Dual effect of audible sound technology on the growth and endogenous hormones of strawberry

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Abstract: Sound waves could improve the growth and increase yield. However, it could be a form of environmental stress. Therefore, the aim of this study was to investigate the effects of audible sound on the growth and endogenous hormones of strawberry plants (*Fragaria_ananassa)*. Five endogenous hormones, namely Indole-3-acetic Acid (IAA), Gibberellin (GA), Abscisic Acid (ABA), Jasmonic acid (JA) and Zeatin Riboside (ZR) have been investigated. Plants were exposed to sound frequency of 0.1 - 1 kHz and sound pressure level (SPL) of 70 - 100 dB for 2 hours, 3 hours and 5 hours at different growth stages. Results revealed that plants had different responses to sound waves at different growth stages. Acoustic frequency could accelerate the blooming and the flowering rates in a short run. In contrast, exposing plants to sound for more than 3 hours per day for a long run more than 40 days could inhibit the growth. However, sound treatment could significantly accelerate the blooming and the flowering rates. The maximum concentration of ABA was in leaves of the treated plants for 90 days, each day for 5 hours. Whereas, mean of IAA levels in leaves of control plants was insignificantly higher than those of the treated plants for 5 hours and 2 hours after 90 days of sound treatment. Moreover, no significant difference was found in the concentration of JA in leaves between all treated plants and control plants after 75 and 90 days. In conclusion, audible sound could stimulate or inhibit the growth of strawberry plants.

Keywords: audible sound, endogenous hormones (IAA, ABA, JA, ZR and GA), strawberry growth.

Citation: Hassanien, R. H. E., B. Li, and T. Hou. 2020. Dual effect of audible sound technology on the growth and endogenous hormones of strawberry. Agricultural Engineering International: CIGR Journal, 22 (3):262-273.

1 Introductions

Audible sound (20 - 20000Hz) exists everywhere in the natural environment of plant community. Sound is the rapid motion of molecules. These molecular vibrations transport energy from a transmitter, a sound source, to a receiver. Thereby, sound travels in waves that transport energy from one location to another. Sound wave technology has recently been applied to a number of plants at various growth stages and more attention has been paid particularly to effects of audible sound on the growth and development of plants. However, the mechanisms of sound effect have not been revealed so far. Moreover, the interaction between audible sound and the endogenous hormones of plants is usually neglected in real filed experiments because most of the previous studies have been conducted under laboratory

Received date: 2019-06-26 **Accepted date:** 2019-09-19

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conditions. Effects of sound waves on plant characteristics and the changes of Chlorophyll fluorescence of cucumber and strawberries were significantly ($P<0.05$) increased in solar greenhouses (Meng, 2012). It was found that sound waves enhanced the strawberries resistance against disease and insects (Hassanien et al., 2014). Meanwhile, the treated strawberries were shifted earlier in blossoming and bearing fruit and Photosynthetic rate significantly increased (Qi, 2010). Audible sound treatments can reduce the germination period and improve the growth of mung bean at a sound intensity of 90 dB and frequency of 2000 Hz (Cai et al., 2014). On the other hand, the leaves of phylodendron could accept external sound wave stimulations, with frequencies lower than 150 Hz giving the strongest responses. The sound pressure level from the plant's leaves increased approximately 20-30 dB under drought stress, while the range of response to external sound wave stimulation decreased 10-20 dB. During the last few years, evidence has accumulated that sound stimulation could enhance disease resistances and decrease requirements for chemical fertilizers and biocides(M.E.K. Chowdhury, 2014). Furthermore, sound waves were efficient at getting the herbicide into the plant by stimulating leaf stomata to open; thereby the plant will be able to increase its uptake of spray fertilizer and dew(Carlson, 2013). Therefore, mature weeds can be sprayed with 50% less herbicide and biocide with sound waves treatments. It has been reported that plants can produce sound waves at relatively low frequencies of 50 Hz to 120 Hz spontaneously. Furthermore, plants might have a meridian system as in humans and other animals namely, internal frequency. Plants also can absorb and resonate to specific external sound frequencies (Hou, 1997). Sound waves might be absorbed by the leaf tissue and converted into heat (Martens and Michelsen, 1981). The effective sound speed in the plant-filled resonator is strongly dependent on plant biomass when exposed to a low frequency of 0.5 kHz to 2.5 kHz (Wilson and Dunton, 2009). Sound wave stress affected on antioxidant enzyme activities and lipid peroxidation of Dendrobium candidum(Li et al., 2008). Furthermore, It was found that audible sound treatment at 2200 Hz could effectively enhance the algae cultures in terms of biomass production and volumetric oil yield(Cai et al., 2016). In addition, the acoustic waves could be served as elicitor which could be a cheaper and friendlier with environment compared to the commonly used biotic or abiotic elicitors(Fernandez-Jaramillo et al., 2018). Sound waves could delay the ripening of tomato fruit by negatively regulating ethylene biosynthesis and signaling genes(Kim et al., 2015)

