



The effects of base station as an electromagnetic radiation source on flower and cone yield and germination percentage in *Pinus brutia* Ten

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Abstract

Electromagnetic radiation is a substantial pollution factor that most of the living things found almost everywhere are constantly exposed to with current technology. The number of studies conducted on the effects of this exposed radiation on the living things constantly is limited; and almost all of the studies conducted are aimed at measuring the effects of short-term exposure. In addition to this, most of the studies conducted on plants focus on herbaceous plant species. In this study, the effects of distance to base station on flower and cone yield and germination percentage were investigated in *Pinus brutia* individuals, one of the critical forest tree species. The study results revealed that being close to the base station significantly reduced the number of flowers and cones in *P. brutia* individuals, and that the values obtained in individuals at a distance of 800 m from the base station were 11 times more than the number of flowers and 7 times more than the number of cones compared to the individuals at a distance of 100 m. In the seeds subject to the study, there is a three-times difference in terms of the germination percentage among the individuals located at the furthest and closest distance to the base station. These results show that *P. brutia* individuals are considerably affected by the base station.

Keywords Base station · Cone · Electromagnetic radiation · Flower · *Pinus brutia* Ten

Introduction

In the last century, the world population has rapidly increased and industry and technology have also equally developed. While the use of natural resources for the supply of raw materials needed in the industry created tremendous pressure on these resources, both production process and the wastes caused many problems, especially environmental pollution (Yucedag et al. 2018; Kaya 2009; Sevik et al. 2019a, 2019b; Kaya et al. 2009; Ozel et al. 2019).

With the advancing technology in recent years, the devices, of which the usage has increased most rapidly, are perhaps the wireless devices. Especially within the last decade, there has been an enormous increase in the use of wireless devices, which has led to an increase in exposure to electromagnetic radiation in our lives (Balmori 2006). Electromagnetic waves are a form of radiation with a great variety from high-energy cosmic rays and gamma rays to low-energy microwave radiation and radio waves (Wdowiak et al. 2017).

Human-made radiation sources are created by radio communications, communication satellites, computer networks, broadcasting and radar. Telecommunication is undoubtedly one of the most important electromagnetic wave sources. More and more wireless devices and routers are used in telecommunication all over the world, and these devices and routers used are substantial radiation sources (Alattar and Radwan 2020).

In many studies, radiation in question is stated to be affecting the functioning of living organisms. Numerous studies have been conducted on the effects of electromagnetic radiation on living systems and on both positive and

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negative effects of this radiation (Taye et al. 2018; Batool et al. 2019). However, it is stated that the current information available on this subject is still not sufficient (Alattar and Radwan 2020). Despite the fact that the effect of electromagnetic radiation on plants has been subjected to various studies (Singh et al. 2013; Vian et al. 2016; Ribeiro-Oliveira 2019), the number of studies, especially on forest tree species, is very limited. In this study, the effects of electromagnetic radiation on *Pinus brutia*, which is widely spread in the area dominated by the Mediterranean climate zone, to be identified.

Material and method

The study was carried out in Cestepe village of Bartın province. In terms of forest management, the study area is located within the borders of Bartın Forest Sub-District Directorate of Bartın Forest Operation Directorate. The study area was afforested in 1994 by planting 2+0 aged tubular seedlings of Antalya-Duzlercami provenance at 2.3 × 1.3 m intervals. The plantation site is located with South and Southeast exposure with an elevation of 300 m, and its soil has a deep and sandy-clay-loam texture. The soil structure is elastic, and the soil, slope and exposure are generally homogeneous in the study area. The average living percentage of the seedlings in the plantation site (as of 2019) was calculated at approximately 78.3%. The study materials were collected from 27-year-old trees in 2019. The base station in the study area was established in 2005.

Within the scope of the study, firstly, the individuals at a distance of 100 m, 200 m, 300 m, 400 m, 500 m, 600 m, 700 m and 800 m from the base station located in the region were identified, and measurements and counts were made for those individuals. With the counts made in the identified individuals in April, firstly, the number of female flowers

(FF), the number of male flowers (MF), the number of one-year-old cones (C1) and the number of 2-year-old cones (C2) were determined. The counts were made on 30 trees. At the end of the vegetation season, ripe cones were collected from the same trees in November. The germination percentage (GP) was determined in the seeds taken out of the cones.

