Utilization of a nutrient film technique on strawberry productivity

G.E.M. Nasr [1], E.M. Darwish[2], Y.F. Sharobeem[3], H.S.Abd-Elrahman[4*]

(1. Deparment Agricultural Engineering, Faculty Agricultural, Cairo University Egypt;
2. Plant. physiology, Faculty Agricultural, Cairo University Egypt;
3. Agricultural Engineering Assistant Researcher. (AEnRI) Agricultural Research Center Egypt.)

Abstract: This research aimed to observe the effect of ultrasound exposure on strawberry product quality. The experiments were done in Giza governorate at lines of 30° 00′ 39″ longitudinal and 31° 17′ 37″ latitude, through successful season about 180 days on 2017-2018. The system include; ultrasound device "≈ 40W" and live material "strawberry seedling", and four A-shape of hydroponic units of Nutrient Film Technique (NFT) under greenhouse covered with “seran”. The fresh fruit of strawberry were collected separately per three months during the harvest period. The studied variables were three frequencies levels "20, 30 and 40 kHz" per three exposure periods "0, 60, 300 and 600 sec", and under dissimilar three vertical distances between plants and ultrasound device "0 – 30 – 60 cm". Wherein, the statistical evaluation of the obtained data is identified. The obtained results can be shown that, ultrasound waves are suitable to improve plant growth of strawberry in most properties and productivity especially when device is used at horizontal distance zero at an exposure time of ultrasound wave 60 sec with wave frequency 40kHz-100dB -40W at wanting to produce fruits for local consumption. If wanted to export strawberry, the best treatment conditions were at wave frequency of 20 kHz-100dB -40W at zero distance between source of waves and plants per 60 sec exposure time of ultrasound wave.

Keywords: ultrasound, exposure time, frequencies, vertical distance.

Citation: Nasr, G. E. M., E. M. Darwish, Y. F. Sharobeem, and H. S. Abd-Elrahman. 2022. Utilization of a nutrient film technique on strawberry productivity. Agricultural Engineering International: CIGR Journal, 24(1):197-206.

1 Introduction

Sound is one of the physical signals that affect plant life although the mechanisms by which plants perceive and act upon a sound stimulus are not well known yet. Theoretically, however, the perception, use and emission of sound have an evolutionary benefit for all living organisms, among them plants (Gagliano and Renton et al., 2012; Gagliano and Mancuso et al., 2012; and Gagliano, 2013). Sound waves are a form of abiotic stress for plants (Telewski, 2006; Wang et al., 2006). Sound energy, when applied to a biological sample, acts as a physical treatment as a form of sonication. Whose effect on biological processes increases as the frequency gets higher (Telewski, 2006; Rokhina et al., 2009).

In the last few years, while, it was supported with Laschimke et al. (2006), Gagliano and Renton et al. (2012), and Gagliano (2013) there have been an increasing number of studies dealing with the emission and perception of sound by plants both in audio acoustic “10–240Hz” and ultrasonic ranges “20–300kHz”. However, this is apart from very early studies conducted by Telewski (2006). Only limited studies are available regarding the effects of sound on both of plant growth and plants physiological to sound signals at different frequencies (Collins and Foreman, 2001; Jia et al., 2003; Creath and Schwartz, 2004; Telewski, 2006; and Qi et al., 2010).

Received date: 2020-09-29 **Accepted date:** 2021-02-09
***Corresponding author: H.S.Abd-Elrahman,** Ph.D., Assistant Researcher of Department..., Bioengineering system, Egypt Country. Email: hebaabedalrhman@yahoo.com. 01115771436.

Confronting the population increase and the lack of cropping area means strenuous efforts to increase and speed of crop growth. Within the scope of this field, many studies have turned to the chemical effect on plant growth by adding some elements that increase the chromosomal number, such as gibberellin and others substances (Vasilevski, 2003). The modern science has turned to some physical affects that the biological growth of plants, including the ultrasound (Zhou, 2011). It was found that the capability of plants to feel and to respond to physical environmental stimuli, such as light, temperature, gravity, mechanical loading, touch, is evolutionary importance (Telewski, 2006; Gagliano and Renton et al., 2012).

Ozkurt and Altuntas (2018) stated the effect of sound applications on fresh and dry for weights of the roots and shoots of strawberry plants, and the pH, total soluble solids (Brix), titratable acidity, vitamin C, total sugar, total acid, and total phenols in fruits. Results show that the sound stress, which was produced at a constant frequency (1000 Hz) under different sound levels (95, 100, 105 dB), caused decreases in the mass of roots and the green parts of the strawberry plants. However, these different sound waves also caused some increases in several fruits quality parameters in the fruits at a statistically significant level. This increase enhances value of fruit and is important for human health, is positive. Salinity, drought, high temperature, and irreversible abiotic stress are factors reduce the growth and development of the plants, causing major losses in terms of yield; plants even die under continuous stress.

