

*Full Length Research Paper*

# Vibration and noise characteristics of hook type olive harvesters

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The objective of this study was to obtain and evaluate the vibration and noise characteristics of portable hook type mechanical olive harvesters. Experiments included five hook type olive harvesters. In this study, the vibration and sound pressure levels of different harvesters were measured at idling and full load condition. The vibration levels on the handle grip of harvesters were measured and analyzed for both operator's right and left hand, respectively. The sound pressure level was measured at ear level of the operator. The frequency weighting acceleration was calculated. The vibration total value was expressed as the root-mean-square (rms) of three component values. The acceleration values vary between 5.52 and 39.15 ms<sup>-2</sup> for right hand and 4.18 and 61.01 ms<sup>-2</sup> for left hand. The equivalent noise pressure levels of the harvesters were measured between 91 and 103 dB (A) in the full loading conditions and between 67 and 80 dB (A) idling working conditions.

**Key words:** Olive harvester, vibration, noise, hav

## INTRODUCTION

Olive (*Olea europaea*) is one of the oldest cultivated fruits. The homeland of olive upper Mesopotamia including south-eastern Anatolia region of Turkey and it has spread to other Mediterranean countries from this region (Sessiz and Özcan, 2006).

90% of the world's olive trees are located in the Mediterranean basin. The 97% of the world olive oil is produced by Mediterranean countries as led by Spain with nearly 45% of the world's olive oil and 35% of the World's table olives. Italy, Greece and Turkey follow Spain as other major producers (FAO, 2005).

While world production is 14 354 000 tons, the olive production of Turkey is 1 200 000 tons (FAO, 2005; TUIK, 2008). The olive production in Turkey is carried at about 190,000 enterprises. The major part (61.3%) of olive production is achieved in the Aegean Region of Turkey. The number of olive trees is approximately 55 million in this region (Saraçoğlu, 2008).

The harvest labour of olive needs more manpower than the other labour. Hand harvesting is currently about 50%

of the total production costs and 50 to 60% of total labour requirement is used for harvesting operations (Özarslan et al., 2001).

At the present time, demand for olive was increased in parallel with increase in health conscious. Therefore, importance of olive is becoming higher and for this reason, concern on olive production and consequently, its most problematic stage harvest mechanization is also increasing (Saraçoğlu, 2008).

Hand held type olive harvester was easily used in sloped lands of olive trees and they are suitable for Turkey where 81% of olive trees are grown in sloped and terraced lands. The olive orchards are generally small enterprises. For that reason, hand held olive harvester are recommended instead of using trunk shakers which are not suitable for those enterprises because of economical and technical reasons. However, hand held olive harvest machines such as pneumatic or electric olive harvester, shakers with knapsack engine, etc. have some disadvantages. For example, work efficiency of some types is insufficient and their usage is tiring (Caran, 1998).

The hand held olive harvesters pick up the fruits by means of impacts produced by vibrational tools driven by little two-cycle engines or electric motors. The hand held

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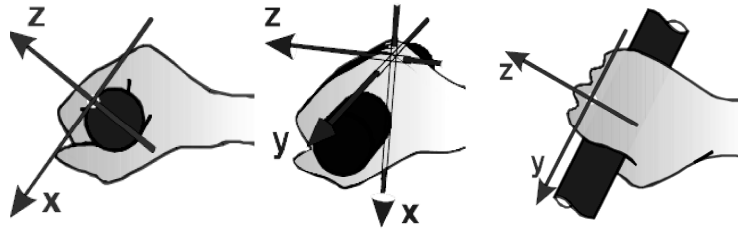


Figure 1. Orthogonal directions for operator hand.

olive harvesters, hook type, have a hook at the top of the rod. The engine produces an alternative motion of the rod and therefore, of the hook. During the work, the operator clasps the olive branch with the machine, which moves the branch with high frequency, detaching the fruits.

The operating mechanisms of hook type mechanical harvesters differ from one to another. The hook type mechanical harvesters operate on different amplitudes and frequencies. The operators of hand-held power tools, commonly used in several industries and similar other applications are exposed to high levels of hand-arm vibration (HAV) at the tool-hand interface. This vibration causes Raynaud's disease that affects the blood vessels and nerves of the hands (Mallick, 2008).