Strawberries are the leading soft fruits crop in the world. They have a high content of essential nutrients and beneficial phytochemicals, which seem to have relevant biological activity in human health(Giampieri et al., 2012). Plant endogenous hormones (IAA, ABA, JA, ZR and GA) concentrations produce a major growth change and play an important role in regulating the growth and development of plants under various environmental conditions and signaling networks (Bari and Jones, 2009). This study has been conducted to investigate the effects of sound waves treatments on the growth of Strawberry and to find out the optimum exposure period of sound waves under controlled conditions inside a Chinese solar greenhouses by exposing the plants to acoustic frequency generator for different exposure periods.

2 Materials and methods

2.1 Greenhouse facilities and plant material

Experiments were conducted from September to January in three Chinese solar greenhouses at Beijing, China (latitude 40.18°N, longitude 116.47°E) and elevation 63 m above sea level. The greenhouses dimensions were equally (50 m length, 7.5 m width and 3.5 m height) constructed of metal arches and included a thick wall on the north side, a partial roof on the north side and the cover over the southern part of the top. The north wall was a layered structure of 0.6 m thick constructed of bricks, Styrofoam insulation and an air layer. The 0.2 m thick north roof was made of layers of wood, Styrofoam and other structural materials. The cover on the south roof was made of a 0.00012 m thick polyvinyl chloride (PVC) film during the daytime with a 0.10 m thick cotton blanket laid over the roof each night. The greenhouses were not heated, and they had roof vents (0.5 m along the roof) that were opened for 5-7 h daily when the weather permitted as shown in Figure 1. The strawberries (*Fragaria_ananassa*) seedlings were planted inside the greenhouses on 1st September. The soil type was clay-loam and soil pH value was 6.4-7.0. Plants were set 0.2 m apart in two rows at raised beds with a distance of 0.8 m between beds; the beds of three greenhouses were oriented in a north-south direction. The strawberry was covered with 0.0003 m thick black polyethylene mulch. Honey bees visit strawberries for nectar and pollen. Thus, there was one colony of honey bees for each greenhouse in the blooming period. The irrigation system was drip irrigation for all treatments. Both Plant protection and fertilization systems were carried out as usual for this crop by the same labor staff.

2.2 Instruments

The Plant Acoustic Frequency Technology (PAFT) generator made by the Qingdao Physical Agricultural Engineering Research Center in China, has eight variable frequency levels arranged from 60 Hz to 1000 kHz and sound pressure levels (SPLs) 50 dB to 120 dB for a distance about 50 m to 100 m. PAFT produces an intermittent pulse of sound waves frequencies, the wave band can be spontaneously adjusted according to the ambient air temperature and relative humidity.