In further studies, greenhouse trials may be performed at sound levels that do not affect plant development and yield at significant levels but increase fruit quality. Dobranszki et al. (2019) key message is response to an ultrasound pulse, several hundred differentially expressed genes (DEGs), including in response to stress, were up- or down-regulated in in vitro potato plantlets. Despite this abiotic stress, plantlets survived. Abstract Ultrasound (US) can influence plant growth and development. To better understand the genetic mechanism underlying the physiological response of potato to US, single-node segments of four-week-old in vitro plantlets were subjected to US at 35 kHz for 20 min. Following mRNA (Ribonucleic acid) purification, 10 cDNA (Deoxyribonucleic acid) libraries were assessed by RNA-seq. Significantly DEGs were categorized by gene ontology or Kyoto Encyclopedia of Genes and Genomes identifiers. The expression intensity of 40,430 genes was studied. Several hundred DEGs associated with biosynthesis, carbohydrate metabolism and catabolism, cellular protein modification, and response to stress, DNAS and DEGs that were expressed mainly in the extracellular region, nucleus, and plasma membrane. Where either up- or down-regulated in response to US. RT-qPCR was used to validate RNA-seq data of 10 highly up- or down-regulated DEGs, and both Spearman and Pearson correlations between SeqMonk LFC and RT-qPCR LFC were highly positive (0.97).

They also, examines how some processes evolved over time (0 h, 24 h, 48 h, 1 week and 4 weeks) after an abiotic stress (US) was imposed on in vitro potato explants, and provides clues to the temporal dynamics in DEG-based enzyme functions in response to this stress. Despite this abiotic stress, plantlets survived. This research aimed to observe the effect of ultrasound exposure on quality of strawberry product.

2 Materials and methods

The experiments done in Giza governorate at lines of 30° 00′ 39″ longitudinal and 31° 17′ 37″ latitude, through successful season about 180days on 2017-2018 using the units of; ultrasonic device (1) greenhouse (2), and hydroponic Nutrient Film Technique system (NFT) (3) beside the strawberry seedling, soilless media and nutrient solution. The experiment includes three economic periods (about 180 days) at the same year. The system can show in Figure (1).

Greenhouse: The greenhouse of "seran" to decrease inlet temperature in summer. It has a dimensions of 9.0 ×3.0 ×2.0 m length, width, and height respectively was erected. It covered with white cloth "seran" (200 □m, thickness, and 0.96 g cm-3, density).

Hydroponic unit: As shown in Figure 3 A-shape hydroponic unit of NFT consists of the following components:

1. Triangle steel frame of 60□ tilt angle. The frame dimensions are 1.0, 1.0 and0.03 m length, height and thickness, respectively.

2. Six PVC pipes of 0.10 and 0.10 m diameter and length, respectively. They were fixed with the frame at height of 0.40, 0.75 and 1.0 m, from soil surface.

3. Pump of 2.4 m head, 1800 L. h-1, discharge, AC 220-240V, and 50Hz. It was used to supply the nutrient solution to a tank of 30 L capacity.

4. Timer was used to supply the nutrient solution at 15 min 2 h-1 daily. The nutrient solution was prepared by the Central Laboratory for Agricultural Climate, Agriculture Research Center, Egypt.

5. Ninety-six polyethylene pots of 0.20 and 0.20 m at diameter and height, respectively. They were filled with a soilless media of petmose and perlite with a ratio of 1:3 which was prepared by the Central Laboratory for Agricultural Climate, Agriculture Research Center, Egypt.

6. Ninety-six strawberry seedling Festival varieties at 25 days age which were transplanted at the polyethylene pots through 108 days.

Figure 1 Hydroponic planting system - units Ultrasonic

Ultrasonic generator device: It was designed and assembled locally (Cairo, Egypt) to generate the different frequencies. It's outlet power was about 40W. The diagram of the ultrasonic circuit was illustrated in Figure (2).