Mechanical vibration arises from a wide variety of processes and operations performed in industry, mining and construction, forestry and agriculture and public utilities (Bovenzi, 2005). Exposure to hand-arm vibration is one of the main physical risks for workers involved in the agro-forestry field. The prolonged use of hand held vibrating power tools like chain saws and hand-held shakers can lead to the hand-arm vibration syndrome (HAVS) that can interest the muscle-skeletal, nervous and vascular peripheral structures of the upper limb. The hand-arm vibration damage depends on multiple factors: the stimulus intensity, the propagation direction, the exposure duration and the operators' grip forces on the tool's handles (Deboli and Calvo, 2009).

Hand-arm vibration syndrome (HAVS) is a disease that involves circulatory disorders (for example, vibration white finger), sensory and motor disorders and musculoskeletal disorders, which may occur in workers who use vibrating handheld tools (Vegara et al., 2008).

The noise exposure can cause different disorders and symptoms. Levels from 66 dB (A) to 85 dB (A) can involve physical and neurovegetative disorders and sometimes, auditory damage. Levels from 86 to 115 dB (A) can cause specific effects to the ear, such as the damage of Corti's cells and can involve psychosomatic diseases (Ragni et al., 1999).

The objective of this study was to determine and evaluate the exposure of the operator to vibration and noise of hook type mechanical olive harvesters and its relative risks.

## MATERIALS AND METHODS

For practical convenience, the magnitude of vibration is expressed in terms of an average measure of the acceleration, usually, the root mean square value ( $\text{ms}^{-2}$ , rms). The rms magnitude is related to the vibration energy and hence, the vibration injury potential. The frequency of vibration is expressed in cycles per second and it is measured in Hertz (Hz).

Biodynamic investigations showed that the response of the human body to vibration is frequency dependent (Griffin, 1990). The adverse health effects of whole-body vibration can occur in the low frequency range from 0.5 to 80 Hz. For hand-transmitted vibration, frequencies from 6.3 to 1250 Hz can provoke disorders in the hand-arm system. To account for these differences in the response of the body to vibration frequency, current standards for human vibration recommend weighting the frequencies of the measured vibration according to the possible deteriorate effect associated with each frequency (ISO, 2001, 2005b). Frequency weightings are required for three orthogonal directions (x, y, and z-axis) at the interfaces between the body and the vibration (Figure 1). For the health effects of hand-transmitted vibration on the upper limbs (ISO, 2005b), the evaluation of vibration exposure is based on the vibration total value ( $a_{hv}$ ), a quantity defined as the square root of the sum of the squares (rms) of the frequency weighted acceleration values ( $a_{hw}$ ) determined on the three orthogonal axis x, y, z.

The coordinate system will then be defined as (ISO, 2005b): Z-axis, directed along the third metacarpus bone of the hand; X-axis, perpendicular to the palm surface area (both these axes are normal to the longitudinal axis of the grip); and Y-axis, parallel to the longitudinal axis of the grip (Dewangana and Tewari, 2008).

Human exposure to hand-arm vibration should be evaluated using the method defined in ISO (2005b) and detailed practical guidance on using the method for measurement of vibration at the workplace is given in ISO (2004).

In the ISO (2005b) recommendations, the most important quantity used to describe the magnitude of vibration transmitted to the operator's hands is the root-mean-square (rms) frequency-weighted acceleration. In addition, it is strongly recommended that for additional purposes, frequency spectra should be obtained. Acceleration values from one-third octave band analysis can be used to obtain the frequency-weighted acceleration  $a_{hw}$ . It was obtained using Equation 1:

$$a_{hw} = \sqrt{\sum_1 (W_{hi} \cdot a_{hi})^2} \quad (1)$$

Where,  $a_{hi}$  is the acceleration measured in  $i^{\text{th}}$  in one-third octave band in  $\text{ms}^{-2}$ ;  $W_{hi}$  is the weighting factor for the  $i^{\text{th}}$  one-third octave band as shown in Figure 2.

