = 1.56 cm, Stand.Dev. = 0.27 cm) than the diameter of trees classified as category 1 (Mean = 5.58 cm, Stand.Dev. = 0.90 cm) and category 2 (Mean = 3.54 cm, Stand.Dev. = 0.49 cm), while the diameters of trees in category 1 and 2 partially overlap. Statistically significant difference was established between damage categories by variance analysis ($F = 117.14$; $df = 2$; $p < 0.0001$). Sheffe's post-hoc test showed statistically significant mutual difference between all damage categories.

Total heights of all trees in category 3 during sampling (the end of 2000) were smaller (Mean = 1.52 m, Stand.Dev. = 0.25 m) than the heights of trees in category 2 (Mean = 3.74 m, Stand.Dev. = 0.67 m), i.e. category 1 (Mean = 5.48 m, Stand.Dev. = 0.70 m). Total heights of all the trees in category 2 were smaller than the heights of trees in category 1. Analyses of variance determined statistically significant difference between damage categories ($F = 128.41$; $df = 2$; $p < 0.0001$). Again, Scheffe's post-hoc test showed statistically significant mutual difference between all damage categories.

Since it is not possible to determine by the above analysis exactly when the differentiation in radial growth of the observed categories occurred a descriptive analysis of ring widths was carried out (Table 1 and Fig. 3), as well variance analysis with repeated measurements for ring width for each damage category during the eight years (Table 2).

T a b l e 1. Descriptive statistics of radial growth at stem base (0.00 m).

Damage category	Year	1993.	1994.	1995.	1996.	1997.	1998.	1999.	2000.	Bark width (mm)
		1.	2.	3.	4.	5.	6.	7.	8.	
		Ring width (mm)								
1 (N = 10)	mean	2.88	2.64	0.65	2.83	4.42	4.87	4.47	3.57	1.57
	stand.dev.	0.80	0.73	0.29	0.64	0.98	1.21	1.14	1.03	0.26
2 (N = 10)	mean	2.17	2.23	0.33	1.36	1.89	2.06	3.67	2.55	1.31
	stand.dev.	0.83	1.12	0.13	0.54	0.46	0.82	0.71	0.82	0.37
3 (N = 11)	mean	1.72	1.61	0.22	0.42	0.36	0.73	0.93	0.88	0.92
	stand.dev.	0.53	0.60	0.14	0.27	0.24	0.64	0.30	0.43	0.19
All trees (N = 31)	mean	2.24	2.14	0.44	1.50	2.16	2.50	2.96	2.29	1.26
	stand.dev.	0.86	0.92	0.31	1.12	1.81	1.96	1.74	1.37	0.39

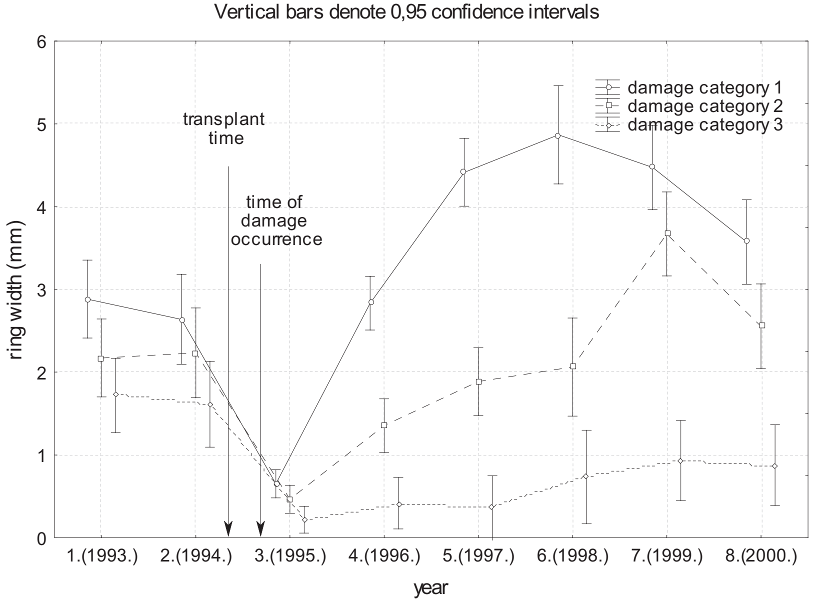

Fig. 3. Radial growth chronologies of the analysed young narrow-leaved ash trees. Full line – category 1; broken line – category 2; dotted line – category 3.

