INFLUENCE OF SOUND WAVE STIMULATION ON THE GROWTH OF STRAWBERRY IN SUNLIGHT GREENHOUSE

Lirong Qi [1,*], Guanghui Teng [1], Tianzhen Hou [1], Baoying Zhu [2], Xiaona Liu [1]

1 College of Water Conservancy and Civil Engineering, China Agricultural University, Beijing, P.R. China 100083

2 Beijing Xiaotangshan National Agricultural Demonstration Zone, Beijing, P.R. China 102211

[*] *Corresponding author, Address: College of Water Conservancy and Civil Engineering, China Agricultural University, Beijing, P.R. China 100083, Tel: +86-10-62737583-1, Email: 525617qi@163.com*

Abstract: In this paper, we adopt the QGWA-03 plant audio apparatus to investigate the sound effects on strawberry in the leaf area, the photosynthetic characteristics and other physiological indexes. It was found that when there were no significant differences between the circumstances of the two sunlight greenhouses, the strawberry after the sound wave stimulation grew stronger than in the control and its leaf were deeper green, and shifted to an earlier time about one week to blossom and bear fruit. It was also found that the resistance of strawberry against disease and insect pest were enhanced. The experiment results show that sound wave stimulation can certainly promote the growth of plants.

Keywords: environmental factors, sound wave stimulation, sunlight greenhouse, strawberry

1. INTRODUCTION

Plants are stimulated inevitably by a variety of external environmental factors in the growth process and these stimulations have different extent influence to plants' growth, and then influence the crops' output and quality. As a flexible mechanical wave, the sound wave is a form of` alternative stress and also a universal source of external stimulation to plants. Studies have shown that a certain frequency or sound intensity of the sound wave stimulation can promote the growth of plants. Scholars have done a lot of research on the role and mechanism of sound waves on plants. The approaches are used mainly in the form of music sound and pure tone (single frequency sine wave).

In music sound processing, music sound (natural sounds) had significantly improved the number of seeds sprouted compared to the untreated control, and there were no significant differences between harsh noise group and the untreated control (Creath et at., 2004). Under both light and dark conditions, sound up-regulated expression of the rbcS and ald by using classical music and single-frequency vibration signal (Jeong et at., 2008).

In pure tone processing, the hypocotyls' elongation and gene expression of Arabidopsis thaliana seeds were both improved by sound stimulus of about 50Hz and 90dB (Johnson et at., 1998). Chinese Academy of Sciences, Department of Applied Chemistry of China Agriculture University and Department of Engineering Mechanics of Tsinghua University jointly find that a range of sound waves can stimulate tobacco's synchronization of cell division and promote DNA synthesis in the S-stage of cell division, and then improves plants growth and development (Li Tao et at., 2001). Sound wave stimulation can significantly enhance or inhibit the ATP content of Actinidia chinensis callus. Moderate sound stimulation can increase the activity of ATP synthase and is conducive to the level of energy metabolism of plants (Yang Xiaocheng et at., 2003; Yang Xiaocheng et at., 2007). By using QGWA-03 plant audio apparatus (frequency range: 100-2000Hz), tomato's yield increased by 13.2%, and its disease of grey mold decreased by 9.0% (Hou Tianzhen et at., 2009).

At present, the sound wave stimulation studies on the impact of plants are increasing, but the sound effect and mechanism are still controversial. To this end, QGWA-03 plant audio apparatus (PAA) was used to stimulate the strawberry growing in the sunlight greenhouse, and the sound effects to leaf area, photosynthetic characteristics rate and other physiological indexes were researched. This paper is our preliminary study of sound stimulation mechanism.

2. MATERIALS AND METHODS

2.1 Test materials and design

The test was started in the sunlight greenhouse from November 2008 to January 2009 in Beijing Xiaotangshan National Agricultural Demonstration Zone. We selected 60 healthy strawberry seedlings (U.S. "Sweet Charlie") which grew in the same condition and transplanted them into white plastic flowerpots with medium loam. Then put the flowerpots into two sunlight greenhouses respectively (30 pots each) which were 80m apart. In the two sunlight greenhouses, conditions of structure, environment, irrigation control, and the relative position of flowerpots were basically the same between each other. We carried out the sound stimulation experiment (the PAA was put in the middle of the pots) in one building, and the other one used as control. Test arrangement is shown in Fig.1.

(a) the sunlight greenhouses (b) strawberry seedlings in the flowerpots

Fig. 1: Layout of sound wave stimulation experiment on strawberry in sunlight greenhouse

The sound wave treatment was begun when the strawberry seedlings were transplanted into the greenhouses, and once every two days to play, and 9:00 to start dealing with each 3h. The frequency and volume were determined by the temperature and humidity of greenhouse. We measured the leaf area and photosynthetic indicators of strawberry at the beginning of growing season, squaring period, flowering period and fruiting stage. The production and disease resistance of strawberry were also determined in the fruiting stage.

