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CAN SHRUB SPECIES BE UTILIZED AS A BIOLOGICAL MEASURE TO REDUCE NOISE POLLUTION?

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Abstract

Today, the use of sound barriers is among the common control methods in combating noise pollution. The use of plant materials as sound barriers, especially in urban spaces, is important due to their ecological, aesthetic and economic contributions. In this study, four shrub species (Rosa canina L., Syringa vulgaris L., Ribes aureum L. and Platycladus orientalis L.), which are widely preferred outdoors in Erzurum province, were used as materials. In the first stage, areas with species with appropriate density, size and volume characteristics were determined. In the second stage of the research, 20 separate noise measurements were made for 4 different shrub species. Then, statistical analysis of the measurement results was made. In the final stage, the effects of each shrub species on noise reduction were ranked. The study concluded that shrub species significantly reduce noise levels. Ribes aureum L. was determined as the most effective shrub against noise with an effective value of 8.5 dB(A) (10.6%). Based on the measurement results and structural characteristics of shrub species, the results were compared, discussed and some suggestions were presented to increase the use of vegetal noise barriers.

Anahtar Kelimeler: *Noise Pollution, Noise Barrier, Plant Materials, Shrubs*

ÇALI TÜRLERİ GÜRÜLTÜ KİRLİLİĞİNİ AZALTMAK İÇİN BİYOLOJİK ÖNLEM OLARAK KULLANILABİLİR Mİ?

Özet

Günümüzde gürültü kirliliği ile mücadelede ses bariyerlerinin kullanımı yaygın kontrol yöntemleri arasındadır. Özellikle kentsel mekanlarda ses bariyeri olarak bitkisel materyallerin kullanımı ekolojik, estetik ve ekonomik katkılarından dolayı önemlidir. Bu çalışmada Erzurum ilinde dış mekanlarda yoğun olarak tercih edilen 4 çalı türü (Rosa canina L., Syringa vulgaris L., Ribes aureum L. ve Platycladus orientalis L.) materyal olarak kullanılmıştır. İlk aşamada uygun yoğunluk, büyüklük ve hacim özelliklerine sahip türlerin bulunduğu alanlar belirlenmiştir. Araştırmanın ikinci aşamasında 4 farklı çalı türü için 20 ayrı gürültü ölçümü yapılmıştır. Ardından ölçüm sonuçlarının istatistiksel analizleri yapılmıştır. Son aşamada ise her bir çalı türünün gürültü azaltmasına yönelik etki sıralaması yapılmıştır. Çalışma ile çalı türlerinin gürültü seviyelerini önemli ölçüde azalttığı sonucuna varılmıştır. Ribes aureum L., 8,5 dB(A) (%10,6) efektif değeri ile gürültüye karşı en etkili çalı olarak belirlenmiştir. Ölçüm sonuçlarına ve çalı türlerinin yapısal özelliklerine dayanılarak sonuçlar karşılaştırılmış, tartışılmış ve bitkisel gürültü bariyerlerinin kullanımının arttırılmasına yönelik bazı öneriler sunulmuştur.

Keywords: *Gürültü Kirliliği, Gürültü Bariyeri, Bitkisel Materyaller, Çalılar*

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1. INTRODUCTION

With the emergence of noise pollution with the industrial revolution, it has become an increasingly important environmental problem in direct proportion to the development of technology today. As a consequence of increasing population density in recent years, this effect is felt more in cities that develop unplanned. Noise pollution is measured by WHO (World Health Organization) as the third deadliest type of pollution in terms of human health (Munir et al. 2021; Berglund et al., 1999).

Noise reduction is possible in three different ways. Interventions can be made to the noise source, measures can be taken between the source and the receiver in case the intervention to the source is insufficient, and finally, measures can be taken at the receiver (Akay & Onder, 2002).

Preventive work is mostly carried out to reduce and limit the negative effects of noise on people and living comfort (Doygun & Doygun, 2018). Noise energy can be reduced with plant material as a biological measure in outdoor spaces (Aylor,1972; Fang & Ling, 2003). In a study conducted, it was emphasized that plants should be preferred in the establishment of noise screens due to their ecological, aesthetic, and economic benefits, and researchers have stated that vegetative barriers can reduce noise by up to 12 dB (A) (Onder & Gulgun, 2010). In another study, on the other hand, it was emphasized that noise screens created with vegetative elements are cheaper and more aesthetic than noise screens with artificial materials (Gur & Onder, 2000).

