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Letter to the Editor

Biochemical and physiological changes in plants as a result of different sonic exposures

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Abstract

The effects of two different sonic exposures on two vegetables, namely Chinese cabbage and cucumber at two growth stages, including seedlings and mature plants were investigated. The 3 h exposures included either 20 kHz sound waves or "green music" that comprised classic music and natural sounds such as those of birds, insects, water, etc. Analysis of variance between groups (ANOVA) was used to determine the appropriate statistics parameters for the different treatments. Both exposures caused significant elevations in the level of polyamines (PAs) and increased uptake of oxygen O_2 in comparison with the controls. For Chinese cabbage the highest PAs' levels were determined for both seedlings and mature plants that were exposed to "green music". The oxygen uptake in Chinese cabbage also increased as a result of sonic exposures, and the highest oxygen uptake was also observed after "green music" treatment. For cucumber, the highest content of PAs for both seedlings and mature cucumber plants was determined as a result of 20 kHz ultrasound exposure. 20 kHz exposure of mature plants also resulted in the highest level of oxygen uptake. No statistically significant differences in the vitamin C level were determined between the different sonic treatments and sham exposed vegetables.

Keywords: Sonic; Vegetables; Polyamine; O_2 uptake; Vitamin C

1. Introduction

In general, there exist relatively few studies describing the influence of music or sound exposure and plants.Although plant's growth after exposure to music and the fact that the "green music" (such music comprises classic music and natural sounds such as those of birds, insects, water, etc.) could promote plants' growth and enhance their infection-resistance to diseases and pests were recently reported [1,2]. However, these works have not attempted to explain the mechanism of such interaction. Therefore, a number of experiments was carried out between 1999 and 2001 to determine the relationship between the exposure of plants to sonic energy and the subsequent plant growth and their insect's susceptibility in South Korea and China. The preliminary results demonstrated that the sonic exposure, particularly to "green music", could increase the yield of the crops and control some insect pests in several vegetables, including Chinese cabbage and cucumber. It was also noted that an exposure to "green music" resulted in the change in the body color of green peach aphids [3,4].

This paper describes the results of a pilot study designed to examine biochemical and physiological changes in selected vegetables, namely cucumber and Chinese cabbage introduced by the exposure to 3 h of "green music" and 20 kHz ultrasound (continuous wave sound).

2. Materials and methods

As a convenient biochemical indicator PAs were selected. Polyamines mainly consist of Put (putrescine, 1,4-diaminobutane), Spd (spermidine), Spn (spermine), Cad (cadaverine), Agm (agmatine), and Dap (diaminopropane). They can be found in every plant and their

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concentration increases in rapidly growing tissues. PAs biosynthesis often increases greatly prior to growth and is related to hormones, level of senescence or ageing and fragility, light and stress. Also, PAs were reported to be able to stimulate and control growth in a number of higher order plants [5,6]. In addition, vitamin C is well known as an important component of vegetables and is considered to be one of the important indices of food quality [10]. One of the goals of our work was to study the influence of external acoustic energy on PAs and vitamin C, so the mechanism of interaction between ultrasound energy and plant tissue could be better understood. Several studies of plant physiology show that a high respiratory rates occur not only in fast-growing tissues, but also as a consequence of environmental stress, e.g. frost, injury or infection, or as an aging phenomenon. Physical injury to higher plant tissues often stimulates oxygen uptake because of increases in respiration (mitochondria-linked oxygen uptake) and in non-mitochondria activities (e.g. lipoxygenase, polyphenol oxidase, peroxidase) [7–9]. Hence, if the respiratory rate is raised during or after a sonic exposure, it is because the plant grows faster or it has suffered a physical injury. A few relevant reports [1,2] and the results of our preliminary research [3,4] indicate that the increase in a respiratory rate of the vegetables caused by the accelerated plants' growth was due to sound exposure. Another goal of our study was to determine whether exposure to external acoustic energy is capable of increasing or decreasing the rate of oxygen uptake in Chinese cabbage and cucumber. The relationship between acoustic exposure and plant growth is complex in that more often than not different vegetables have different responses to acoustic energy. Also, at different growth stages the same plants may have different responses to same acoustic energy. In the following our experimental methods are briefly described and the results obtained are discussed.

The Chinese cabbage and cucumber were exposed in three different greenhouses to "green music" (G.M.), 20 kHz continuous wave ultrasound (U.S.), and natural background sound (control) respectively. The vegetables were exposed to 3 h per day of "green music" and 20 kHz ultrasound in 3 m × 3 m × 2.2 m, vegetable greenhouses. 20 kHz was selected as the exposure frequency because this frequency lies outside that of human hearing and did not represents any annoyance to the farmers working in the greenhouse. Also, 20 kHz frequency lies relatively close to the highest frequency components in the green music spectrum, which makes the comparison between those two exposures easier.

A 200 W tape recorder/power amplifier unit (KGM-60F, S. Korea) with associated loudspeakers was used for green music exposure while 300 W ultrasonic generator (KW-506, S. Korea) was used to produce 20 kHz continuous wave. The generator was capable of generating frequencies beyond 20 kHz and therefore, it was used with a 20 kHz low pass filter. The tape recorder and ultrasonic generator were positioned in the corners of the two greenhouses respectively. The third greenhouse was used as control. Equivalent exposure level (Leq) of the green music was determined to be 75 ± 5.54 dBA (here "75" is the mean value of numerous data of sound pressure level and "5.54" is the standard deviation), and the sound pressure level (SPL) of the CW, 20 kHz ultrasonic wave was kept at the level of 75 dBA. Both measurements were carried out in the center of the greenhouse room. Because the greenhouse volume (3 m × 3 m × 2.2 m) was relatively small all plants were exposed to a relatively uniform level of acoustic energy.

The exposed vegetables were sampled twice: after 15 days (15 d) when they start to grow the second genuine leaves and after 70 days (70 d), that is when the plant reached its early maturity. As discussed below, analysis of variance between groups (ANOVA) was used to determine the appropriate statistic parameters for each treatment.

3. Results and discussion

In the discussion below, the following notation is used:

F	describes: F statistic, F = (variance between groups)/(variance of random),
df	denotes: degrees of freedom in ANOVA,
P	is probability in ANOVA analysis, e.g. $p < 0.01$ or $p < 0.05$ means the difference between groups is significant, and the level of confidence is over 99% or 95% respectively; "Significantly" means notable difference in statistics between groups,
d	refers to days after exposure.

3.1. Polyamines content

Fig. 1 presents the results obtained for Chinese cabbage: PAs content of 15-d seedlings was significantly higher after 20 kHz and green music exposure than that determined for control (genuine leaf: $F = 538.28$, df = 2, 12, $p < 0.01$; cotyledon: $F = 3720.11$, df = 2, 12, $p < 0.01$; stem: $F = 2183.97$, df = 2, 12, $p < 0.01$). For 70-d mature Chinese cabbage vegetable PAs content was significantly higher after green music exposure than that determined after 20 kHz ultrasound treatment and that measured in control ($F = 1157.28$, df = 2, 12, $P < 0.01$). The primary PAs detected were conjugated spermidines (Spd). Among all three different treatments, the green music exposure also resulted in the highest growth rate and fresh weight.