2.2 Determinations

We used LI-3000 portable leaf area meter (LI-COR Inc. USA) and LI-6400 (LI-COR Inc. USA) portable photosynthesis meter to measure the leaf area and photosynthetic characteristics. Results are expressed as means ± SDs. Data were analyzed using Non-parametric test of two independent samples included in the SPSS version 13.0 software (SPSS Inc, Chicago, Ill). Statistical significance was set at $P<0.05$.

3. RESULTS

3.1 Sound effect to the leaf area of strawberry

Fig.2 shows that in the beginning of growing season, squaring period and fruiting stage, the leaf area in the treatment are significantly greater than control ($P<0.01$); but there is no significant difference in the flowering period.

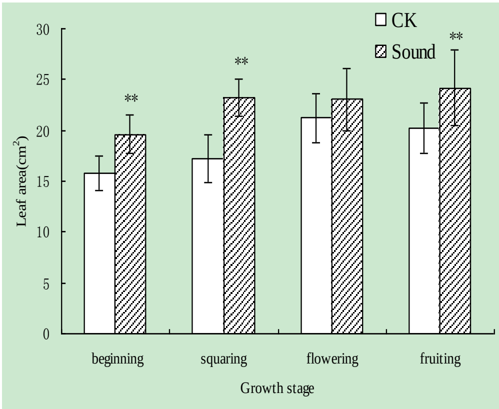
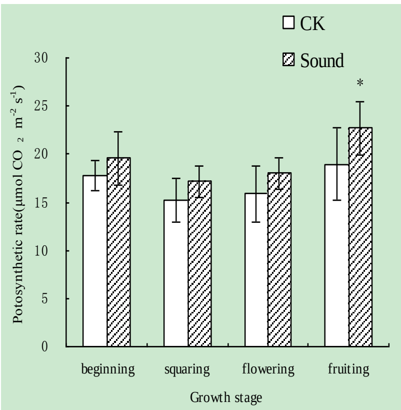


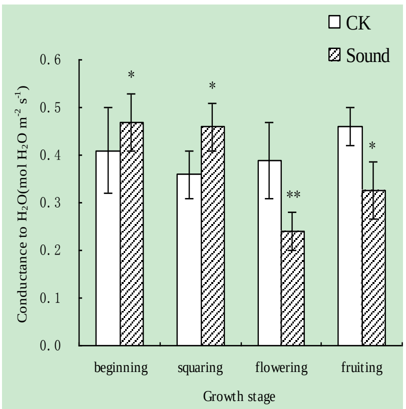
Fig. 2: Sound effect to the leaf area of strawberry

3.2 Sound effect to the photosynthetic characteristics of strawberry

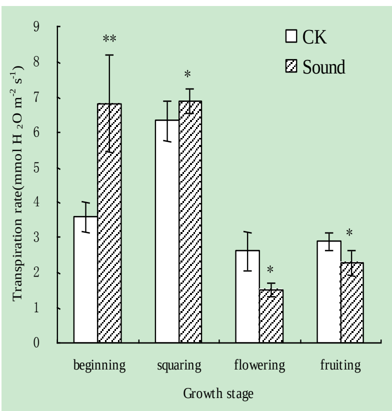
Fig.3 shows that during the four stages, there is no significant difference of the intercellular CO_2 concentration (Ci) between the two groups, but the transpiration rate (Trmmol) and conductance to H_2O (Cond) are significantly greater than control ($P<0.05$). Only in the fruiting stage, the photosynthetic rate (Photo) has significant difference ($P<0.05$).

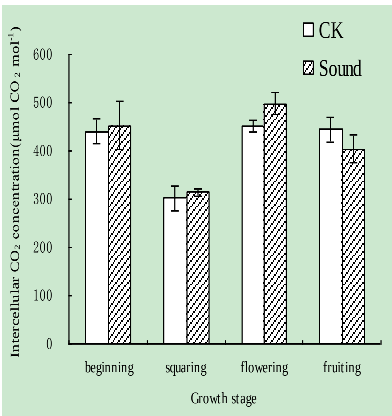


(a) photosynthetic rate



(b) conductance to H_2O





(c) transpiration rate (d) intercellular CO_2 concentration

Fig.3: Sound effect to the photosynthetic characteristics of strawberry

3.3 Sound effect to the yield and disease resistance of strawberry

We surveyed the yield and disease situation in January 18, 2008. Table1. shows that the disease rate in the treatment is significantly less than control; but there is little effect on the yield.

Table 1. Sound effect to the yield and disease resistance of strawberry

	Yield (kg)	Yield per plant (kg)	Disease rate (%)
Sound stimulation	1.53	0.051	16.67
CK	1.63	0.054	50.00

3.4 Discussion

It is found that sound stimulation has great effect on the physiology of strawberry, and it has different impact in the different physiological stages.