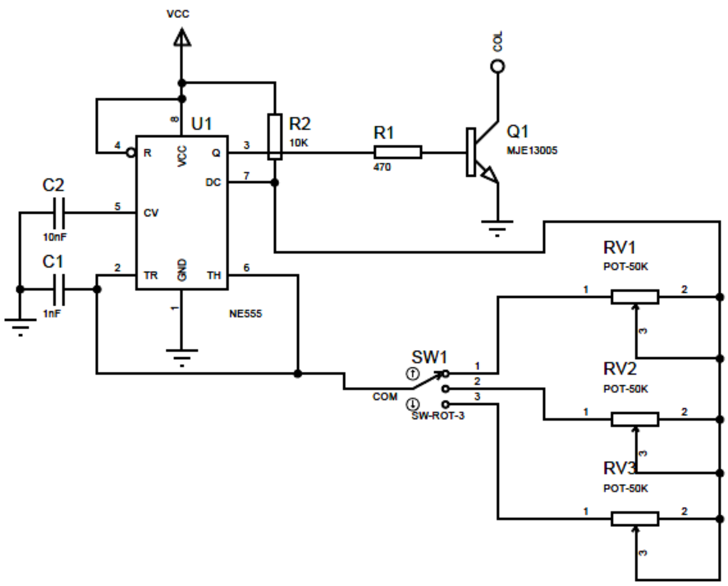


Figure 2 Components of ultrasonic generator translator circuit

Note: C1: Capacitor 1 µf; R1: Resistor 450 Ω; RV1: Resistor covariance 20 kHz

C2: Capacitor 10 µf; R2: Resistor 10 K; RV2: Resistor covariance 30 kHz

U1: Ultrasonic microphones; EFROSB40K65; RV3: Resistor covariance 40 kHz

NE 555: IC1; SW1: key switch.

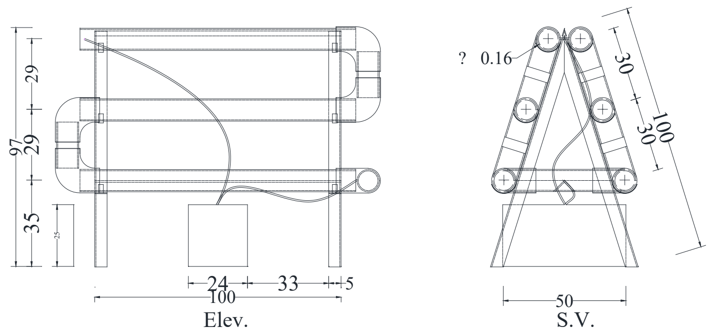


Figure 3 Main parts of hydroponic system

Treatments and statistical design:

During the experiment the following treatments were tested:

1. Ultrasound frequency: It included the levels of 20, 30 and 40 kHz.

2. Exposure times of ultrasound: It included the levels of 0, 60, 300 and 600 sec.

3. Distance between the ultrasonic device and the strawberry plants at the vertical level: It included the levels of 0, 0.30 and 0.60 m).

The experiment was established and designed statistically as a factorial completely randomized design with three replicates.

The matured strawberry fruits were collected three times. The period between the two sequent collections is one month. The following measurements were estimated:

1. Number of leaves per plant.

2. Number of fruits per plant.

3. Fruit yield per plant.

4. Fruit firmness.

Properties of ultrasound wave

The ultrasound wave affect by many factors but the most important sound wave properties are intensity, pressure and length. These properties must calculated to determine the proper ultrasound generator specifications and safety area around the planting field and also the effect area, for these reasons the formulas used by (Tole, 2005) can applied as follow:

- Intensity of sound (I)

The intensity of sound calculated from Equation 1

$$I = \frac{P}{4\pi r^2} \quad (1)$$

Where: I is intensity of sound per area (W m^{-2}), P is the power (W), r is surface area of a spherical wave of a point source "$4\pi r^2$" (m^2).

By substituting in Equation 1, the sound intensity values (I) were found to be 1273.24, 25.98; 7.53 and 3.35W m^{-2} at distances (r) were 0.05, 0.35, 0.65 and 0.95 m respectively.

- Sound pressure levels (SPLs)

The sound pressure levels "β" is expressed in the form

$$\beta = 10 \log \left(\frac{I}{I_0} \right) \quad (2)$$

The sound pressure levels "β" is dimensionless and the unit is given as decibel (dB), where I_0 = 10-12W m^{-2}.

From Equation 2 SPLs value were found about 141.04, 124.15, 118.77 and 115.48Wm^{-2} at distances (r) of 0.05, 0.35, 0.65 and 0.95 m respectively for 20, 30, 40 kHz.

- Wave length ƛ

The wave length is calculated from Equation 3,

ƛ = V/f (3)

Where: ƛ is the wave length (m), V is the velocity (m/s), and f is the frequency (kHz).

Using Equation 3 by substituting the "V = 220ms^{-1}" (Abuhamade et al., 2014). It was found wave length (ƛ) were 0.0165, 0.011 and 0.0083 m at frequencies (f) of 20, 30 and 40kHz.