The data obtained were evaluated by variance analysis, and there were differences at a statistically significant ($p < 0.05$) level in the characters subjected to the study in terms of their distances to the base station. Later, the data obtained were tabulated and interpreted by applying Duncan test.

Results

The changes in characters evaluated within the scope of the study depending on the distance to the base station, F value obtained as a result of the variance analysis, and the groupings formed as a result of the confidence level and the Duncan test are given in Table 1.

Table 1 shows that all characters depending on the distance are statistically significant ($p < 0.001$). When the table values are examined, it is seen that all characters are negatively affected by the distance, there is a considerable decrease in the number of flowers and cones when the base station is closer, and that the germination percentage decreases, significantly. In order to understand how the characters changed depending on the distance from the base station more easily, the distance values of the 800 m, which was the farthestmost distance to the base station and where the highest values were obtained, were accepted as 100, and the changes in the characters depending on the distance were evaluated by proportioning to this value. Thus, as the distance decreased, the rate of getting affected to be determined

Table 1 Changes in the characters depending on the distance

Distance (m)	FF: the Number of Female Flowers (piece)	MF: the Number of Male Flowers (piece)	C1: the Number of One-year-old Cones (piece)	C2: the Number of Two-year-old Cones (piece)	GP: Germination Percentage (%)
100	44.26	247.94	59.74	57.30	33.2
200	69.68	435.84	66.70	53.86	41.0
300	119.48	538.06	89.52	75.58	50.2
400	134.00	673.28	138.76	136.90	62.2
500	181.96	820.24	150.94	140.28	68.2
600	220.68	1278.56	164.14	147.08	70.6
700	322.42	1735.42	238.56	221.14	79.2
800	502.02	2868.26	434.24	417.16	91.0
F Value	$F(7, 39) = 199.312^{***}$	$F(7, 39) = 87.042^{***}$	$F(7, 39) = 68.884^{***}$	$F(7, 39) = 63.608^{***}$	$F(7, 39) = 65.266^{***}$

***Significant at 0.001 level

in percent. The proportional values obtained as a result of this calculation are given in Table 2.

The proportional values given in Table 2 shows that the level of getting affected of the characters depending on the distance to the base station can be seen more clearly. It is seen that the values obtained at 100 m distance, which is the closest distance, are 8.82% of the values obtained at 800 m distance for FF, 8.64% for MF, 13.76% for C1, and 13.74% for C2. That is to say, the number of flowers and cones in the individuals at a distance of 100 m decreases to an average of 10% of the individuals at a distance of 800 m. GP rate decreases down to approximately 1/3. In order to understand the decrease in values more easily, proportional changes depending on the distance are given graphically in Fig. 1.

Discussions

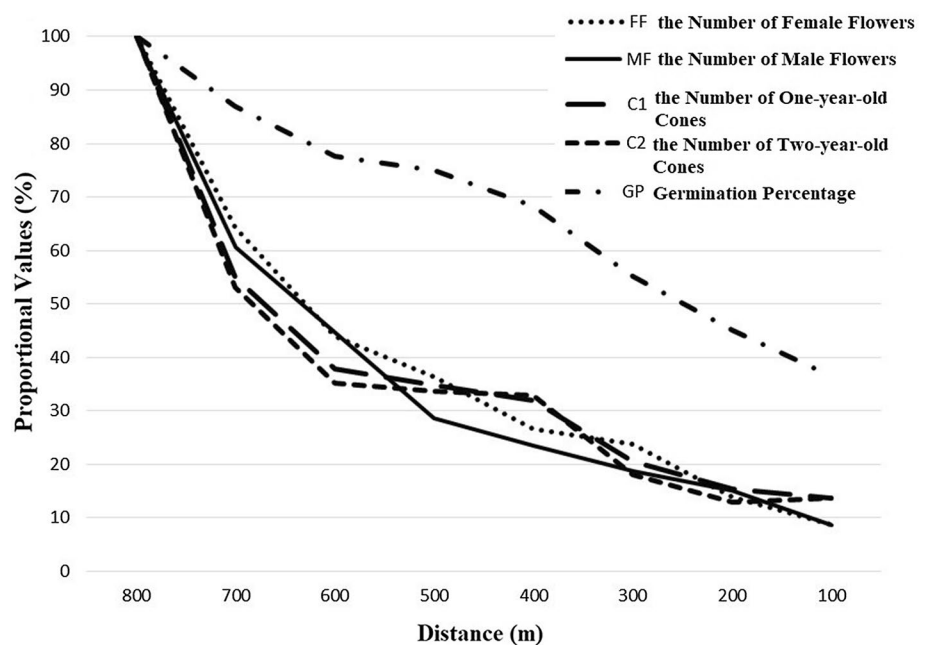
The study results revealed that the location of the base station significantly reduced the number of flowers and cones in the *P. brutia* individuals, and that the values obtained in individuals at a distance of 800 m from the base station were 11 times more than the individuals at a distance of 100 m from the base station in the number of flowers and 7 times in the number of cones. In the seeds subject to the study, there is a three-times difference in terms of the germination percentage among the individuals furthest and closest to the base station. These results show that the individuals of *P. brutia* are affected by the base station, significantly.