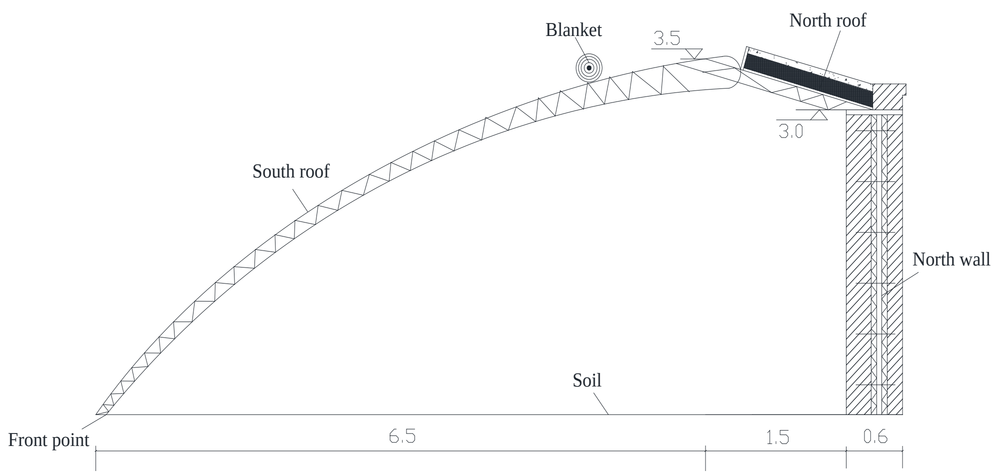

Figure 1 Cross-sectional view of a solar greenhouse with dimensions in m

The design of PAFT generator as shown in Figure 2 consisted of two main parts. The first part is the structure design and the second part is the circuit design, including five sections: (1) power 110/220 AC or 12V DC, (2) base frequency signal generate circuit (80-2000Hz), (3) impulse signal generate circuit, (4) amplifier, (5) speaker. The effective area for PAFT starts from 2500 m^2 to 15000 m^2. Sound level meter is used to measure the sound pressure level (dB) and made in China. Thermo recorder device RT-12/RS-12, made in Japan, is used to measure air temperature and relative humidity at accuracy of ±0.5°C and ± 5% RH.

A B C

(A) PAFT Generator, (B) Sound level meter, (C) Thermo recorder

Figure 2 Instruments

2.3 Sound waves treatments

Sound exposure treatments started at 17th of October, after the plants have four real leaves and the exposing period finished at the end of January. There were three treatments in three greenhouses about 100 m apart from each other. The first one was set as a control, and the second one was treated with PAFT for 2 hours, and the third was treated with PAFT for 5 hours on five days per week. Thereby, there were two days without any sound treatments for allowing farmers to irrigate or harvest the crop, all treatments were in the morning from 8:00 am to 12:00 noon as shown in Figure 3. The PAFT was fixed inside each greenhouse and the treatments were as pulse sine waves. There was a problem with sound dumpling in terms of the distances (E). Therefore, all measurements were in different distances from the source of sound.

(a) (b) (c)

(a) 5 hours (b) Control (c) 2 hours

Figure 3 Greenhouses and sound treatments

2.4 Measurements

2.4.1 Climate measurements

Air temperature (T) and Relative humidity (RH) inside and outside the greenhouses were monitored by a Thermo recorder, installed in the center of each greenhouse, 1.8 m above the floor for hourly recording.

2.4.2 Crop measurements

A series of non-destructive measurements were made in 40 randomly selected plants per greenhouse at different distances from PAFT (5 m, 10 m, 15 m and 20 m) from November to January namely day after treatment (DAT) 22, 32, 42, and 72 DAT. Measurements of number of leaves and number of flowers (including the fruits) were carried out. In addition, 40 leaves were randomly chosen in each greenhouse on the 60, 75 and 90 DAT to analyze five endogens hormones such as Indole-3-acetic acid (IAA), Abscisic acid (ABA), Jasmonnic acid (JA), Zeatin Riboside (ZR) and Gibberellin (GA). Leaves were sampled and stored at -80°C until use for the analysis of hormone levels.

2.5 The extraction, purification and determination of endogenous hormones levels

The extraction, purification and determination of endogenous levels of IAA, GA, JA, ZR and ABA were performed using an indirect ELISA technique (He, 1993; You-Ming et al., 2001).The samples were homogenized in liquid nitrogen and extracted in cold 80% (v/v) methanol with butylated hydroxytoluene (1 mmol L^{-1}) overnight at 4°C. The extracts were collected after centrifugation at 10000 ×g (4°C) for 20 min; the liquid supernatant was dried in N_2. The residues were dissolved in PBS (0.01 mol L^{-1}, pH 7.4) in order to determine the concentrations. Microfiltration plates (Costar) were coated with synthetic IAA, GA, JA and ABA ovalbumin conjugates in $NaHCO_3$ buffer (50 mmol L^{-1}, pH 9.6) respectively, then incubated at 37°C for 3 hours. Ovalbumin solution (10 mg ml^{-1}) was added to each well in order to block nonspecific binding. After incubation for 30 min at 37°C, standard IAA, GA and ABA, samples and antibodies were added respectively, and incubated for a further 30 min at 37°C. The antibodies against IAA, GA, JA and ABA were obtained as described

(Weiler, 1981; You-Ming et al., 2001). Then horseradish peroxidase-labelled goat antirabbit immunoglobulin was added to each well and incubated for 30 minutes at 37°C. Finally, the buffered enzyme substrate (orthophenylenediamino) was added, and the enzyme reaction was carried out in the dark at 37°C for 15 min and then terminated using 2 mol L^{-1} H_2SO_4. The absorbance was recorded at 492 nm.

2.6 Statistical analyses

The program SPSS 18.0 (SPSS Inc., Chicago, IL, USA) was used for the statistical analysis. Data and results from each sampling were analyzed separately. The data were given as the mean ± Standard Deviation and the level of statistical significance was set at $P < 0.05$.