Statistical analysis:

Microsoft Excel 2019 computer software was used to employ the analysis of variance test and the LSD tests for the obtained data .

3 Results and discussion

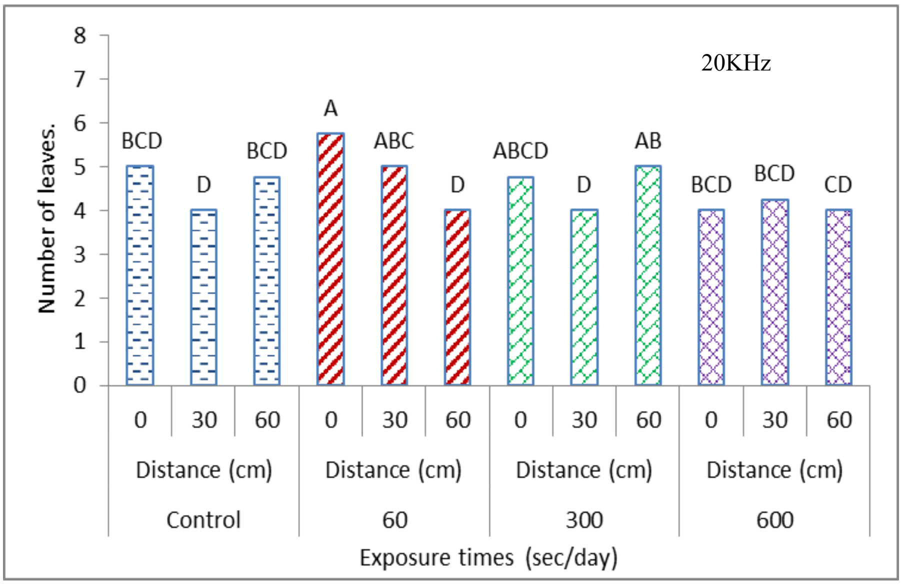
3.1 Leaves strawberry number per plant

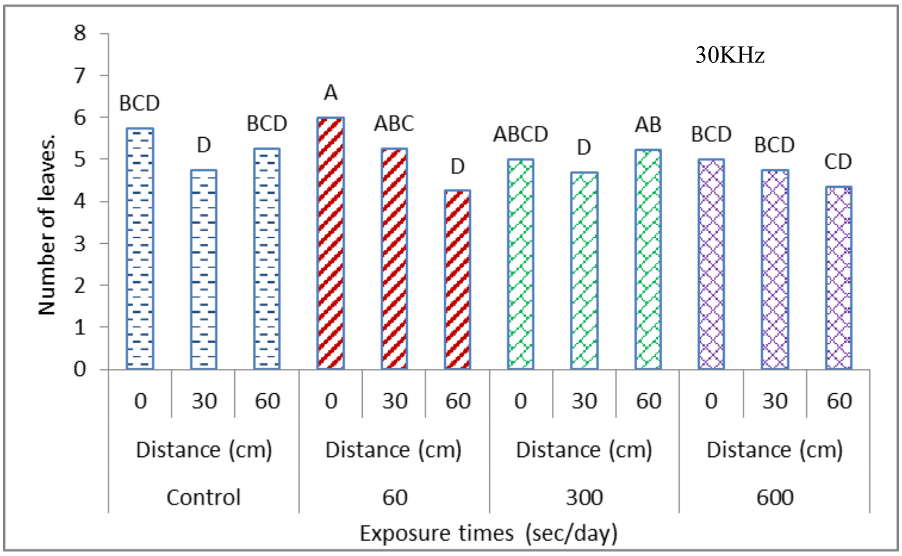
Figure (4) showed that the effect of distances and exposure times of ultrasound wave on number of strawberry leaves at different wave frequencies. From the figure, it can see that, the highest leaves number was 5.75, 6.00 and 7.25 plant respectively at wave frequencies of 20, 30 and 40 kHz. These leaves number by using frequencies 20 and 30 kHz were obtained at distance from the wave source zero and exposure time of ultrasound wave of 60 sec/day. On the other side, at

using frequency of 40 kHz it was obtained at three treatments, distances of 30 and 60 cm and exposure time of ultrasound wave of 60 sec /day and at distance of 30 cm and exposure time of ultrasound wave of 300 sec /day. These results mean that the high number of leaves found in generally at the highest wave frequency (40 kHz). Then the ultrasound waves with high frequency more suitable the leaves vegetables. These were results agreement with Ozkurt and Altuntas (2018).

Therefore, the statistical analysis conducted that the high differences effect found between the high number of leaves treatments at exposure time of ultrasound wave of 60 sec day^{-1} and distance between the source of

ultrasound and the plant of zero and all levels of frequencies (Figure 4). These results equal the same level of studied variables at control treatments.