Table 2. Results of Repeated Measures ANOVA for ring width.

Ring width	df	MS	F	p
Among trees				
Damage category	**2**	**124.152**	**115.63**	**< 0.0001**
Error a – tree (damage category)	28	1.074		
Inside trees				
Year	**7**	**18.605**	**44.178**	**< 0.0001**
Damage category*year	**14**	**6.312**	**14.9882**	**< 0.0001**
Error b	196	0.421		

Note: Bold p values are considered statistically significant
Notes: df – deegre of freedom; MS – mean square; F – value; p – value

As it can be seen from Table 2 all the measured effects (damage category, year and their interaction) are statistically significantly different. There is statistically significant mutual difference between all damage categories, regardless of the year. Also, there is statistically significant difference in ring widths during years, regardless of damage category (Table 2). The results of Scheffe's post hoc test are shown in Table 3. They show that on average, the ring width in the first year did not significantly statistically differ from the average ring width in the second, fifth, sixth and eighth year, while it statistically significantly differed from the average in the third, fourth and seventh year. The average ring width in the third year statistically significantly differed from the ring width in all other years. The same was determined for the average ring width in the fourth year. The interaction between the damage categories and years is also significant, which indicates that ring widths for certain damage categories are not "developed" in the same way during the years, which can be seen in Fig. 3.

Table 3. Results of Scheffe's post hoc test for ring width between years.

Year	1.	2.	3.	4.	5.	6.	7.
2.	1.000						
3.	**< 0.001**	**< 0.001**					
4.	**0.007**	**0.037**	**< 0.001**				
5.	1.000	1.000	**< 0.001**	**0.029**			
6.	0.932	0.710	**< 0.001**	**< 0.001**	0.760		
7.	**0.011**	**0.002**	**< 0.001**	**< 0.001**	**0.002**	0.354	
8.	1.000	0.998	**< 0.001**	**0.003**	0.999	0.978	**0.025**

Note: Bold p values are considered statistically significant

The targeted ANOVA for certain years showed that in the eighth year of observation there was a statistically significant difference in ring widths between all three damage categories (Table 4). However, if we look at the first observation year, we can see that there is a statistically significant difference in the ring width between damage categories 1 and 3. That difference is also present in the second and third observation year, while in the fourth year, two vegetation seasons after the transplantation, the ring widths for all three damage categories are mutually statistically significant (Fig. 3).

T a b l e 4. Results of Scheffe's post hoc test for ring width between damage categories.

Year	1.		2.		3.		4.		8.	
Damage category	1	2	1	2	1	2	1	2	1	2
2	0.101		0.564		0.298		**< 0.001**		**0.026**	
3	**0.004**	0.374	**0.031**	0.253	**0.003**	0.113	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**

Note: Bold p values are considered statistically significant

Discussion and conclusion

In stable and balanced natural forest ecosystems small rodents have their place and ecological significance (Turček, 1968). However, a high percentage of damage (85.16% of the investigated sample of young ash plants) indicates that small rodents can be considered a significant factor in the procedure of biological restoration of pedunculate oak forest stands. Such a high percentage of damaged plants are connected with the gradation of small rodents during the occurrence of damage (Margaletić, 1998). Increased damage to young plants can be closely related with the height of snow cover and the density of the terrain grass cover (Hansson, 1971; Ferns, 1976).

In the sampling period (at the end of 2000) none of the trees on the experimental plot had died back. No similar research on damage to young ash plants was found in the literature with whom the results of this investigation could have been compared. Investigating damage to species lombardy poplar (*Populus nigra* L.), purple willow (*Salix purpurea* L.) and European alder (*Alnus glutinosa* L.) by root vole (*Microtus oeconomus* P a l l.), Buchalczyk et al. (1970) established that out of 48–67% of the damaged trees only 6–7% had died back as a result of the direct inflence of dormice.

The differentiation of the 8-year old trees between three damage categories is clearly visible according to heights and diameters (Fig. 2). The results show (Fig. 3) that the plants which were most damaged by small rodents (category 3) were in the smallest nursery (the first two years). This fact leads to the conclusion that after transplantation into a forest stand small rodents damage the thinnest plants, facilitating the differentiation of trees into height and thickness classes.