3 Results and Discussions

3.1 Air temperature and Relative humidity

The average air temperatures inside greenhouses were 9.4°C, 9.4°C and 9.2°C and the average relative humidity ratios were 87.1%, 86.2% and 89% in the control greenhouse, treated greenhouse for 2 hours and treated greenhouse for 5 hours respectively. Meanwhile, the average Air temperature and relative humidity outside the greenhouses were -5.2°C and 47.7% as shown in Table 1. Air temperature inside the greenhouse fluctuated substantially, as well as that of the solar radiation. North wall is commonly employed for east-west oriented greenhouse. Because in east-west oriented greenhouse, maximum solar radiation falls on the south wall during winter months and leaves greenhouse through north wall due to low altitude angle of the sun.

A thick north wall and partial roof on the north side act as heat sinks to absorb solar energy during the daytime incident solar radiation impinges on the wall and significantly raises its thermal storage as shown in Figure 2. This stored energy is released during the night for thermal heating inside the greenhouse. On clear days, diurnal changes of air temperature show a steep increase in temperature after sunrise, maximum values near 2:00 pm then followed by a steep decrease with low values before the sunset.

Table 1 Maximum, minimum and average air temperature and relative humidity from 11 November to 25 January inside and outside greenhouses

Treated Greenhouses (Inside and outside)	Air temperature (° C)			Relative humidity (%)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
Greenhouse (Control)	39.6	-1.6	9.4	99	10	87.1
Greenhouse for 2 hours	39.5	- 2.0	9.4	99	9	86.2
Greenhouse for 5 hours	33.5	- 1.6	9.2	99	19	89.0
Outside the greenhouse	11	-20.2	-5.2	99	11	47.7

In contrast, the changes of relative humidity show a steep increase in relative humidity after sunset, maximum values at 7:00 p.m. to 6:00 a.m. and then followed by a steep decrease with low values at 12:00 noon to 15.00 after the sunrise on sunny days. Environmental control of flowering of the cultivated strawberry has been extensively studied (Taylor, 2002).Temperature is an important factor for floral initiation under short day conditions. The optimum temperature for short day floral initiation is 15°C-18°C, while below 10°C and above 25°C short day induction is rather ineffective (Verheul et al., 2007). These results indicated that Chinese solar greenhouses could retain the inside air temperature higher than the outside air temperature within about 12.5°C during the winter seasons. On the other hand, the increase of relative humidity in the morning was a critical problem in Chinese greenhouses which could increase the fungus diseases. Therefore, we tried to control this problem by opening the ventilation vents early morning after sunrise.

3.2 Effect of sound waves on plant growth parameters of strawberry

3.2.1 Effect of sound waves on the number of leaves

Figure 4 shows the dynamics of cumulative leaves per plant for different treatments from early November to late

January. The number of leaves per plant in the control greenhouse after 22 days of treatment was (5.4) significantly more than that of the treated greenhouses for 2 hours and 5 hours (p<0.05). Subsequently, the number of leaves per plant in the treated greenhouse for 32 days, each day for 2 hours was (6.6) significantly more than that of the control greenhouse. Consequently, no statistically significant difference was found between the treated greenhouses for 2 hours and 5 hours. Number of leaves increased with plant growth and reached a maximum (10.75) on 72 DAT in the treated greenhouse for 2 hours. It was also observed that the number of leaves in treated plants for 2 hours and 5 hours were insignificantly more than that of control after 42 and 72 days of treatments. That is to say, the long run of acoustic frequency technology treatments for only 32 days produced plants with more and vigorous leaves development.

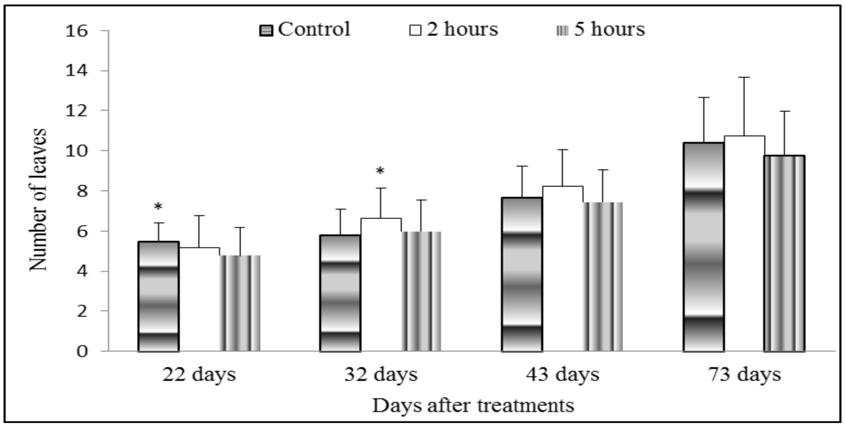

Figure 4 Effect of sound waves on the number of leaves

Note: * means significantly different at P <0.05 (n = 40). Vertical bars represent ± Standard Deviation of the mean.

