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The Effects of Sound Waves upon Plant Nutrient Elements Uptake of Sword Fern (*Nephrolepis Exaltata*) Plants

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ABSTRACT

The plants are frequently exposed to stress during their growth and development under both natural and agricultural production conditions. In our study, the effects of sound waves which are an alternative mechanic stress upon the nutritional element uptake of *Nephrolepis Exaltata* plant were researched. *Nephrolepis Exaltata* is an interior area plant existing commonly within closed areas such as houses and workplaces. At 90 dB constant sound intensity level and 3 different frequency values as 600, 1240 and 1600 HZ, nutritional element (N, P, K, Mg, Ca, Fe and Zn) analysis were performed for the plants that were sent sound waves for a one-week period. As result, N, Mg and Ca contents were determined as the highest at 1240 HZ sound frequency and the P and K contents as the highest at 600 HZ sound frequency. Uptake of Fe and Zn micro elements increased with the increase at the frequency; the level of frequency creating a negative effect was not determined in this study. A new further study is necessary to determine this.
KEYWORDS: Sound wave, dB, *Nephrolepis Exaltata,* plant nutrient elements

1. INTRODUCTION

Under both natural and agricultural production conditions, plants are frequently exposed to environmental stress. Environmental stresses can be biotic (such as weeds, pathogens, and insects) and abiotic (such as drought, salinity) [11]. The concept of stress is closely correlated with the concept of tolerance. Stress tolerance is the coping potential of a plant with inappropriate environmental conditions. The stress leads to metabolic and physiologic changes that affect the growth and development in plant [1].

Stress of the sound waves mentioned in this study takes place within the group of abiotic stress factors. Stress waves have effects upon growth and development of plants as an alternative mechanic stress [2], [3].

Plant nutrition uptake provides nutrition of plants and development and growth of plants and has a role in biochemical events [4].

The changes in nutritional element uptake of sword fern (nephrolepis exaltata) plants exposed to sound stress at a Constant sound level (dB) and 3 different HZ values were researched. The purpose to choose interior type as a sample plant in this study is these plants' being exposed to constant sound stress in closed areas such as houses and workplaces. Because the frequency of sound intensity has not been fixed in houses and workplaces, the frequencies were changed in the experiment and their efficiency on nutritional element uptake of the plants was analyzed. As nutritional elements, N, P, K, Mg and Ca contents required to be at macro level for plant growth and two important element contents required to be at a micro level were analyzed.

2. MATERIAL AND METHOD

2.1 Sound Sizes : Sound pressure *p*(t) is a most frequently encountered and time-dependent size that is not only characterized with sinusoidal vibrations. In a simplified form, active sound pressure *p* is more practical. The average value from the changing sound pressure during observed *T* can be calculated as such:

$$P=\sqrt{\frac{1}{T}\int P^2(t)dt}\ ,\ [Pa]$$

Here, Pa unit shows Pascal $\left[\frac{N}{m^2}\right]$.

This calculation has recently been used by the numerical sound measurement instruments. The second characteristic size of the sound is sound velocity changing according to the time ($v(t)$).

Similar to the sound pressure, average sound velocity (v) can be calculated as:

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$$v = \sqrt{\frac{1}{T}\int_0^T v^2(t)dt} \left[\frac{m}{s}\right]$$

The rate of sound pressure to sound velocity gives a sectional and time-dependent constant. This constant is the characteristic size of the environment and referred as the impedance or internal resistance – wave resistance:

$$Z_0 = \frac{\rho}{v}$$

Here; ρ is the density of the environment the sound propagation, *v*: sound velocity and *c*: sound propagation velocity. Perception limit of the people includes different sound intensities that are tens of times bigger than each other. And this compels us to use the unit of decibel [dB] which is a level criterion. When the level is mentioned, it should be understood the logarithm of an energy-physical size's rate to a specific basic value. Another meaning of dB is perceived level of sound or noise level. The basic sound intensity for a sound intensity level is the acoustic nerve at I_0; 1000 Hz:

$$L_I = 10\text{Log}\frac{I}{I_0} \left[dB\right]$$

Sound intensity is proportional to the square of sound pressure $(I \sim p^2)$. Here, the level of sound pressure is found as:

$$L_p = 10\text{Log}\frac{p^2}{p_0^2} = 20\log\frac{p}{p_0} \left[dB\right]$$

Here, the basic sound pressure is accepted as 2.10^{-5} Pa at p_0; 1000 Hz acoustic nerve. Sound level meters directly show the level of sound pressure at decibel unit through the help of these formulas [5]. Sound Power Level is the measure of total sound power propagating in a non-directional way from the source and it is referred as logarithmically as in the level of sound intensity. Reference power is 1picowatt/m^2; namely, $10^{-12}W/m^2$. [10].

$$SPL = 10\text{Log}\frac{W_{source}}{W_{reference}}$$

Here W_{source} refers the total power propagating from the source [10]. Sound waves are in the form of a sine wave. The distance between the two crests is called as the wavelength and the number of wave crests observed in a second is called frequency. This physical term is the same with the quantity mentioned as the level of sound by the musicians. Taking sound pressure of a sound depending upon the frequency is known as frequency Analysis. Graphical presentation of the results is called Sound Spectrum. Sounds with low frequency are bass and sounds with high frequency are high-pitched.

2.2 Experimental Apparatus: In the experiment, dB indicative sectional adjustable Amplifier, signal Generator (Adjustable frequency oscillator) in order to create a frequency, sound-deadening 3 2x2 rooms openable and closable on 4 sides and a sound level meter were used.

In the experiment, totally 3 rooms were used and each room only heard the sound inside itself. As it shown figure 1. No outside sound came into any rooms and other rooms in the experimental area did also not hear each other. Before the experiments, tests were performed.

Within each room, a 360^0 sonorous speaker at a 43 cm height from the ground was used as being located in the center of the room. In the experiment, 2-liter pots including the plants were placed to the cabins to which sound waves having different frequency values were applied. In the experiment with three replications, 15 pots in the same type were placed within each cabin because the samples will be taken for 3 weeks. These pots were placed at a nearly 65 cm distance to the speaker circularly. So, each pot had the same distance to the speaker. The reason for choosing the distance as 65 cm is to perform sound measurements in a sufficient distance from the source in order to protect the sound pressure and sound velocity rate. Then, dB value measured with sound level meter was taken to 90 dB, and this dB value was adjusted constantly from the amplifier. The experts mention that being exposed to the sound over 85 dB can be dangerous. So, dB value in the experiment was chosen as 90dB constantly. Moreover, control plants were placed to a cabin in which no sound waves were sent, and the applications were compared with the control.