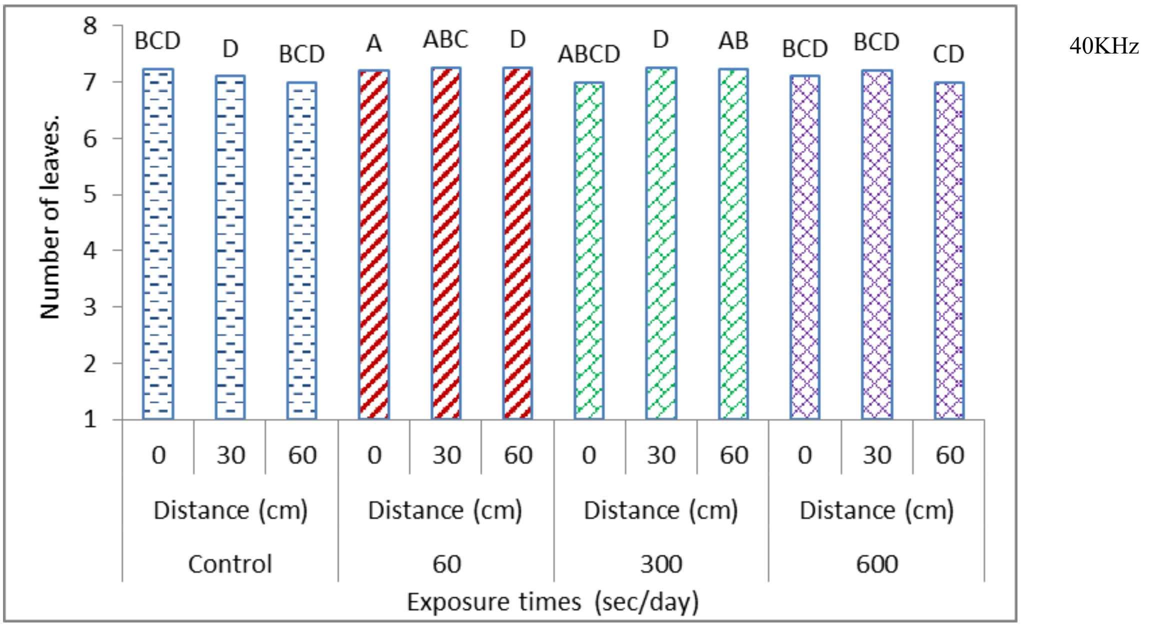
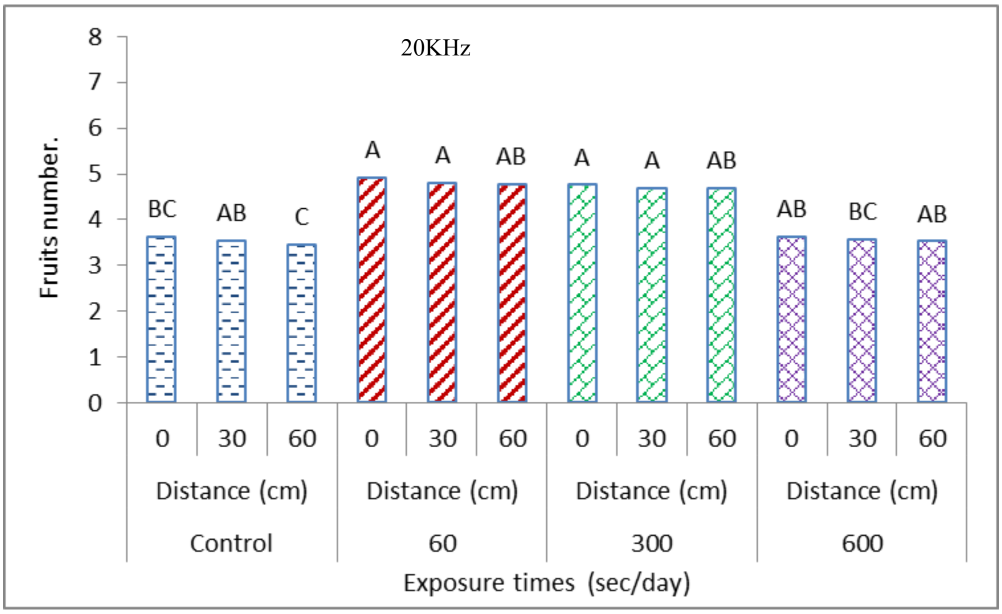


Figure 4 Effects of ultrasound waves on number of leaves at different ultrasound waves