3.2.2 Effect of sound waves on the number of flowers and berries per plant

Figure 5 shows the average dynamics of cumulative flowers including berries per plant for different treatments from early November to late January. Mean number of flowers including berries per plant after 22 days in the treated greenhouse for 5 hours was (1.70) significantly more than those of control greenhouse at p < 0.05. Meanwhile, there were no significant differences between the treated greenhouses for 2 hours and 5 hours. It was also observed that number of flowers and berries in treated greenhouse for 2 hours and 5 hours were insignificantly more than that of control after 32,42 and 72 days of treatments. Thereby, the strawberry plants grown in the treated greenhouse for 2 hours and 5 hours were better than those in control greenhouse. These results illustrated that the sound wave did not improve the vegetative growth after 22 days but accelerate the blossoms, which stimulated the strawberries to shift a week earlier in blossoming and bearing fruit. Acoustic technology could improve the flowering and number of fruits in two different ways. Firstly, sound energy and light energy both work together to improve the photosynthesis thereby, the growth will be improved. Secondly, acoustics could stimulate bees to go out from boxes for moving around which results in the improvement of the pollination and the fruit quality. Thus, using acoustic technology could allow the farmers to produce berries fruits at an earlier time and high quality to sell it with high prices. These results are quite similar to the previous studies (Francis et al., 2012) when noise pollution (around 95 dB) in natural gas wells area indirectly increased artificial flower pollination by hummingbirds, but altered the community of animals that prey upon and disperse *Pinus edulis* seeds, potentially explaining the reduced *P. edulis* seedling recruitment in noisy areas because black-chinned hummingbirds are more likely to visit and nest in noisy areas.

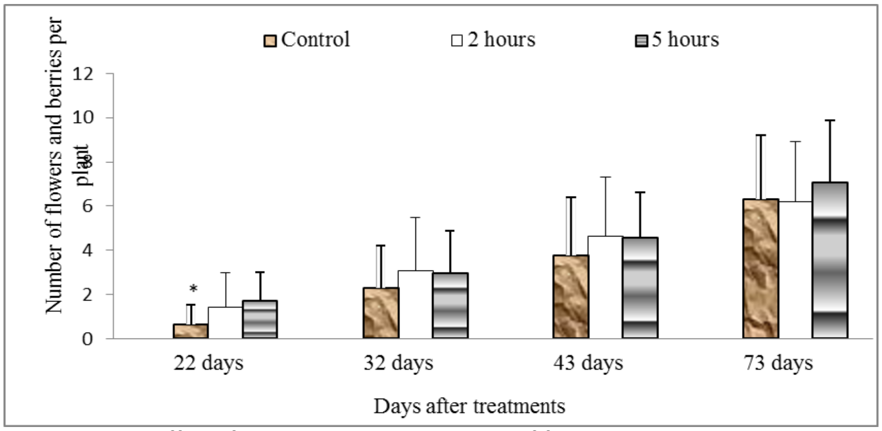

Figure 5 Effect of sound waves on the number of flowers and berries per plant

Note: * means significantly different at P <0.05 (n = 40).

3.3 Effect of sound waves on the concentration of endogenous hormones

Figures 6-8 show the mean concentrations of the endogenous hormones (IAA, ABA, JA, ZR and GA) after 60 days, 75 days, and 90 days of audible sound treatments. It was observed that endogenous hormones concentration significantly varied with the growth and treatments conditions.