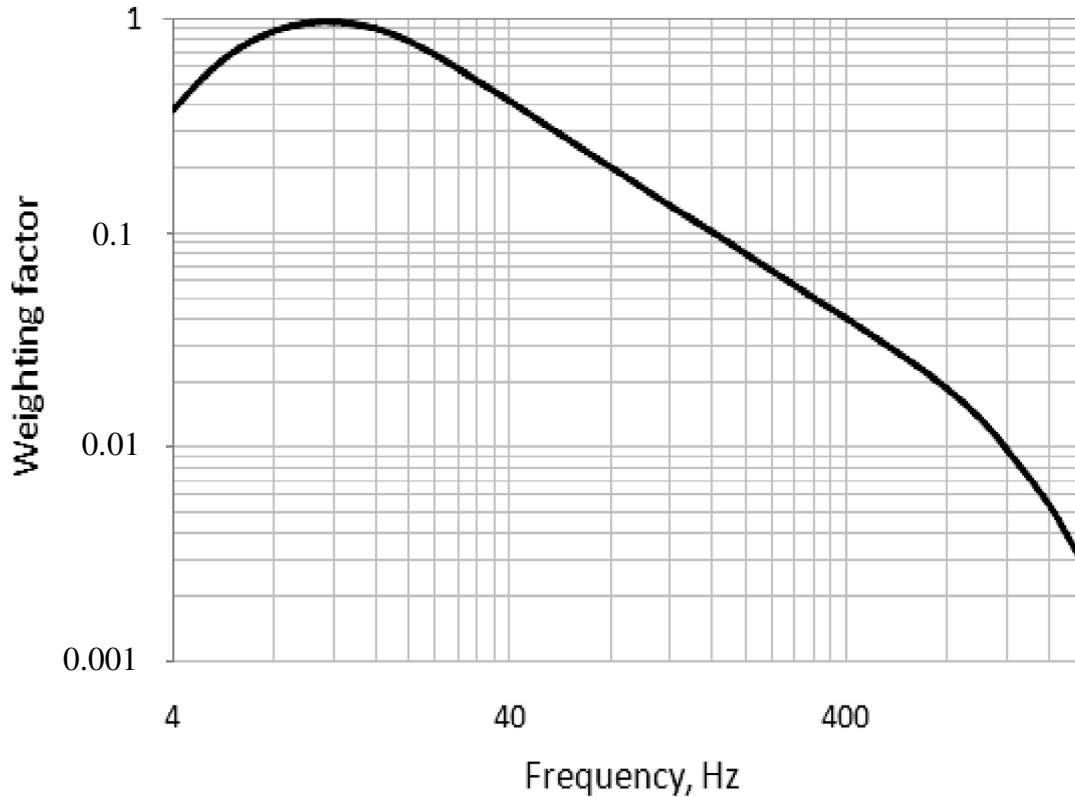


Figure 2. Frequency weighting factor ( $W_i$ ) curve for hand-transmitted vibration.

The evaluation of vibration exposure in accordance with ISO (2005b) is based on quantity that combines all three axes. This is the vibration total value  $a_{nv}$  and it is defined as the root-mean square of three component values shall be obtained by using Equation 2.

$$a_{nv} = \sqrt{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2} \quad (2)$$

Where,  $a_{hwx}$ ,  $a_{hwy}$ ,  $a_{hwz}$  are the frequency weighted acceleration values for the single axis.

The vibration exposure depends on the magnitude of the total value of vibration and the duration of the exposure. Daily exposure duration is the total time for which the hands are exposed to vibration during the working day. It is very important to base estimates of total daily exposure duration on appropriate representative samples for the various operating conditions. The daily vibration exposure shall be expressed in terms of the 8 h energy equivalent frequency weighted vibration total values as  $A(8)$ .

If the work is such that the total daily vibration exposure consists of several options (idling and loading) with different vibration magnitudes, than the daily vibration exposure,  $A(8)$  shall be obtained using Equation 3.

$$A(8) = \sqrt{\frac{1}{T_0} \sum_{i=1}^n a_{hvi}^2 T_i} \quad (3)$$

Where,  $a_{hvi}$  is the vibration total value for the  $i^{th}$  operation;  $n$  is the number of individual vibration exposures;  $T_i$  is the duration of the  $i^{th}$  operation and  $T_0$ : reference time (8 h = 28800 s).

The European Technical Report CEN/TR 231064 (2004) gives  $T_i$  as half of total working time for idling and half of total working time for nominal maximum speed for hook type mechanical olive harvesters.

In order to estimate 10% of operators are exposed to a risk of vibration-induced white finger was used Equation 4.

$$D_y = 31,8[A(8)]^{-1,06} \quad (4)$$

Where,  $A(8)$  is the daily vibration exposure ( $ms^{-2}$ ) and  $D_y$  is the group mean of exposure time of vibration (year).

The vibration levels transmitted to the operator's hands were measured under two operating conditions; idling and full loading. For this purpose, the procedure defined in ISO (2005b) was followed. The vibration levels were measured in all three axes simultaneously and the frequency spectra were obtained. Each test was repeated 5 times with an acquisition period of 60 s. The vibration was measured at the handle grip level for both hands of the operator.