3.2 Number of fruits

Figure 5 illustrated that the effect of distances and exposure times on number of strawberry fruits at different wave frequencies. From the figure it clear that the highest number of fruits was 4.93, 5.82 and 7.60 respectively at wave frequencies of 20, 30 and 40 kHz. These fruits number were obtained at the distance from the wave source zero and exposure time of ultrasound wave of 60 sec day^{-1}. On the other side, lowest number of fruits was 3.45, 4.84 and 2.45 at using wave frequencies of 20, 30 and 40 kHz respectively. These results obtained at exposure time of ultrasound wave of 600 sec day^{-1} for all frequencies used and 60 cm distance from the wave source for frequencies of 20 and 30 kHz and zero cm at using wave frequency of 40 kHz. These results mean that the high number of fruits found in generally at the highest wave frequency of 40 kHz. Then the ultrasound waves with high frequency more suitable the fruits vegetables.

Correspondingly, the statistical analysis explained that the high differences effect between the high number of fruits treatment and all other treatments (Figure 5).



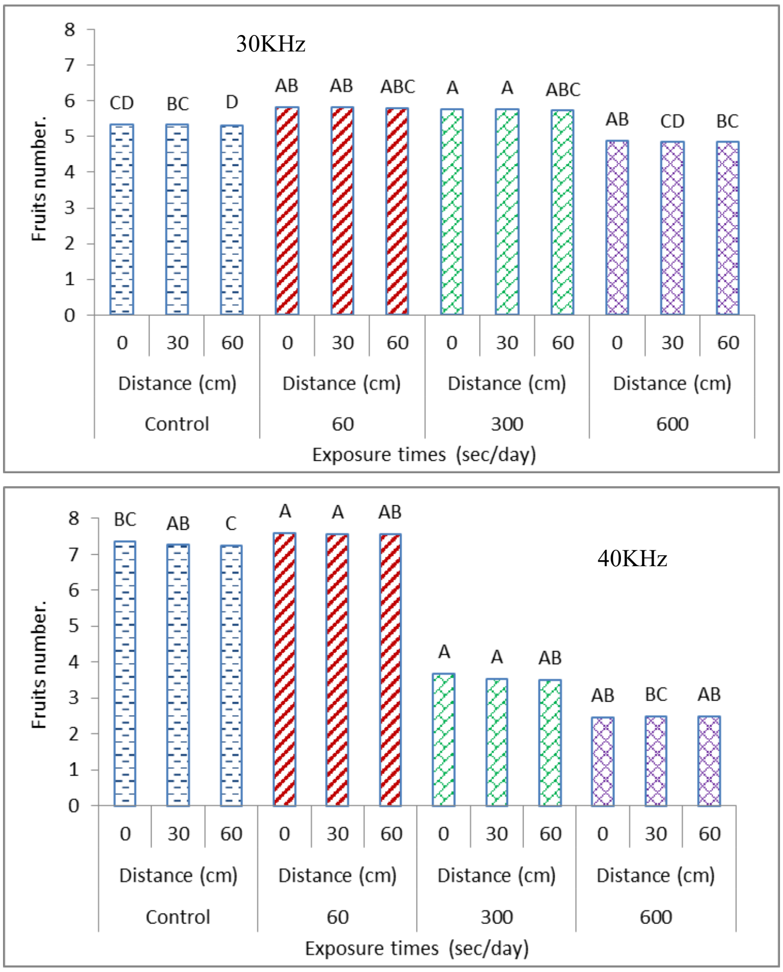
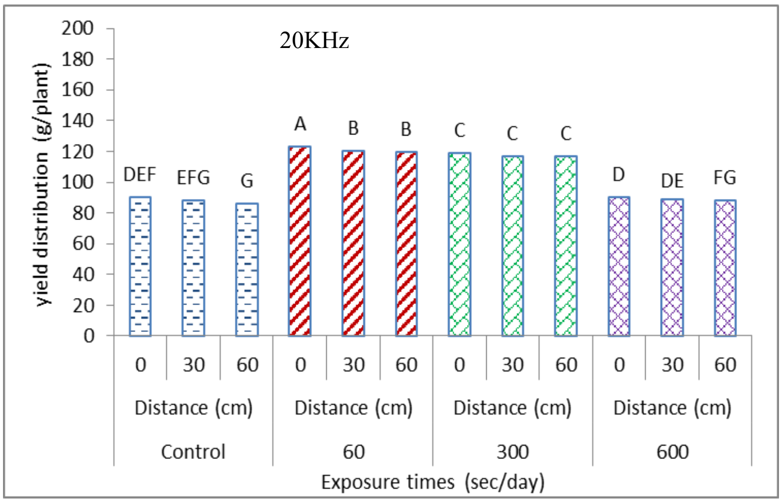