Table 2 Proportional values depending on the distance

Distance (m)	FF: the Number of Female Flowers (piece)	MF: the Number of Male Flowers (piece)	C1: the Number of One-year-old Cones (piece)	C2: the Number of Two-year-old Cones (piece)	GP: Germination Percentage (%)
100	8.82	8.64	13.76	13.74	36.48
200	13.88	15.2	15.36	12.91	45.05
300	23.8	18.76	20.62	18.12	55.16
400	26.69	23.47	31.95	32.82	68.35
500	36.25	28.6	34.76	33.63	74.95
600	43.96	44.58	37.8	35.26	77.58
700	64.22	60.5	54.94	53.01	87.03
800	100	100	100	100	100
F Value	F (7, 39)=65.543***	F (7, 39)=46.154***	F (7, 39)=38.776***	F (7, 39)=42.719***	F (7, 39)=51.155***

***Significant at 0.001 level

Fig. 1 Proportional changes depending on the distance



All living beings are continuously exposed to both artificial and natural electromagnetic radiation (Alattar and Radwan 2020). However, as seen in the study results as well, the effect of artificial radiation on plants is at a quite high level. Electromagnetic radiation, especially radiation emitted from the routers, can affect all living systems, cells, tissues and organs in various ways (Belpomme et al. 2018; Miller et al. 2019; Batool et al. 2019). In the studies conducted to date, the effects of electromagnetic radiation on humans (Baah et al. 2019; Przystupa et al. 2019), mammals (El-Shanshoury et al. 2016; Narayanan et al. 2018; Micheli et al. 2019; Elwasife et al. 2019), amphibians (Cramp and Franklin 2018; DeMarchi et al. 2018; Londero et al. 2019), ants (Cammaerts et al. 2013), birds (Everaert and Bauwens 2007), fruit flies (Panagopoulos 2012), ticks (Vargova et al. 2018) and honey bees (Kumar 2018; Taye et al. 2018) were examined.

Electromagnetic radiation is considered as an effective stress factor on the growth and development of plants (Majd et al. 2012). The responses given to the stress factors by plants are shaped by the mutual interaction of many factors such as plant species, genetic structure, stress level, and other environmental conditions (Cetin et al. 2018a, b; Sevik et al. 2020a, b). Also, the effect of electromagnetic radiation on living systems changes depending on the characteristics of the exposed tissue, power level, exposure time, frequency and pulsed or continuous wave (Nyangaresi et al. 2019; Romeo et al. 2019). The responses occurring in different plant species are based on both the physical parameters of the radiation source and the condition of the biological material such as plant and population structure and environmental conditions (Ursache et al. 2009).

Being exposed to radiation affects metabolic activities, gene expression and plant development in plants (Alattar et al. 2017, 2018). In fact, these changes are not only seen in tissues exposed to direct radiation, but also in adjacent tissues (Vian et al. 2016). In plants, electromagnetic radiation exposure is reported to affect important physiological processes such as respiration (Kebeish et al. 2015), substance transport (Singh et al. 2013; Kumar et al. 2017), photosynthetic pigments (Goh et al. 2014; Hong et al. 2014), photosynthesis (Ahuja et al. 2014), functioning of the hormonal system (Deng et al. 2017; Bitarishvili et al. 2018), antioxidant system (Noctor et al. 2018; Czarnocka and Karpiński 2018) and cellular division process (Răuciu et al. 2018).