Sound with high volume damages the hearing nerves inside the inner-ear. The higher the volume of the sound is the higher the risk of damage. The damage to the ear depends not only on the volume of the sound, but also the duration of exposure (Demir et al., 2005). Noise-induced hearing loss is a function of sound level and duration of exposure. For long-term exposure, the level of 85 dB (A) is regarded as the critical intensity; at exposures below 85 dB (A) the hearing losses were significantly lower than for exposures exceeding this value. International standards (ISO 1999:1990) recommended the equivalent sound pressure level ( $L_{equ}$ , 8 h) of 85 dB (A) (A filter-weighted, 8-h working day-weighted average) as the exposure limit for occupational noise (ISO, 2005a).



**Figure 3.** Position of piezoelectric accelerometer.

However, this limit did not guarantee the safety for the auditory system of workers. Therefore, the new EC directive on the minimum health and safety requirements regarding exposure of workers to the risks arising from physical agents (noise) introduces lower exposure action value at  $L_{EX, 8h} = 80$  dB(A) (Directive 2003/10/EC, 2003). In order to counteract noise-induced hearing loss more effectively, it has been established the minimal security level at the equivalent noise exposure limit to 80 dB (A) for 8 h working day (or 40 h working week), assuming that below this level, the risk to hearing is negligible. The 8-h equivalent level ( $L_{equ, 8h}$ ) is a widely used measurement for the risk of hearing damage in industry and can equally be applied to leisure noise exposure.

With regard to noise, the continuous equivalent acoustic pressure level weighted "A" was determined according to ISO (2003) and ISO (2005a). The noise was measured at the operator's ear level.

The transducers employed include; miniature triaxial piezoelectric accelerometer (B&K, 4520-002) handle mounted adapter (B&K UA-3015) inserted between the operator's fingers and the grip and fixed on the grip by tape (Figure 3) (Ying et al., 1998; Ragni, et al., 1999). The transducer is inserted between the middle and index fingers of the right and left hand, respectively.

The right hand was used for operating the controls. The condenser microphone (B&K, 4189) used for measuring noise was mounted on a suitable helmet. Each test was repeated 5 times with an acquisition period of 60 s.

To measure vibration and noise, a portable multianalyser system (Bruel and Kjaer Type 3560 C, Denmark) was used. The multianalyser system is a versatile, task oriented analysis system for vibration and noise analysis. Type 3560 C is a portable system powered by internal batteries or an external DC supply. This system consists of a PC with LAN interface, PULSE 5.1 software "Noise and Vibration Analysis Type 7700" and data acquisition front-end hardware. PULSE 5.1 software provides a graphical user interface

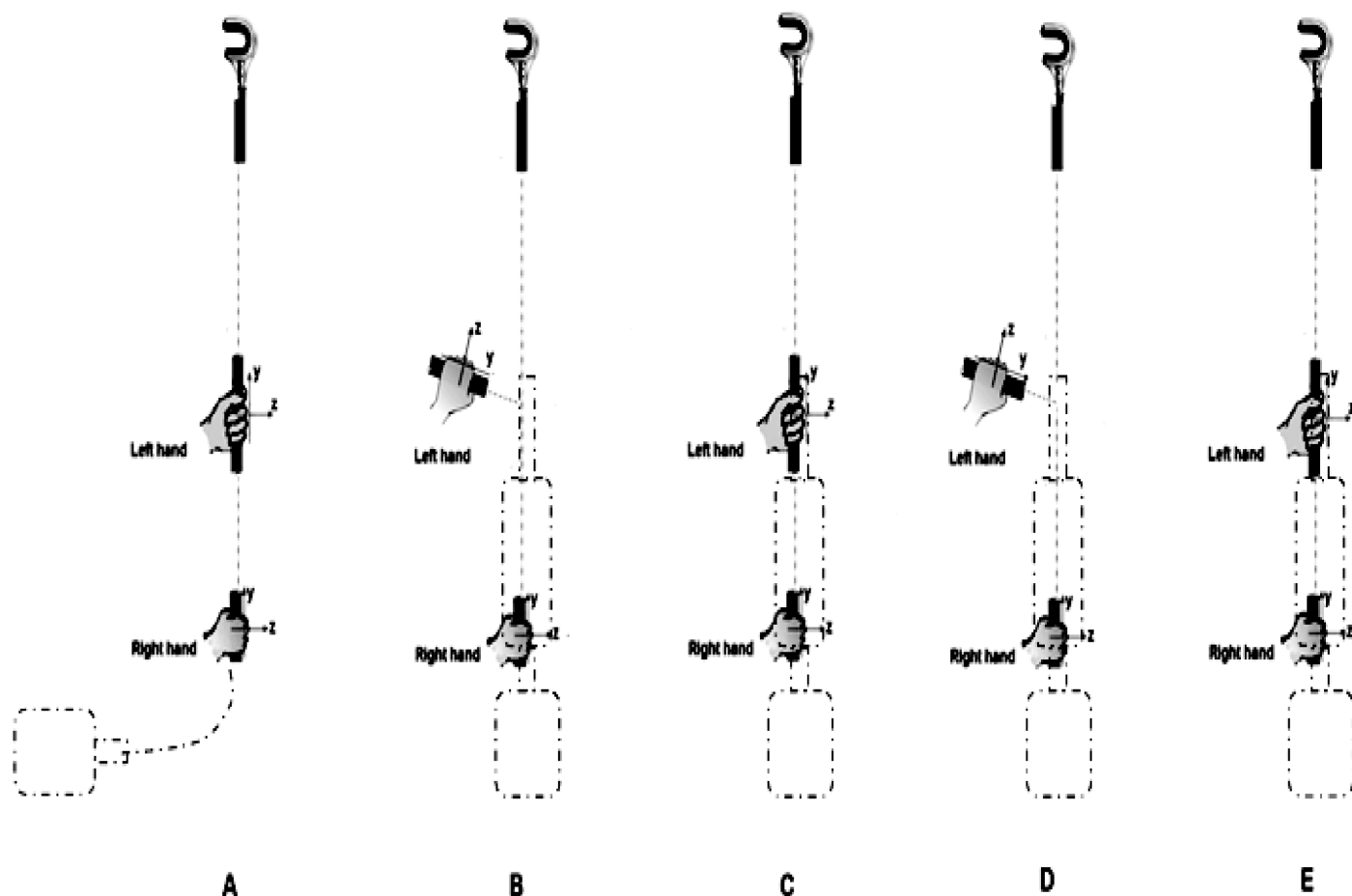
to the measuring system and serves as a platform for other analyzer accessories and applications Type 3560 C.