3.3.1 Gibberellin (GA)

Mean concentration of GA in leaves of the treated plants for 60 days, each day for 5 hours (7.78 ng g^{-1} FW) was significantly higher than those of treated plants for 2 hours (5.35 ng g^{-1} FW). Meanwhile, there were insignificant differences between the treated greenhouse for 5 hours and the control greenhouse (6.83 ng g^{-1} FW). Subsequently, after 75 days of sound treatments, there were insignificant differences in the mean concentration of GA in leaves between all treated plants and control plants. Thereafter, mean concentration of GA in leaves of the treated plants for 90 days, each day for 2 hours (6.5 ng g^{-1} FW) was significantly higher than those of control plants (5.50 ng g^{-1} FW). However, there were insignificant differences between the treated plants for 5 hours and 2 hours in the greenhouses. GA is involved in almost all phases of plant growth and development, GA promotes germination, elongation growth of roots and stems, flowering, and fruit development. Furthermore, the level of any hormone affects the levels of the others by affecting their biosynthesis, degradation, conjugation, or transport. This is called the hormonal crosstalkings (Peleg and Blumwald, 2011). Therefore, mean concentration of GA under sound treatments changed but did not show any significant differences at 60 days after treatments because of increasing ABA and JA concentration. it was reported that GA improved the salinity tolerance by improving membrane permeability and nutrient levels and also maintaining SOD, POD and PPO enzyme activities in leaves which ultimately leads to better seedling growth and shoot(Tuna et al., 2008). Furthermore, the GA promotes plant growth by stimulating degradation of negative regulators of growth called DELLA proteins. gibberellin signaling components play major roles in plant disease resistance and susceptibility (Tanaka et al., 2006).

3.3.2 Zeatin Riboside (ZR)

The effect of acoustic technology on the mean concentration of ZR in leaves did not show any significant differences between the treated and untreated plants at 60 days and 90 days after treatments. However, when the treatment was for 75 days; the mean concentration of ZR in leaves of the treated plants for 2 hours was significantly (14.92 ng g^{-1} FW) higher than those of the control plants (12.62 ng g^{-1} FW). In addition, there were insignificantly differences of ZR concentration between the treated plants for 5 hours (12.62 ng g^{-1} FW) and 2 hours. The maximum concentration of ZR was 16.88 ng g^{-1} FW in leaves of control plants. When cytokinin oxidase in plant leaves is inactivated the ZR content increases. Thus, a significant increase of ZR concentration in strawberry leaves can be regarded as an indicator of serious injury to strawberry plants. Nevertheless, zeatins and zeatin riboside (ZR) are cytokinins that play an essential role in regulating plant growth and development (Silverman et al., 1998).

3.3.3 Jasmonnic acid (JA)

Mean concentration of JA in leaves of treated plants for 60 days, each day for 5 hours, five days per week (51.20 ng g^{-1} FW) was significantly higher than those of treated plants for 2 hours (43, 26 ng g^{-1} FW). On the other hand, there were insignificant differences of JA concentration between the treated greenhouse for 5 hours and the control greenhouse (50.48 ng g^{-1} FW). In contrast, after 75 days and 90 days of sound treatments, there were no significant differences in the mean concentration of JA in leaves between all treated plants (39.3 ng g^{-1} FW) and control plants (33.6 ng g^{-1} FW). It was found that the increasing levels of JA caused changes of cellular metabolism, resulting in increased resistance of the organism or intensification of stress symptoms. On the other hand, the concentration of JA can be modified in various ways, such as conjugation to different amino acids or hydroxylation, forming compounds of extreme importance for the activation of jasmonate-responsive defense genes (Avanci et al., 2010; Chen and Li, 2009; Thines et al., 2007). It have been demonstrated that the concentrations of JA increase locally upon biotic stress such as, herbivory or pathogen attack and abiotic stress such as, wounding or tissue damage, ozone or UV light and exogenous application of JA induced the expression of defense related genes (Dar et al., 2015; Kazan, 2015; Koo and Howe, 2009; Tsukada et al., 2010).

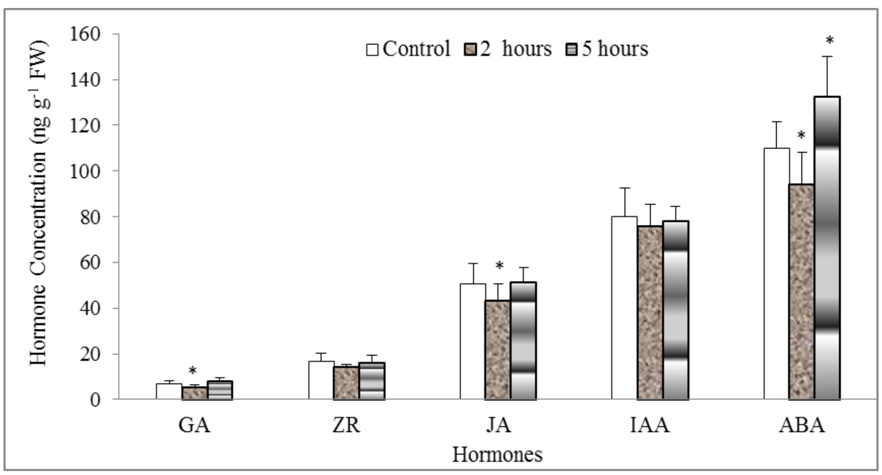

Figure 6 Levels of plant hormones after 60 days of sound treatment

Note: * means significantly different at P <0.05 (n = 12). Vertical bars represent ± Standard Deviation of the mean.