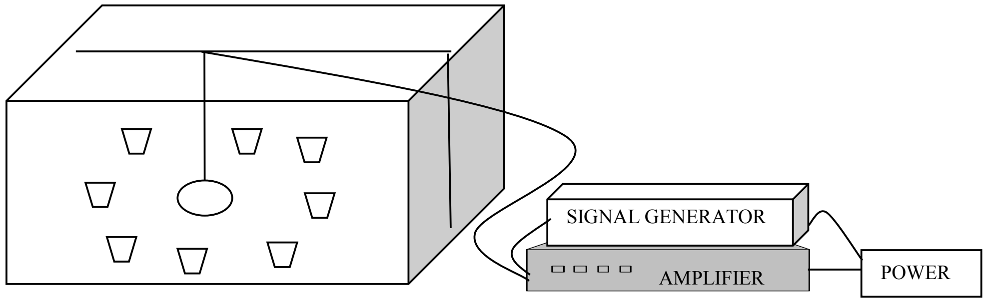

Figure 2.1 Experimental setup

The experiment lasted for 3 weeks. To the each cabin, sound waves at 90 dB sound intensity with 600Hz for the 1st week, 1240Hz for the 2nd week and 1600Hz for the 3rd week were sent, respectively. During the experiment, the amount of frequency at a constant dB value was changed at the end of each 7 days. Namely, an analyzed plant at the end of 3 weeks was exposed to a sound wave at 3 different frequency levels. The sound wave was sent to cabins for 30 minutes in 6 hour intervals for twice. These hours were 9.00 and 9.30 in the Morning and 3.00-3.30 in the Afternoon. In the experiment, when the plants were only exposed to stress, they were within a closed area. The plants, including the ones that were not exposed to the sound wave, were not fed during the 3-week experimentation period and they were only watered at equal amounts once in 2 days. The leaf samples were taken in 7th, 14th and 21st days after starting the sound application. In nutritional element analysis, total nitrogen was determined according to Kjeldahl and phosphor was determined according to Barton methods. K, Ca, Mg, Fe, Zn analysis were made according to the dry combustion method. The samples were dried and grinded, and then combusted at 550 ^{0}C, solubilized within %3.3 (v/v) HCl and their element concentrations were read at atomic absorption spectrometer (Varian 220 FS) in emission mode. The amount of chlorophyll was determined colorimetrically based upon leaves' homogenize in 80% acetone [7].

3. RESULTS

The effects of sound stress upon the nutritional element uptake of sword fern (*Nephrolepis exaltata*) plant were found as statistically significant upon phosphor and magnesium, among the macro nutritional elements. It also created an affect upon the uptake of other nutritional elements; however, this effect was not found as statistically significant (Table 2).

Table 1- Plant nutritional element content in leaves of sword fern (*Nephrolepis exaltata*) plant exposed to different sound frequencies

Nutritional element	Control	600 HZ	1240 HZ	1600 HZ	LSD % 5
N	15.06	14.7	18.1	16.4	
P	13585 b	31175 a	10985 b	12910 b	5612.65***
K	8280	15820	7490	10760	
Mg	2959 b	2385 c	3656 a	2948 b	517.23**
Ca	6526	4912	8805	6711	
Fe	44.53	46	71.1	82.8	
Zn	**22.5**	**18.3**	**27**	**29.9**	

The nitrogen content in leaves was determined in 1240 HZ application with the highest frequency value; the subsequent applications were 1600 HZ, the control and 600 HZ (Figure 3.1).

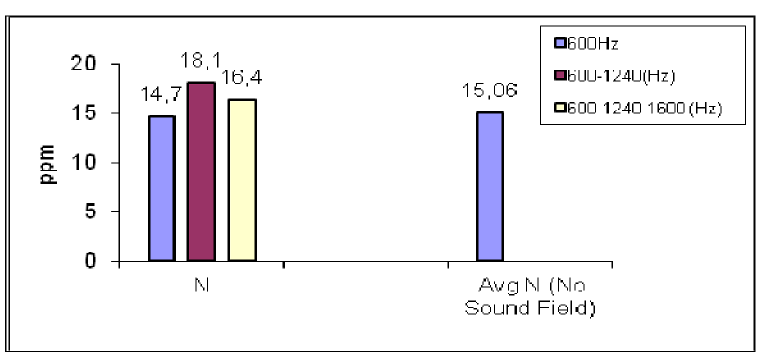

Figure3.1 Changing nitrogen contents with various frequencies

600 HZ frequency value of phosphor and potassium amount was noticed to be increased much more than the control plants. Phosphor and potassium contents were determined less in 1240 HZ frequency value than the control plants. At 1600 HZ, the level of phosphor was determined as nearly the same with the control plants, but the amount of potassium was determined as increased. (Figure 3.2)