The measurement of vibration and noise levels were carried out in the experimental fields of the Faculty of Agriculture of Ege University. The experiments were carried out in 2008. Five different type olive harvesters (Figure 4) were used. The technical specifications of these harvesters are given in Table 1.

## RESULTS AND DISCUSSION

Vibration levels depend on the operating system of hook type mechanical olive harvesters. The operator felt the vibration in his hands at the grip of handle. It was observed that the rms acceleration values decreased for Harvesters B (Figure 5). In addition to vibration, the weight of the harvester is the other difficulty for the operators that they have to carry them during the operation period.

The  $a_{hw}$  acceleration values for each measurement direction for the five different type olive harvesters are given for right and left hand of operator in Figure 5a, b, respectively along with the standard deviation values. The  $a_{hw}$  acceleration values vary between 5.52 and 39.15  $ms^{-2}$  for right hand and 4.18 and 61.01  $ms^{-2}$  for left hand (Table 2). The maximum vibration intensity on the right and left hands in the y direction of Harvester A was measured. On the other hand, minimum vibration values were determined on the right hand in they direction and



**Figure 4.** Accelerometer locations, right and left hand position on handle boom.

**Table 1.** The technical characteristics of the tested hook type mechanical olive harvesters.

Base	A	B	C	D	E
Total weight (kg)	14.7	14.9	14.5	12.7	15
Engine displacement (cm <sup>3</sup> )	60	52	52.5	44	41
Power (kW)	1.47	2.4	2.1	2.1	1.8
Working frequency (cycle min <sup>-1</sup> )	2500	1800	1360	1900	2400
Working amplitude (mm)	40	40	60	50	50

on the left hand in the z direction of Harvester B. It is seen clearly that vibration values in the y direction is the biggest for Harvester A among the entire harvester because there is no damper on this harvester.

The peak acceleration values were read on the left hand since the olive harvesters were held in the middle of the boom by the operator's left hand. The full loading and idling conditions are depicted in Figure 6. As seen from Figure 6, the  $a_{hv}$  (the vibration total values) values are almost similar to Harvesters C, D and E. On the other hand, the maximum and the minimum vibration total

values were measured for Harvesters A and B, respectively.