Figure 5 Effects of ultrasound waves on fruits number at different ultrasound waves

3.3 Accumulative yield

Figure 6 showed that the effect of distances and exposure times on accumulative yield of strawberry at different wave frequencies. From the figure it can shows that the highest accumulative yield was 190.00 g plant^{-1} per season at wave frequencies of 40 kHz, distance from the wave source zero and exposure time of ultrasound wave of 60 sec/day. Then the lowest accumulative yield was 61.29 g plant^{-1} per season at wave frequencies of 40 kHz, distance from the wave source zero and exposure time of ultrasound wave of 60 sec day^{-1}. These results were normally which the highest yield of fruit plant^{-1} found at the same levels of studied factories. This results agreement with Fan et al. (2010), Zhou et al. (2010), Qi et al. (2010) and Meng et al. (2012).

Therefore, the statistical analysis from Figure 6 cleared that the high differences effect between the high number of fruits treatment and all other treatments.



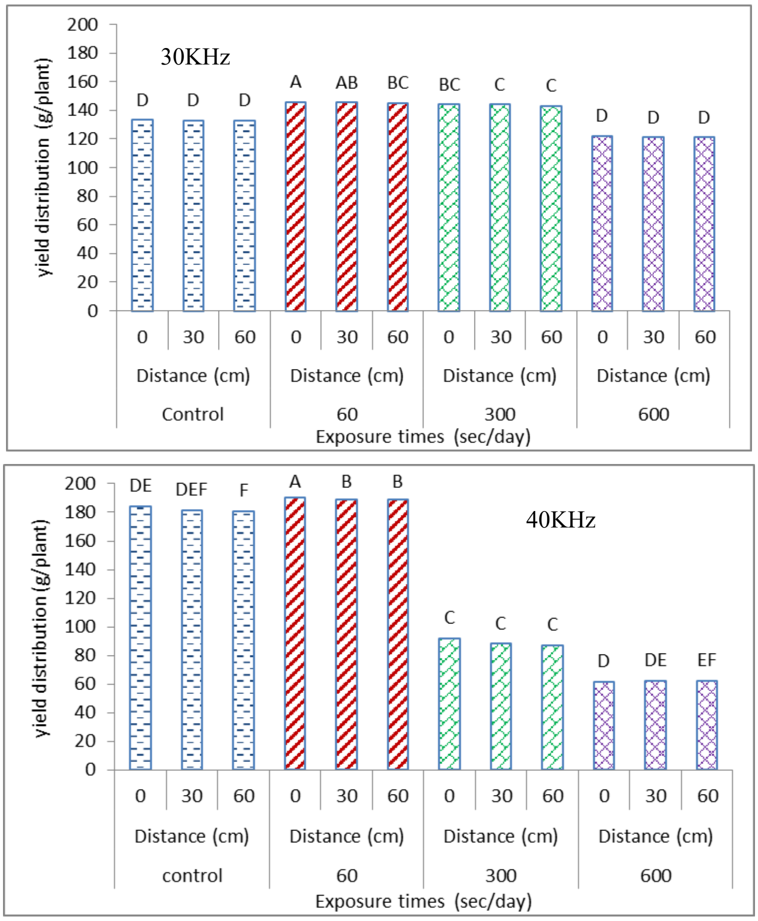
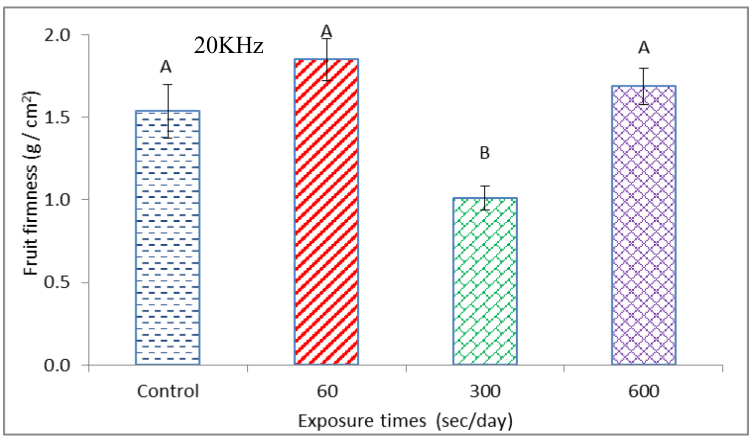


Figure 6 Effects of ultrasound waves yield distribution at different ultrasound waves