3.3.4 Indole-3-acetic acid (IAA)

When the plants treated for 60 days of acoustic frequency technology, the results showed that the mean concentration of IAA in leaves of control plants was insignificantly (79.87 ng g^{-1} FW) higher than those of the treated plants for 2 hours (75.9 ng g^{-1} FW). Mean concentration of IAA in leaves of the treated plants for 2 hours and 5 hours was insignificantly (73 ng g^{-1} FW and 70 ng g^{-1} FW) higher than those of the control plants (65 ng g^{-1} FW) during the long run of sound treatments at 75 days of treatment. In contrast, mean concentration of IAA in leaves of control plants was insignificantly (82 ng g^{-1} FW) higher than those of the treated plants for 5 hours (67.2 ng g^{-1} FW) and 2 hours (74 ng g^{-1} FW) at 90 days of treatment. It has been reported that the IAA level in maize roots significantly increased under water stress conditions (Xin et al., 1997) and decreased in the shoots. Ross and O'Neill (2001) found that normal level of IAA promoted the biosynthesis of active Gibberellin in pea and it was also required to maintain normal levels of bioactive Gibberellin in elongating pea. Therefore, these concentrations of IAA in treated plants for 60 days and 90 days resulted in ABA ratio to IAA or other hormones. Furthermore, recent evidence proved that the young root tips of *Zea mays* were clearly bending towards a continuous sound source and the high bending percentage was measured between 0.2 kHz and 0.3 kHz (Gagliano et al., 2012). Indole-3-acetic acid can also induce cell elongation and cell division which subsequently affects plant growth and development (Wilkinson and Davies, 2010).

3.3.5 Abscisic acid (ABA)

Mean concentration of ABA in leaves of the treated plants for 60 days, 5 hours per day (132.56 ng g^{-1} FW) was significantly higher than both of control plants and treated plants for 2 hours. Moreover, mean concentration of ABA in leaves of control plants was (110.01 ng g^{-1} FW) significantly higher than those of the treated plants for 2 hours (94.16 ng g^{-1} FW). Nevertheless, after 75 days of sound treatments, there were insignificant differences in the mean concentration of ABA in leaves between all treated plants and control plants. Thereafter, there was a significant increase of the mean concentration of ABA in leaves of the treated plants for 90 days, each day for 5 hours (133.2 ng g^{-1} FW) than those of control plants (104.3 ng g^{-1} FW). Concurrently, there were insignificant differences between the treated plants for 5 hours and 2 hours (124.8 ng g^{-1} FW) in the greenhouses. Similar results have been previously reported by Bochu et al. (2004).

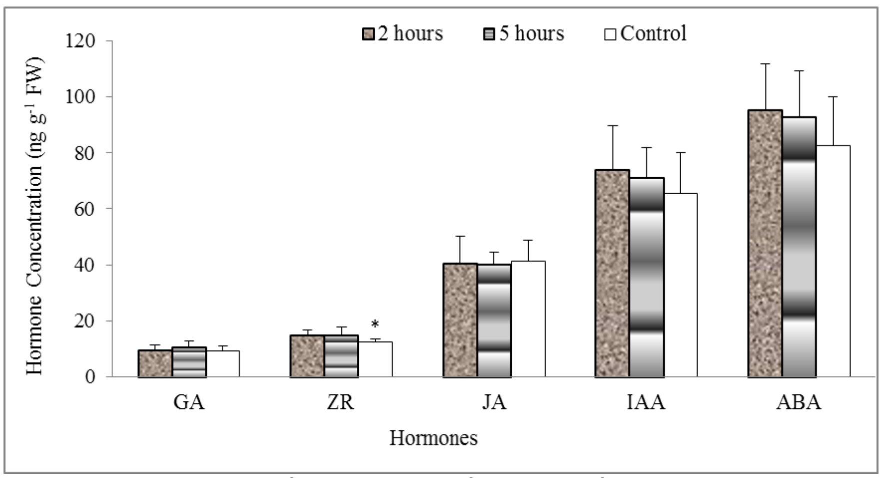

Figure 7 Levels of plant hormones after 75 days of sound treatment

Note: * means significantly different at $P < 0.05$ ($n = 12$). Vertical bars represent ± Standard Deviation of the mean.