Daily exposure values were also calculated with the maximum daily time. Values in this case vary from 0.63 year for Harvester A and 2.64 years for Harvester B (Figure 7). Noise pressure level dB (A) of olive harvesters is higher in full loading conditions than noise pressure level of idling. The equivalent noise pressure levels of the harvesters were measured between 91 and 103 dB (A) in the full loading conditions and between 67 and 80 dB (A) idling working conditions. The highest

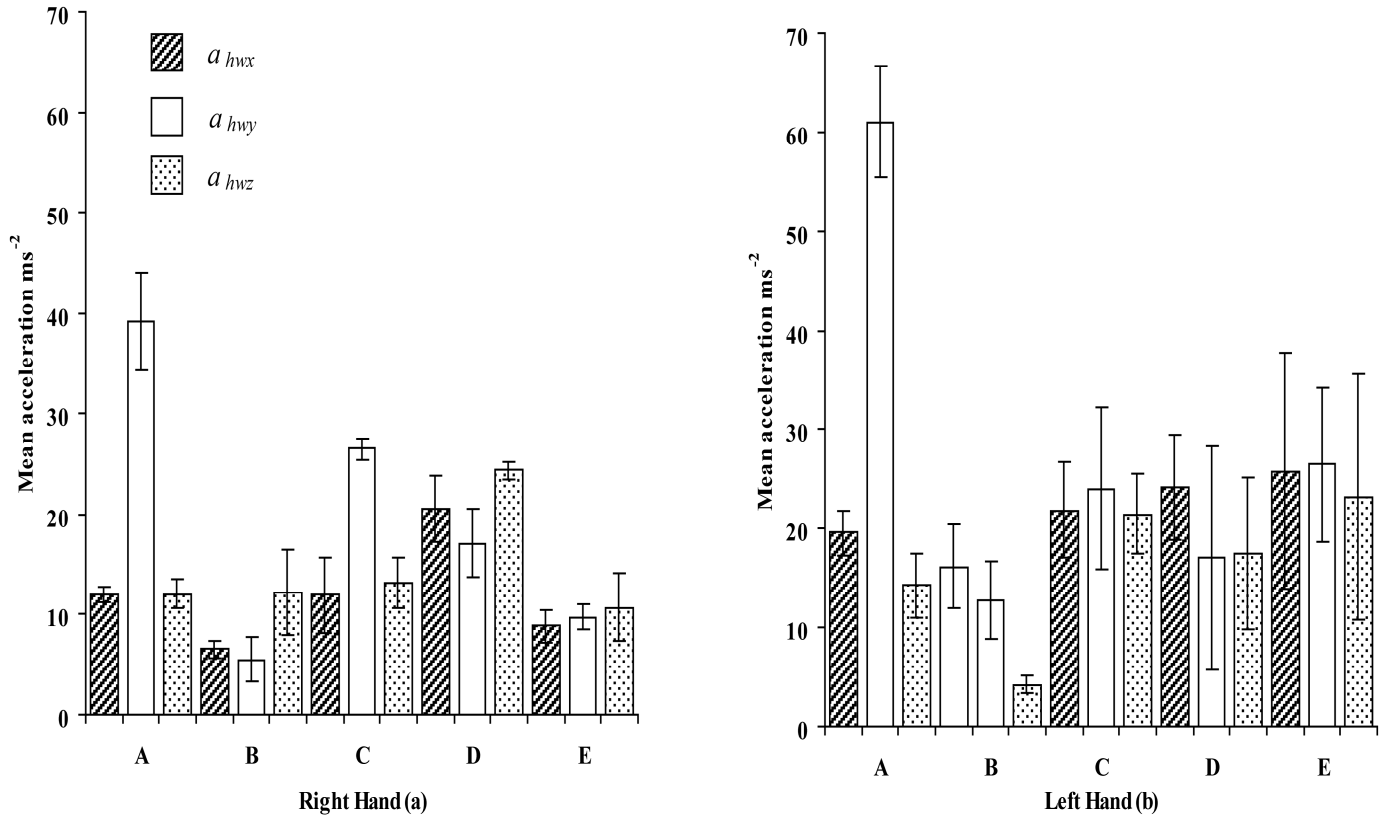


Figure 5. The rms ( $a_{hw}$ ) acceleration values and standard deviations of harvesters for right and left hand in three axes.

Table 2. The Duncan grouping of rms ( $a_{hw}$ ) acceleration values of harvesters for left and right and in three axes.