There have also been studies on the use of various tree and shrub species related to the effects of vegetated noise screens (Fan et al., 2010; Ow & Ghosh 2017). In most of the studies, methods are based on the principle of screening between the source and the receiver. It was stated by Erdogan and Yazgan that every part of the habitus of plant material is effective in absorbing and spreading sound (Erdogan &Yazgan, 2007). The noise reduction values of the *Pinus sylestris* L. and *Populus nigra* L. grove located around the transit road in Erzurum were determined by Özer et al. (Ozer et al., 2008). Mutlu and Önder determined the noise suppression values of some shrubs growing in Konya (Mutlu & Onder, 2012). Noise measurements were made in parks in Trabzon province by Özdemir et al., and it was suggested to use *Syringa vulgaris* L., *Viburnum lantana* L., and *Acer pseudoplatanus* L. plants at the edges of the parks for noise prevention (Ozdemir et al., 2014).

In the creation of noise-canceling plant screens, it is recommended to include species from the natural vegetation of the region. This is because natural species can easily adapt to environmental conditions and exhibit the physical performances expected of them due to their ideal developmental characteristics (Doygun & Doygun, 2018; Erdogan &Yazgan, 2007; Onder & Kocbeker, 2012).

Today, studies to identify ecological materials that can reduce the sound intensity in noisy environments (Akay & Onder, 2002, Jamaludin et al. 2021, Zhao et al. 2021, Ganesan & Subbaiyan 2022, Wickramathilaka et al. 2022) continue.

In urban areas and nearby areas where traffic noise is intense, the use of biological vegetative barriers as well as structural noise barriers is important in terms of ecological, economic, and aesthetic gains as well as function. In this study;

- Can shrub species be utilized as a biological measure to reduce Noise Pollution?
- It is aimed to contribute to the literature on this subject by determining the noise reduction levels of different shrub species,
- It is aimed to encourage/increase the effective use of these plants against noise, especially in urban landscapes.

2. MATERIAL AND METHOD

The study was conducted in Erzurum, one of the most important cities in the Eastern Anatolia Region of Turkey, which has the highest and coldest climate (Figure 1). The city is located at an altitude of 1950 m. and has a population of 756,893. The city has a harsh continental climate. Winters are very cold and snowy, and summers are hot and dry. Snow covers the city for 150 days of the year (Anonymous, 2022). Having hosted the 2011 Universiade Winter Olympic Games in Turkey, Erzurum is one of the most important winter tourism centers with its ski resorts and winter activities.

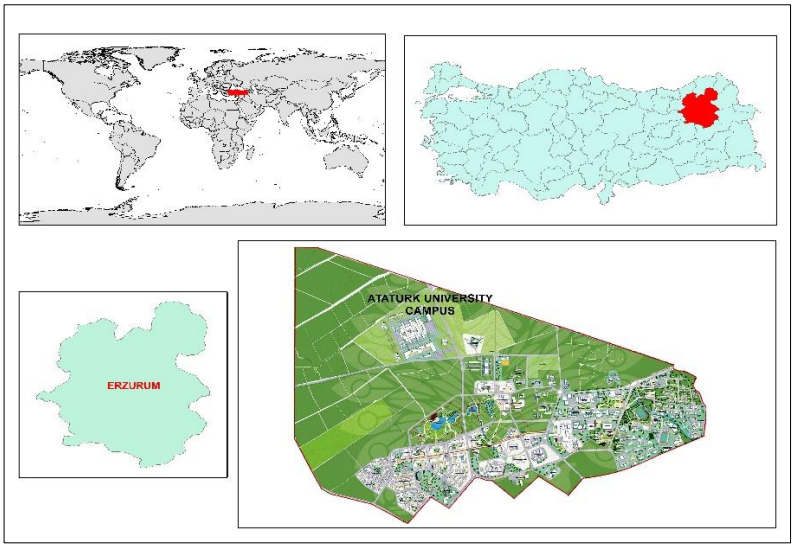

Figure 1. The Location of Erzurum City and Ataturk University

Noise pollution has become an important environmental problem for the city of Erzurum in recent years. The most important noise sources in the city are roadways with noise levels of 70 dB (A) and above (Yilmaz & Ozer, 2005). The number of motor vehicles registered in Erzurum in June 2022 was 123,232. The city ranks 3rd among the provinces in the region and 46th in the country in terms of the number of motor vehicles and automobiles (Turkish Statistical Institute, 2022).