3.4 Fruit firmness

The effects of distances and exposure times on fruit firmness of strawberry leaves at different wave frequencies were illustrated in Figure 7. From the figure it can realize that the maximum and minimum fruit firmness were 1.85 and 1.01, 1.55 and 0.4 and 1.08 and 0.28 g cm^{-2} at wave frequencies of 20, 30 and 40 kHz respectively. The maximum values found at distance from the wave source zero and exposure time of ultrasound wave of 60 sec day^{-1} using wave frequency of 20 kHz. While, it achieved at distance from the wave source zero and exposure time of ultrasound wave of 600 sec day^{-1} using wave frequencies of 30 and 40 kHz and vice versa for the minimum fruits firmness. These results mean that the high fruit firmness found in generally at the lowest wave frequency (20 kHz). Then the ultrasound waves with high frequency were bad to export on firmness of fruits. These were results agreement with Russowski et al. (2013), Ozkurt and Altuntas (2018), and Dobranszki (2019).

Therefore, the statistical analysis conducted that there were high differences effect between the high number of fruits treatment and all other treatments (Figure 7).



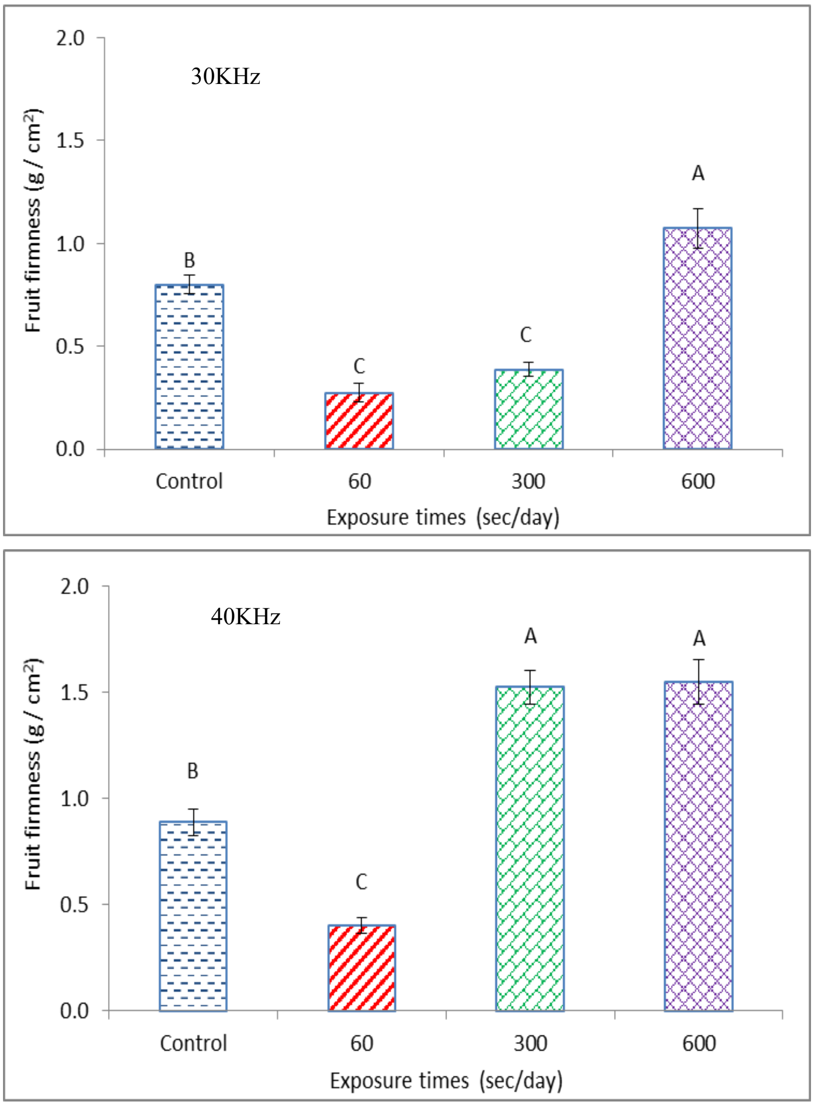


Figure 7 Effects of ultrasound waves on fruit firmness at different ultrasound waves

4 Conclusion

The use of ultrasound waves is suitable to improve plant growth of strawberry in most properties and productivity especially when device used at horizontal distance zero at exposure time of ultrasound wave 60 sec with wave frequency 40kHz-100dB -40W at wanting to produce fruits for local consumption. If wanted to export strawberry, the best treatment conditions were at wave frequency of 20 kHz-100dB -40W at zero distance between source of waves and plants per 60 s exposure time of ultrasound wave.

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