Harvester		A	B	C	D	E
Left hand	$a_{hwx}$	19.62 <sup>ab</sup>	16.17 <sup>a</sup>	21.90 <sup>ab</sup>	24.12 <sup>ab</sup>	25.84 <sup>b</sup>
	$a_{hwy}$	61.01 <sup>c</sup>	12.82 <sup>a</sup>	24.02 <sup>b</sup>	17.03 <sup>ab</sup>	26.46 <sup>b</sup>
	$a_{hwz}$	14.27 <sup>b</sup>	4.18 <sup>a</sup>	17.57 <sup>b</sup>	21.50 <sup>b</sup>	23.28 <sup>b</sup>
Right hand	$a_{hwx}$	11.82 <sup>b</sup>	6.50 <sup>a</sup>	11.95 <sup>b</sup>	20.56 <sup>c</sup>	6.84 <sup>ab</sup>
	$a_{hwy}$	39.15 <sup>d</sup>	5.52 <sup>a</sup>	26.47 <sup>c</sup>	17.11 <sup>b</sup>	9.77 <sup>a</sup>
	$a_{hwz}$	12.09 <sup>a</sup>	12.20 <sup>a</sup>	13.17 <sup>a</sup>	24.34 <sup>b</sup>	10.71 <sup>a</sup>

Mean followed by similar letters in each column, are not significantly at the 5% level of probability.

equivalent noise pressure levels were found on the Harvester C (Figure 8).

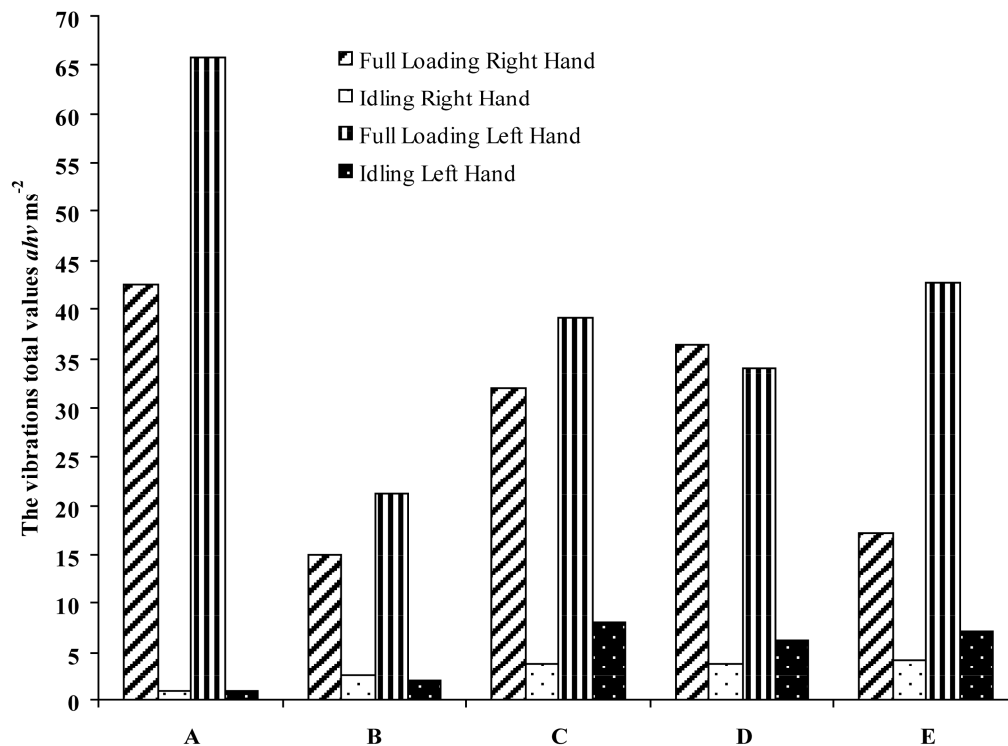
**Conclusion**

Based on results, it is evident that the vibration level (acceleration-rms) transmitted from the hook type olive harvester to the operator’s hands will produce finger blanching in 10% of the exposed persons after less than 0.63 year for Harvester A. Therefore, it is necessary for operators to take responsibility for occupational health and safety. They should take safety precautions. It is