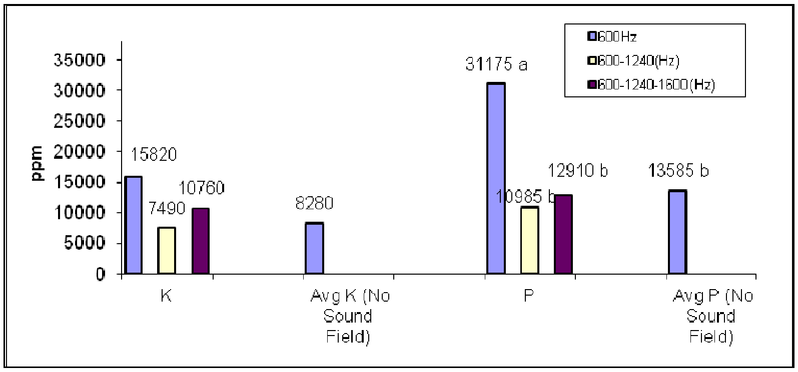

Figure 3.2 Changing phosphor and potassium contents with various frequencies

When the other nutritional elements (N, Ca, Mg and Zn) were analyzed, it was determined that they decreased at 600 HZ frequency value and nutritional element uptake of those increased more than the control plants at 1240 and 1600 HZ (Figure 3.3 and Figure 3.4).

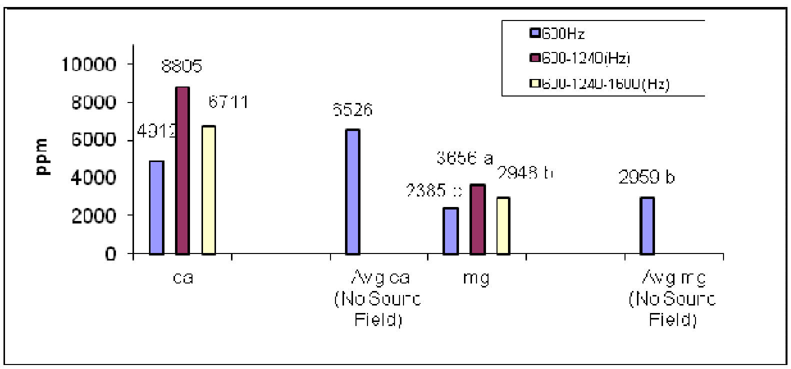

Figure 3.3 Changing calcium and magnesium contents with various frequencies

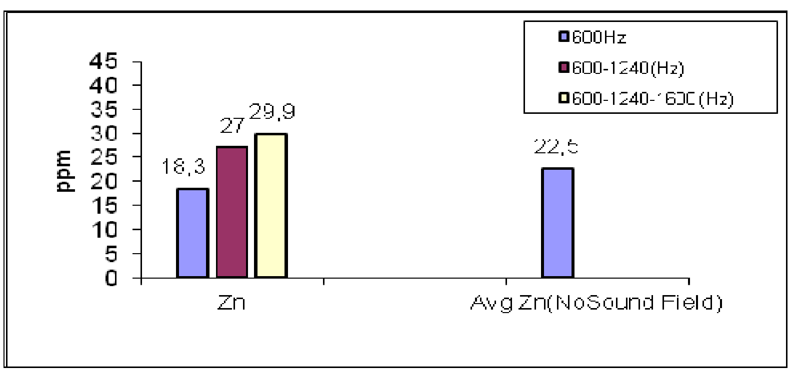

Figure 3.4 Changing zinc contents with various frequencies

The content of iron increased more than the control plants in each of the three applications. As the frequency value increased, the iron uptake increased, as well (Figure 3.5).