The plants of *Syringa vulgaris* L. (Lilac), *Ribes aureum* L. (Currant) and *Platycladus orientalis* L. (Eastern thuja), and *Rosa canina* L. (Rosemary) were used as materials in the study. The selection of these species was based on the following considerations;

- The widespread use of plants in Erzurum city center,
- The availability of examples of these species applied as hedges in different areas for research and their suitable characteristics in terms of volume, density, and size,
- Some of them (*Ribes aureum and Rosa canina*) are found in natural vegetation,
- Being easily and economically available in local nurseries,
- The literature lists plants recommended for noise suppression (Elmas & Murat, 2009).

The research method consists of 4 stages. Initially, after a literature review on the subject, a suitable area for the research was identified. In the selection of the specimens for the measurements, we preferred the hedge specimens of the shrub species with sufficient width and length, in single rows, unpruned, and in natural form. Measurements were made between 02:00 and 04:00 on weekdays, when people use the area the least and the noise is least. An average of 20 measurements were taken at each measurement site.

In a study based on noise measurement, it was mentioned that there is a noise problem in the Atatürk University campus (Ozer et al., 2014). For this reason, as a result of the surveys carried out as the study area, the most suitable area was determined in the garden of the Faculty of Agriculture in the central campus of Atatürk University (Figure 2, Figure 3). Below are some characteristics of the measured shrub species (Table 1).

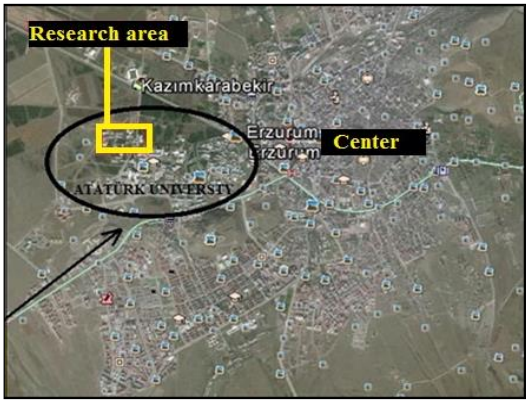

Figure 2. The Location of Research Area (Google Earth)

Figure 3. Test Measurement Points (Google Earth)

Table 1. The physical characteristics of the shrubs being measured

Shrub species	Diameter (mt)	Height (mt)	Density	Shape
Platycladus orientalis L.	2	4	Normal	Natural
Ribes aureum L.	2.5	2.5	Normal	Natural
Rosa canina L.	1.5	1.5	Normal	Natural
Syringa vulgaris L.	2	3.5	Normal	Natural

In the second phase of the stage, the noise reduction performance of the plants from the source at a fixed distance was measured. A noise source (water motor) was used to create a constant noise source for the measurements. The studies of Ozer et al. were utilized in the selection of this method (Ozer et al., 2008). The noise measurement method used in the study is given in Figure 4.

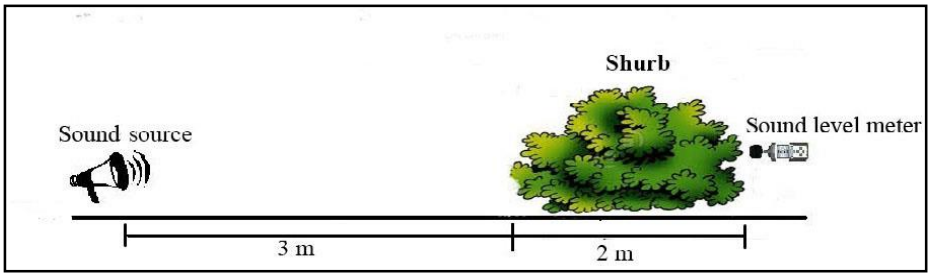

Figure 4. The Method Plan of the Test Measurement

1.4 dB Accuracy IEC 61672 CLASS 2 sonometer was used for noise measurement. Measurements were made in the summer and at 2:00 am when the noise was lowest. The absence of wind and rain was taken into consideration while taking the measurement. First of all, it was ensured that the intensity of the sound emitted by the noise source was close to each other for each measurement. Noise measurements were made at a distance of 5 m from the noise source, just behind the bush groups (Figure 4). In this study, 20 separate noise measurements were made for each shrub species, taking into account a previous study (Fan et al., 2010).