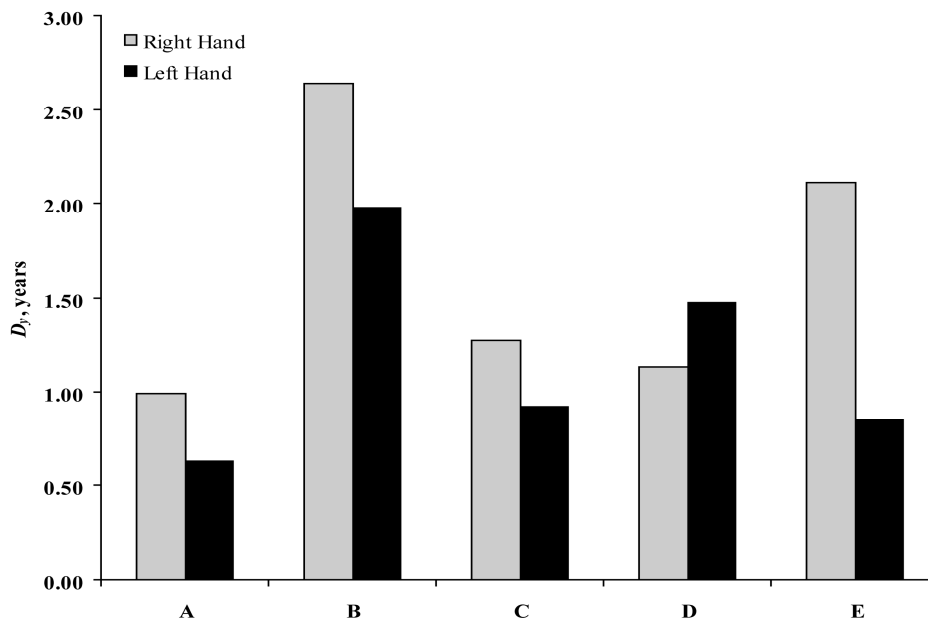
presumed that vibration hazards are reduced when continuous vibration exposures over long periods are avoided. Hence, the work schedules should be arranged to include vibration-free periods.

The harvester B provide most comfort harvesting conditions for operator when compared with Harvesters A, C, D and E. Therefore, Harvester B could be preferable harvesters for long-term olive harvesting. The level of noise allowed by most countries’ noise standards is generally 85 to 90 dB (A) over an eight-hour workday (although some countries recommend that noise levels be even lower than this).

Exposure to higher noise levels may be allowed for



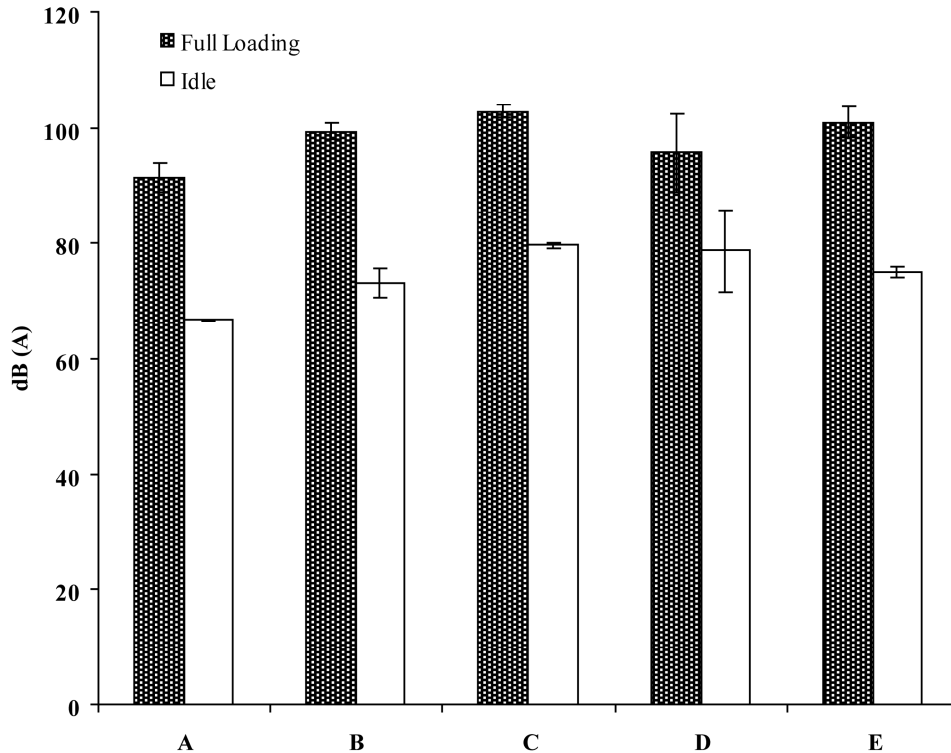
**Figure 6.** The vibration total values ( $a_{hv}$ ) of hook type olive harvesters in the full loading and idling working conditions.



**Figure 7.** Daily exposure values with the maximum daily time.

periods of less than eight hours of exposure time. Exposed workers should be provided with ear protection, while exposed at this level and rotated out of the noise areas after working periods of continuous work. Control-

ling noise at the harvester operator, it should use ear protection. Generally, there are two types of ear protection: earplugs and earmuffs. Both are designed to prevent excessive noise from reaching the inner ear.



**Figure 8.** Noise pressure level dB (A) of hook type olive harvesters in the full loading and idling working conditions.

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