Viewing in the entire growth period, sound waves do promote the leaf area of strawberry, but the effects on the Photo and Ci are not obvious. The trend of sound influence on Cond and Trmmol are both firstly increasing and then decreasing. It indicates that the Trmmol of strawberry leaf is mainly affected by stomata factors. Trmmol decreases in the latter growth stage. It shows that sound has little effect on the growth of strawberry after the flowering period and also explains the reason of production without significant changes. In addition, the experiment was not started in the breeding period, so it may be another reason for the un-improving production. During the initial growth period, the improvement of Trmmol promotes the transportation of water and mineral elements, so it increases the disease resistance (Wu Weihua, 2003).

4. CONCLUSION

In this paper, experimental results show that sound waves not only can promote the growth of strawberry, but can also increase the disease resistance. About the mechanism of sound waves improving the growth of plants, there are three possible reasons: environmental stress (including the sound waves stimulation) changes the fluidity and permeability of membrane; the signaling molecule of Ca^{2+} deliveries the stress signaling to other signaling molecules; the spread of stress signal causes related gene expression (Liu yiyao, et at., 2000). But we believe that there is phenomenon of spontaneous sound in plants. When the frequency between external vibration and plants spontaneous sound are consistent, the resonance will occur, thus promoting plants growth. We did the pre-test by using the He-Ne laser Doppler vibrometer to measure the sound frequency of Alocasia, and found that in normal growth conditions, plants' spontaneous sound frequency was in low-frequency range of 40-2000Hz (Luan Jiyuan, et at., 1995; Hou Tianzhen, et at., 1994). At the same time, we used low-frequency sound waves to stimulate more than 50 kinds of crops, and achieved remarkable effects (Hou Tianzhen, et at., 2009).

To sum up, we believe that the mechanism of sound effect to plants can be explained in two ways. From the biological point of view, sound may affect the characteristics and function of plant cell membrane, and gene expression. But from the physics point of view, the frequencies of sound vibration and plants spontaneous sound are in line, and then the resonance occurs. This experiment is only the initial discussion on the mechanism of sound stimulation to plants, and it is the foundation for exploring the mechanism from the perspective of plants' vibration characteristics.

ACKNOWLEDGEMENTS

This study was financially supported by the subject group of urban agriculture projects of Joint-Build Plan of Beijing Education Commission (item no. XK100190553). We thank the laboratory members (Guo Nan, Yu Ligen, et al.) for the help.

REFERENCES

C. R. Sukumaran, B. P. N. Singh. Compression of bed of rapeseeds: the oil-point, Journal of Agricultural Engineering Research, 1989, 42:77-84

E. Davion, A. G. Meiering, F.J. Middendof. A theoretical stress model of rapeseed, Canadian Agricultural Engineering, 1979, 21(1): 45-46

Hou Tianzhen, Luan Jiyuan, Wang Jianyou, et al. Experimental evidence of a plant meridian system: III. The sound characteristics of phylodendron (Alocasia) and effects of acupuncture on those properties. American Journal of Chinese Medicine, 1994, 22:205-214

Hou Tianzhen, Li Baoming, Teng Guanghui, et al. Application of acoustic frequency technology to protected vegetable production, Transactions of the Chinese Society of Agricultural Engineering, 2009, 25(2):156-159(in Chinese)

K. Creath, G. E. Schwartz. Measuring effects of music, noise, and healing energy using a seed germination bioassay, The Journal of Alternative and Complementary Medicine, 2004, 10(1):113-122

K. A. Johnson, M. L. Sistrunk, D. H. Polisensky, et al. Arabidopsis thaliana response to mechanical stimulation do not require ETR1 or EIN2. Plant Physiol., 1998, 116:643-649

Li Tao, Hou Yuexia, Cai Guoyou, et al. Analysis of the effect of strong sound wave on plant cells cycles using flow cytometry. Acta Biophysica Sinica, 2001, 17(1): 195-198(in Chinese)

Liu Yiyao, Wang Bochu, Zhao Hucheng, et al. The biological effects of plant caused by environmental stress stimulation. Letters in Biotechnology, 2000, 11(3):219-222(in Chinese)

Luan Jiyuan, Hou Tianzhen. Principle and design of a laser Doppler Vibrometer for measuring acoustical characteristics of plants, Bulletin of Science and Technology, 1995, 11(5):266-267(in Chinese)

M. J. Jeong, C. K. Shim, J. O. Lee, et al. Plant genes responses to frequency-specific sound signals, Mol Breeding, 2008, 21:217-226

Wu Weihua. Plant physiology, Beijing: Science and Technology Public, 2003, 4:64-65(in Chinese)

Yang Xiaocheng, Wang Bochu, Duan Chuanren, et al. Effects of sound stimulation on ATP content of Actinidia chinensis callus. Progress in Biotechnology, 2003, 23(5): 95-97(in Chinese)

Yang xiaocheng, Ding jianping, Wang Bochu. Effects of different sound frequency on roots development of Actinidia chinensis plantlet, Journal of Chongqing University (Natural Science Edition), 2007, 30(11):72-74(in Chinese)