In the third stage of the study, the noise values obtained were statistically analyzed. For this purpose, firstly, the Kolomogrow-Smirnov normality test was applied to the data, and it was determined whether the distribution was suitable for normal. Then, the differences between the means determined by using the One-Way Analysis of Variance (One-Way ANOVA) method were examined with the Duncan multiple comparison test. Statistical analyzes were made using IBM SPSS 20.0 software package program.

Experimental model (Yildiz et al., 2020);

$y_{ij}= \mu+ a_i+ e_{ij}$

y_{ij} = i. treatment and j. response variable from repetition

μ = population mean

a_i = Treatment impact margin

e_{ij} = Random error

In the last stage of the study, the difference between the values measured from the bushes and the value created by the noise source was examined to determine to what extent the bushes reduced the noise.

3. RESULTS AND DISCUSSION

Noise source and averages of 20 noise measurements taken for each bush were determined. The average values obtained from the measured values of the bushes are subtracted from the average value of the noise source, and the noise reduction effects of the bushes are presented in Table 2.

Table 2. Noise reduction values of the shrubs

	Noise Source	***Rosa canina* L.**	***Syringa vularis* L.**	***Platycladus orientalis* L.**	***Ribes aereum* L.**
1	79.2	74.4	73.2	72.9	72.4
2	79.4	74.8	74.2	73.1	72.6
3	80	75	74.3	73.5	72.4
4	79.9	74.8	74.1	73.4	72
5	80.4	74.7	74.3	73.1	72.1
6	80.2	75	74.5	73.2	71.2
7	81	74.9	74.9	73.3	71.4
8	80.6	75	74.7	73.1	72.2
9	80.7	74.9	74.6	73.2	72.1
10	81.2	75	74.7	73.4	72
11	81	74.6	74.8	73.5	72.2
12	80.8	75.2	74.9	73.4	71.9
13	80.9	75	74.5	73.5	72.1
14	80.7	74.9	74.6	73.6	71.4
15	81	74.8	74.7	73.2	72.1
16	80.4	74.6	74.9	73.4	71.8
17	80.6	74.3	74.8	73.8	72
18	80.4	74.7	74.7	73.6	71.9
19	80.7	74.8	74.9	74	72.2
20	80.9	74.5	75.2	73.7	71.1
Average	**80.5**	**74.8**	**74.6**	**73.4**	**72.0**
Difference		**5.7**	**5.9**	**7.1**	**8.5**

The noise reduction effect of these shrub types in their natural form was examined; in the measurements, it was determined that the most effective shrubs in noise suppression were *Ribes aureum* L. with 8.5 dB (10.6%), *Platycladus orientalis* L.with 7.1 dB(A) (8.8%), and *Syringa vulgaris* L. with 5.9 dB(A) (7.3%), respectively, and *Rosa canina* L. with 5.7 dB(A) (7.1%) in the last place (Figure 5).

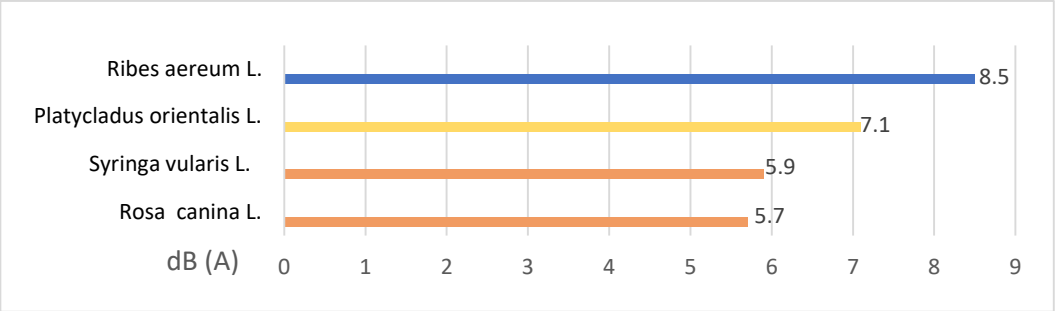

Figure 5. Noise reduction values of the shrubs

The differences between the means determined using the One-Way Analysis of Variance (One-Way ANOVA) method were verified with the Duncan multiple comparison test (Table 3, Table 4).