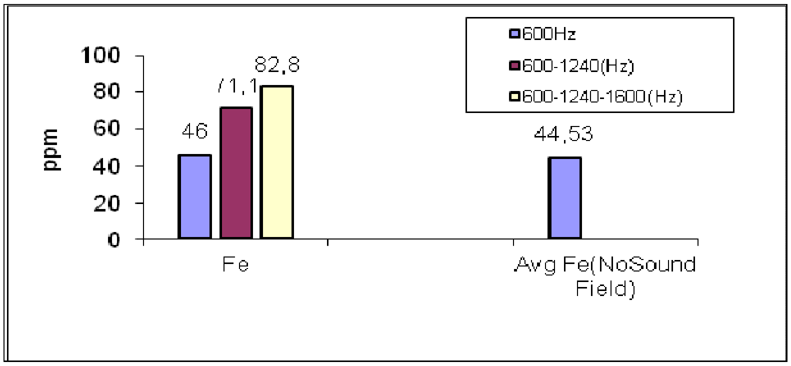

Figure 3.5 Changing iron contents with various frequencies

Lichtenhaler [7] mentioned that environmental factors prevented the growth of plant and gave damage when they were beyond the tolerance threshold of plants. However, it has been recently determined that if the stress is low it is not harmful and even advantageous. In our study represented here with its results, it was specified that the stress at a specific level affected the nutritional element uptake positively; but when the continuity and severity of the stress increased, the uptake was determined as decreasing.

4. DISCUSSION AND CONCLUSION

When the results of our study were analyzed, it was noticed that the highest N content was at 1240 Hz frequency value. The plants reduced N uptake in the first one-week 600 Hz frequency application in which they were exposed to the stress, but this uptake increased at 1240 Hz. Afterwards, this uptake was noticed to be decreasing as the frequency increased. The best frequency level for N uptake which is an efficient nutritional element on vegetative development of plants was determined as 1240 HZ for sword fern (*Nephrolepis exaltata*) plants, this can be accepted as a reference value. In terms of phosphor, 600 Hz was determined as the best frequency value. As the frequency increased, phosphor uptake was highly affected and this effect was found as statistically significant. P uptake at 600 Hz was doubled though phosphor is an element that is hard to take out of the soil. As in the phosphor, 600 Hz was determined as the best frequency value in potassium and K content was found as two times more. However, determining a K content lower than the control plants at 1240 and 1600 Hz revealed that potassium uptake decreased at high sound frequencies and it was affected negatively. In terms of the Mg and Ca uptake, effect of the frequencies was nearly the same. In the first week when the stress emerged, Mg and Ca uptake at 600 Hz decreased in the plant, and had the highest value at 1240 Hz. As the frequency increased, the uptake started to decrease again. Iron uptake increased as the frequency increased and the highest value was obtained at 1600 Hz. The zinc content decreased in the first week as in Ca, Mg and Fe; however, it increased at 1240 Hz and determined as the highest at 1600 Hz.

The limit value for Fe and Zn as the most important ones among the micro nutritional elements could not be determined. Uptake of these two elements increased at 1600 HZ; namely, Fe and Zn uptake was positively affected from the increase at frequency. In order to determine at which frequency Fe and Zn uptake would decrease; in other words in order to determine at which Hz the negative effect occurred, a new study should be carried out. However, in terms of sword fern (*Nephrolepis exaltata*) plant, the best frequency value for macro nutritional elements N, Mg and ca was at 1240 Hz, and for P and K, the best frequency value was determined at 600 Hz.

In the study carried out by Yi et al. [8] It was determined that the most efficient frequency value at 100 dB sound level for the growth of chrysanthemum callus was 1000 Hz, but 2000 Hz had a harmful effect upon the plant growth. In terms of the chrysanthemum, 1000 Hz and 100 dB were determined as having the positive effect upon the growth. In that study, positive and efficient sound frequency determining for sound waves was performed as in our study. In a study carried out by Yiyao et al. [9] with chrysanthemum, it was also specified that the best dB and frequency value when the calcium - an important element for the plant growth - uptake was the best was at 100 dB and 800 Hz. This value was determined as 90 dB and 1240 Hz for sword fern (*Nephrolepis exaltata*) in our study.

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