The average height of heavily damaged trees (category 3) is only 27.74% of the average height of undamaged trees (category 1). Investigating the influence of damage caused by social vole (*Microtus socialis* P a l l.) on the height growth of young box elder plants (*Acer negundo* L.), Stoddart (1979) determined that the average height of damaged plants is 86.18% of the average height of the undamaged young plants. Schneider (2000) in his investigation on the influence of damage (artificial imitation of damage by small rodents) on the height growth of beech trees, determined that the height of damaged trees is 60.83% of the height of undamaged trees, which is significantly lower than the results of this investigation. Such large differences between the mentioned results can be explained by the fact that Schneider carried out his investigation on plants of other species (beech) which were also not transplanted (transplant stress) and were not influenced by competition. According to Schneider (2000), damaged plants fall behind in their height growth a long time after the damage has occurred. However, due to the competition which exists among the investigated young narrow-leaved ash trees, which were transplanted into a forest stand, it can be concluded that young ash plants of the third damage category have no chance of survival and formation of a future stand. Some of the trees in the second damage category, together with undamaged plants, remain in the competition and fight for survival.

The descriptive analysis of radial growth (Table 1, Fig. 3) indicates the special radial growth dynamics of the investigated narrow-leaved ash trees differentiated according to damage categories. In radial growth chronology, the third vegetation period is particularly important when the radial growth (ring width) for all categories is significantly below 1 mm, only 0.22 mm for the category of heavily damaged trees. This is the result of the transplantation of two-year seedling plants from a nursery into a forest stand, as well as of plant damage which occurred immediately after transplantation. It is known that plants experience stress after transplantation (Watson et al., 1986; South, Zwolinski, 1997) which causes the decrease in increment (Bey, 1972). It is difficult to determine how much damage to the investigated plants influenced the radial growth decrease. In 1995, while investigating the radial growth of ash trees growing in a stand (there was no transplant stress) Anić (2000) did not determine radial growth depression, as was the case in our investigation (the time of transplantation and damage to the investigated researched trees). Also, it was determined that climatic conditions for that year were normal and corresponded to a 10-year average.

The obtained statistically significant difference between the radial growth of undamaged and heavily damaged plants both before and after transplantation (Table 2) confirms the fact that these are two different narrow-leaved ash tree populations. In the nursery, during the first two years of life, the average ring width of heavily damaged plants is about 60% of the average ring width of undamaged plants. After transplantation there is a drastic stagnation in radial growth of heavily damaged plants, amounting to only 8.2 to 14.6% of the radial growth of undamaged plants. Such a radial growth is the result of the mutual action of the initial inferiority, transplant stress, damage and increased influence of competition of heavily damaged and undamaged plants. The damaging of plants influenced to a certain extent the stagnation in radial growth. This can be explained by the fact that damaged plants spend a part of reserve nutrients and energy for occlusion of the wound surface. Systematic research with a specifically set experiment to determine the influence of some of the aforementioned factors on the decrease in radial growth should be carried out (initial inferiority, transplant stress, damage by rodents, competition).

It is a well-known fact that mechanical damage to plants causes the attraction of rodents in a stand and increases the damage intensity on other neighbouring plants (Alibhai, 1985; Watts, 1970). However, the established fact that small rodents, by damaging the weakest plants, accelerated their stagnation in height and radial growth in relation to undamaged plants, leads to the conclusion that small rodents help in the positive selection of perspective narrow-leaved ash trees.

According to Kerr (2003), whose results suggest that better growth at closer spacings may be a silvicultural characteristic of ash, closer spacings should be applied in the treatment of stand melioration. In this respect, it can be presumed that by transplantation of a greater number of ash plants per area unit, there will be a sufficient number of weak plants which will attract the attack of small rodents to themselves. Therefore, in the case of small rodent gradation such plants will be sacrificed in favour of better quality and perspective trees.

For the purpose of examining new ideas on the relationship between plants and small rodents there is a need for further research, in order to understand the place and role of small rodents in the forest zoocoenosis, and also to find the answer to the question of why small rodents prefer (damage) thinner trees.

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