Table 3. One-Way Analysis of Variance Results

	N	Average ± Std. Deviation	Std. Error	95% Confidence Limits		Minimum	Maximum
				Lower limit	Upper limit		
Noise Source	200	80,5000±0,53410[a]	0,11943	**80,2500**	**80,7500**	79,20	81,20
Rosa canina L.	200	74,7950±0,22821[b]	0,05103	**74,6882**	**74,9018**	74,30	75,20
Syringa vularis L.	200	74,5750±0,42287[b]	0,09456	**74,3771**	**74,7729**	73,20	75,20
Platycladus orientalis L.	200	73,3950±0,26848[c]	0,06003	**73,2693**	**73,5207**	72,90	74,00
Ribes aereum L.	200	71,9550±0,39931[d]	0,08929	**71,7681**	**72,1419**	71,10	72,60
Total	1000	75,0440±2,94808	0,29481	**74,4590**	**75,6290**	71,10	81,20

Table 4. Duncan Multiple Comparison Test Results

Grup	N	Subset for alpha = 0.05			
		1	2	3	4
Ribes aereum L.	20	**71,9550**			
Platycladus orientalis L.	20		**73,3950**		
Syringa vularis L.	20			**74,5750**	
Rosa canina L.	20			**74,7950**	
Noise Source	20				**80,5000**
Sig.		1,000	1,000	,075	1,000
Means for groups in homogeneous subsets are displayed.					
a. Uses Harmonic Mean Sample Size = 20,000.					

The values found in this study are important because the effect of noise is logarithmic, and a change of 5 dB(A) is felt as a doubling or halving of the noise intensity at the ear (Uslu et all., 2000).

In this study, only the noise reduction values of single species of shrubs were determined. The results obtained support Onder and Gulgun's statement that properly installed vegetative noise screens can reduce noise by up to 12 dB (A) (Onder and Gulgun, 2010). Shrubs and trees can be used as a single species, or they are preferred because they increase their effects together (Mutlu and Onder, 2012). In studies investigating the noise reduction of green buildings, it was shown that denser vegetation would be more successful in reducing noise levels (Margaritis and Kang, 2017). That is why, in future studies, more effective results can be obtained by making measurements by forming plant groups in the selection of materials.

The area to be left for the noise source and the vegetative buffer area are very important in noise reduction. In this study, measurements were made at distances of 5 meters while determining the noise suppression level of single-species shrubs. It was stated by Ow and Ghosh that the distance for plant curtains should be at least 5 m (Ow and Ghosh, 2017). Erdogan and Yazgan recommend this distance between 6-30 m, while Ozer et al. emphasized that a wide vegetative buffer can reduce noise more effectively (Elmas and Murat,2009, Ozer et all., 2008).

The fact that *Ribes aureum* L. has a dense branch and leaf structure from the soil level is thought to increase the effectiveness of the shrub in preventing noise (Finke, 1980). *Platycladus orientalis* L. being evergreen, branching from the bottom, and tall, was found to be the reason for the high level of noise prevention. However, since the shrubs at the noise measurement point were not a large enough community, the noise reduction level was lower than that of *Ribes aureum* L.

Syringa vulgaris L. is a tall shrub, but the low noise reduction level may be because the lower parts of the shrub have few leaves and few branches due to a lack of light. Indeed, the results obtained confirm the study of Finke (Finke, 1980). *Rosa canina* L., with fewer branches and leaves, especially its shorter stature compared to other shrubs (Bendtsen, 2010), was considered to be the reason for the lower noise reduction level.

4. CONCLUSION

Many measures (such as planning, technical, biological, educational, legal, etc.) have been emphasized against noise pollution, but the problem of noise is still current in living spaces. Since structural measures (such as noise barriers and improvement of road conditions) create more cold surfaces in urban and rural areas, studies on noise prevention combining structural and biological measures have started to gain intensity.