Moreover, electromagnetic radiation is reported to cause some changes in plants at the cellular and molecular level (Gudkov et al. 2019; Ribeiro-Oliveira 2019). In general, it is known that electromagnetic radiations stimulate physiological, cytological, ultrastructural and genetic modifications of living cells (Gudkov et al. 2019). Electromagnetic radiations primarily act on the cell membrane and affect the activation of ions and the polarization of dipoles in living

cells (Mohorič and Bren 2018). It has been proved that electromagnetic radiation creates a real environmental stimulus to evoke specific responses in plants. Exposures to electromagnetic radiation have been found to evoke the expression of specific genes previously found in plants in response to injury and to help modification of the plant. It has also been found that both biochemical and molecular changes are observed after the plant is exposed to electromagnetic radiation, and also some morphogenetic changes are observed in plant development (Vian et al. 2016; Ansal et al. 2018). The studies conducted show that mobile phone EMR is effective on the growth of plants. Sometimes, these effects can be positive. In fact, it is stated that EMR may increase plant growth in some plants (Pietruszewski et al. 2007; Editya et al. 2015). However, in most of the studies, it is reported that plant growth is adversely affected, and the number of trees decreases when getting closer to a base station (Batool et al. 2019).

Afzal and Mansoor (2012) found that 72 h long cell phone exposure (900 MHz) did not affect germination in *Vigna radiata* and *Triticum aestivum* plant seeds, but there were a growth inhibition, a decrease in protein content, and a strong growth in enzyme activity of ROS metabolism for the seedlings of both species. The fact that electromagnetic waves significantly affect the hormone composition of plants has been mentioned in other studies as well (Mildažienė et al. 2019). This is a proof that the said radiation can cause some damages, which are not visible or noticeable in a short time, to plants. Plant development is shaped by the mutual interaction of genetic structure and environmental conditions (Yigit et al. 2019; Cetin et al. 2020). The studies conducted show that electromagnetic radiation may cause changes in plant genetic structure (Tewari et al. 2016; Panagopoulos 2019; Ortega and Masood 2020). In addition, it is stated that electromagnetic radiation can affect plant growing conditions, which then affect plant growth. For example, EMR may generate heat, and microorganisms on the upper surface of the soil may die due to this heat (Sivani and Sudarsanam 2012). Similarly, it is stated that the water exposed to the radiation in question can also affect the plant growth, significantly. The studies conducted on the subject show that environmental conditions exposed to radiation directly or indirectly affect differentiation of flower buds, flower development, fruit ripeness and growth, and fruit quality (Julian et al. 2010; Fischer et al. 2016; Alattar and Radwan 2020). Electromagnetic radiation can significantly affect plant growth either directly or indirectly. In this study, it was found that the number of flowers and cones decreased significantly as they got closer to the base station. Similar results were obtained by other researchers as well. For instance, Amir et al. (2018) revealed that the number of fruits in plants obtained from seeds treated with gamma rays considerably decreased compared to the control group. In other studies, UV-B radiation has been found to affect flower size

and number (Van de Staaij et al. 1997; Barbir et al. 2014). In addition to this, there are also some studies indicating that UV-B radiation does not have a significant effect on the number of flowers (Petropoulou et al. 2001; Wang et al. 2008). Being directly or indirectly exposed to radiation causes some effects on plant stress and vegetative tissue, as well as plant morphology such as flower formation and the structure and number of flowers (Ballare et al. 2011; Llorens et al. 2015). Since flower formation is related to environmental conditions, there is a delay in flowering in plants under stress (Tooke et al. 2005; Chaudhry and Khan 2006). Radiation exposure of plants may also cause this process to occur.

Conclusions for future biology

There is a large number of devices that constantly surround us and expose us to electromagnetic radiation. Nevertheless, the number of studies on the effects of continuous exposure is a minute amount. A great difference was found between the number of flowers and cones in trees growing at a distance of 100 m from the base station and those growing at a distance of 800 m. However, in the literature, there are some study results indicating that exposure to the radiation in question does not significantly affect fruit and flower yield in plants, in fact it increases the yield. These studies model the short-term exposure. For this reason, it is recommended to conduct studies regarding the results of long-term exposure based on periodical checks. Therefore, it will be quite useful to diversify the studies regarding the subject on different living things and to continue the studies in a way to evaluate the changes in terms of biological diversity in detail and to take all variables into consideration. It is recommended that future studies will focus on the damages that electromagnetic pollution can cause in living things at the cellular level, the change of these damages on the basis of species and subspecies, especially the exposure times and harm relationships for humans, and the necessary measures to be taken to prevent these damages.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest. The none of the authors have any competing interests in the manuscript.

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