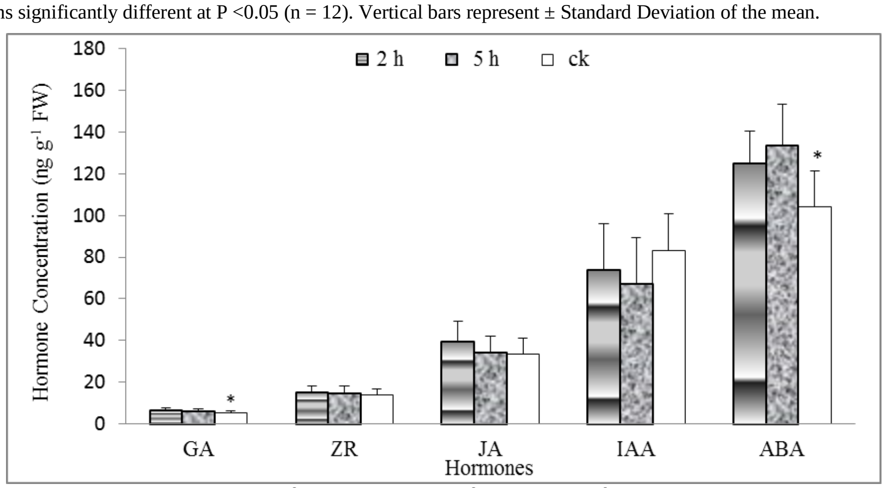

Figure 8 Levels of plant hormones after 90 days of sound treatment

Note: *: means significantly different at $P < 0.05$ ($n = 12$). Vertical bars represent ± Standard Deviation of the mean.

These results prove that sound waves may have a dual effect on the growth of strawberries; it positively decreases the ABA in the short run at 60 days after treatments, which means that the plants are not stressed. Moreover, low concentrations of ABA at more 'normal' condition, has been shown essential for vegetative growth in several organs. e.g., primary root growth and seedlings developments (Hwang et al., 2012). The plant hormone abscisic acid (ABA) plays a major role in plant responses to stress (Zhang et al., 2006) .On the other hand, sound waves negatively affected on the growth in the long run for more than 75 days after treatment and significantly increased the concentrations of ABA hormone. Nevertheless, the accumulation of ABA plays a major role in stomatal closure that helps to minimize water loss by reducing transpiration occurring through stomata. Moreover, stomatal closure is part of a plant innate immune response to restrict bacterial invasion (Adie et al., 2007).

4 Conclusions

The effects of acoustic frequency technology on vegetable plants have received much attention in the last century in China. However, few studies focus on their effects on plants for different exposing periods inside greenhouses in terms of endogenous hormones. Therefore, the aim of this study was to investigate the effect of sound waves on Strawberry growth. Results revealed that the strawberry plants grown in the treated greenhouse for 2 hours and 5 hours were better than those of control greenhouses. However, acoustic frequency could be considered as a form of alternative environmental stress because it had a dual effect on strawberries pants. The first positive effect is useful in the seedling and blooming stages; that could improve the growth and enhance the plants immune system by adjusting the endogenous hormones concentration Thereby, lower pest and disease impact on the crop, lower pesticide load and lower costs will be obtained to benefit the grower. Moreover, this technology could accelerate the blooming and the flowering rates a week earlier with a high quality of fruits. Since crop yield is the most effective method of assessing economic benefits of agricultural production systems. The main target of planting any crop is to get the highest yield and the highest quality in a short period of time. The second negative effect is to apply this acoustic technology for a long run more than 75 days of starting the treatments every day 2 hours for five days per week, which somehow stresses the plants and increases the plant ABA hormone concentration and decreases the IAA hormone. This study was conducted by using only sound wave technology and the effects of sound wave to provide some information to the database for the physiological aspects of sound waves effects on endogenous hormones of strawberries. However, supplementary experiments addressing to the issue must be performed to confirm these findings. Furthermore, a collaboration work of different disciplines is needed to figure out the suitable mechanism of sound treatments and its biological and physiological effects on the growth of different plants.

Acknowledgements

This article supported by Chinese Government Doctorate Scholarship particularly China Scholarship Council (CSC) and also supported by project number 33456 from Science and Technology Development Fund (STDF) in Egypt.

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