Located in one of the highest-altitude settlements in Turkey, Erzurum has extreme climatic conditions. As in the rest of the world, noise is an important environmental problem in Erzurum due to the increasing number of vehicles and urbanization. This research aims to seek an answer to the question of whether plant material can be utilized for a more livable comfort in living spaces (such as housing, education, and recreation) as a biological measure for noise prevention. In particular, whether different types of shrubs, which take up less space, can reduce the noise level to the desired level has been emphasized. Considering that large areas are needed for noise prevention zoning with vegetative barriers in cities, shrub species that take up less space have the feature of being hedge plants and can be easily used as living walls become more important. *Syringa vulgaris* L., *Ribes aureum* L., *Platycladus orientalis* L., and *Rosa canina* L., which are frequently used in urban and rural landscapes in Erzurum, do not occupy much space and grow rapidly, were used for this purpose.

According to the results of the study, it was observed that different shrub species with a width of about 2 m significantly reduced noise. It was determined that *Ribes aureum* L. reduced noise by 8.5 dB(A), *Platycladus orientalis* L. by 7.1 dB(A), *Syringa vulgaris* L. by 5.9 dB(A), and *Rosa canina* L. by 5.7 dB(A). These results confirm the hypothesis that different shrub species can be effective in reducing noise. Although the noise reduction level of Platycladus orientalis L. was expected to be higher due to its structural features, it was lower than Ribes aureum L. This is another important result indicating that, in addition to the structural features of the shrubs to be used as noise barriers, their use in a sufficiently large group supports an increase in the noise reduction level.

The plant species used are resistant to cold climatic conditions, easily available, fast-growing, economical, can be pruned like a wall without occupying too much space, have aesthetic values, and some species are in natural vegetation, which can contribute to urban biodiversity by supporting wildlife. In the research conducted, it was

concluded that these plant species could be easily used against noise for different land uses in the city and its immediate surroundings. Planners and decision-makers have a responsibility for a more livable environment.

Noise reduction levels of 4 different existing shrub species were determined in this research. The measurements were made in summer and cover the leafy season when plants are planted to reduce noise. As the method used does not include the responses of the same plant species to noise in winter, the same research should be carried out during the leafless period (winter months) to determine their effectiveness against noise throughout the year. During the winter months, the occasional snow cover of shrub groups can also lead to more positive results in noise reduction. Similarly, in addition to the pure shrub groups used in this study, measurements of the noise reduction effect can be made with vegetative barriers composed of different shrub species.

Research is also needed on the use of some summer green shrub species (*Berberis vulgaris, Eleagnus angustifolia, Hippophae rhammnoides, Lonicera tataricum, Sambucus nigra,* etc.) as noise barriers, either as single species/mixed species or in combination with structural elements. It is also very important to use these species suitable for the ecology of the region for efficient, economic, and sustainable use of resources in the current climate change scenarios.

Evergreen shrub groups of appropriate width, size, and height in cold climate regions can give more effective results with the aesthetic values they add to the landscape throughout the year, as well as noise reduction. For this purpose, along with *Platycladus orientalis* L. used in the study, some natural (Juniperus excelsa Bieb, Juniperus communis L, Juniperus oxycedrus L.) and cultivated juniper species (Juniperus virginniana 'Skyrocket', Juniperus virginniana) that are resistant to extreme climatic conditions in Erzurum and cities with similar climate characteristics. 'Blue Arrow'), thuja species (Thuja occidentalis 'Smaragad', Thuja occidentalis 'Pyramidalis') can be used in small spaces. However, there is a need for research to determine the effectiveness of these plants in preventing noise.

The structural characteristics (number of shoots, leafing status, leaf hardness and size, height, crown width), environmental requirements, and aesthetic, ecological, and economic values of the plant species to be used in plant barriers are very important. The width of noise barriers, however, has a direct impact on the reduction of noise levels. Indeed, in a study (Ozer et all., 2008), it was stated that the noise level of 90 dB (A) can only be reduced to the acceptable level of 55 dB (A) with a 100 m vegetative buffer. This suggests that to achieve significant reductions in noise levels with vegetation, vegetative buffering with the noise source should be at greater distances.

In conclusion, noise pollution, especially from vehicle traffic, is one of the most important environmental problems that we encounter in most parts of our lives and affects the entire ecosystem for long periods. It was concluded in this study that noise levels can be reduced by biological measures in areas with heavy traffic and noise pollution. Technical, planning, educational, and legal measures should be taken as well as biological measures in living spaces, and the search for more livable, ecological, and aesthetic spaces should continue.

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