KSÜ Tarım ve Doğa Derg 25 (2): 348-356, 2022
KSU J. Agric Nat 25 (2): 348-356, 2022
DOI:10.18016/ksutarimdoga.vi.770711

Noise Exposure in Olive Harvest Mechanization

Seçil Coşkun ÖZKUL[1], Sarp Korkut SÜMER[2]
[1,2]Çanakkale Onsekiz Mart University, Faculty of Agriculture, Agricultural Machinery and Technologies Engineering, 17020 Çanakkale/Turkey
[1]https://orcid.org/0000-0003-2859-9935, [2]https://orcid.org/0000-0001-7679-6154
✉: sarpksumer@comu.edu.tr

ABSTRACT
The purpose of this study was to determine the daily noise exposure levels in olive harvesting and to evaluate its effects on employees' health. The sound pressure levels (dBA) at the ear level of the employees were measured during olive harvest operations performed by hand-held, self-propelled and tractor-driven machines. It was determined that equivalent sound pressure levels and daily personal noise exposure levels at the operator ear level were in the range of 74-88 dBA and 66-82 dBA, respectively. These values for other employees ranged from 71 to 81 dBA and 65 to 75 dBA. It was determined that the hand-held and tractor driven machines driven by internal combustion engines had higher noise parameters compared to other machines, and the lower exposure action value was exceeded in these machines. The study showed that the health and work efficiency of the employees could be adversely affected, due to prolonged exposure during olive harvest activities.

Research Article

Article History
Received : 17.07.2020
Accepted : 30.05.2021

Keywords
Olive harvest machinery
Sound pressure level
Employees
Ergonomics

Zeytin Hasadı Mekanizasyonunda Gürültü Maruziyeti

ÖZET
Bu çalışmada makinalı zeytin hasadı faaliyetlerinde günlük kişisel gürültü maruziyet seviyelerinin belirlenmesi ve çalışanların sağlığı üzerindeki etkilerinin değerlendirilmesi amaçlanmıştır. El tipi, kendi yürür ve traktör tahrikli makinelerle yapılan zeytin hasatlarında çalışanların kulak seviyesindeki ses basıncı seviyeleri (dBA) ölçülmüştür. Operatör kulak seviyesinde eşdeğer ses basıncı düzeylerinin ve günlük kişisel gürültü maruziyet seviyelerinin sırasıyla 74-88 dBA ve 66-82 dBA aralığında olduğu belirlenmiştir. Diğer çalışanlar için bu değerler 71 ila 81 dBA ve 65 ila 75 dBA arasında değişmiştir. Termik motor tahrikli el tipi ve traktör tahrikli makinelerin diğer makinelere göre daha yüksek gürültü parametrelerine sahip olduğu ve bu makinelerde en düşük maruziyet eylem değerinin aşıldığı belirlenmiştir. Makinalı zeytin hasadı faaliyetlerinde, maruz kalınan gürültü seviyelerinin insan sağlığına fiziksel, fizyolojik ve psikolojik yönden olumsuz etkilerinin olabileceği ve çalışma performansını olumsuz etkileyebileceği sonucuna varılmıştır.

Araştırma Makalesi

Makale Tarihçesi
Geliş Tarihi : 17.07.2020
Kabul Tarihi : 30.05.2021

Anahtar Kelimeler
Zeytin hasat makinaları
Ses basınç düzeyi
Çalışanlar
Ergonomi

To Cite: Özkul SC, Sümer SK 2022. Noise Exposure in Olive Harvest Mechanization. KSÜ Tarım ve Doğa Derg 25 (2): 348-356. DOI: 10.18016/ksutarimdoga.vi.770711.

INTRODUCTION

Harvesting activities covering 70% of the production process constitute the last and most important part of olive cultivation (Saraçoğlu, 2001). The harvest period (October-February) and possible adverse weather conditions cause problems in finding workers, increasing labor cost, and hand harvesting constitutes and decreasing working efficiency (Saraçoğlu, 2001; Çiçek et al., 2012). In parallel with the technological advances, there have been important developments in olive harvest mechanization, and in recent years, traditional vehicles have been replaced by hand-held, tractor driven and self-propelled machines. Tree form and land structure are two important criteria in choosing these machines.

Since most olive orchards were established in slopy lands in most countries, hand-held machines were preferred in olive harvesting in the past, but recently, the use of tractor driven and self-propelled machines has become widespread due to the higher work capacities. While these technologies and innovations provide important advantages such as saving time and decreasing the dependence on labor, they can also have some undesirable effects on employees (Sola-Guirado et al., 2014; Bernardi et al., 2018). Particularly, machine operators and the other employees work under various hazards and risks in terms of occupational health and safety. Noise is one of the most widely and frequently experienced problems of the man-machine systems (Çiçek et al., 2015; Stangl et al., 1973; Sabancı and Sümer, 2015). The effects of noise in agricultural activities have attracted the attention of many researchers, and studies have focused on tractors, known as a common source of farm noise. It has been determined that tractors produce dangerous levels (range from 75-106 dBA, L_{eq}) of noise under various working conditions (Matthews, 1968; Sullivan et al., 1980; Meyer et al., 1993; Aybek et al., 2010; Bilski, 2013; Sümer et al., 2016). Various studies have also been carried out to determine the noise levels (range from 56-90 dBA, L_{eq}) caused by various self-propelled and hand-held machines. The examples include wine and cereal growing (Franzinelli et al., 1988), hand-held olive harvesters (Saraçoğlu, 2001), motor scythes (Çakmak and Alayunt, 2009; Çakmak et al., 2011), combine harvesters (Sümer et al., 2006; Jahanbakhshi et al., 2016), grain dryers (Reinvee et al., 2013), hazelnut harvester (Sauk and Beyhan, 2016), and grass cutting machine (Calvo et al, 2016).

There are two studies on noise formation in olive harvest, and only hand-held electric machines (hook and flap types) were examined in the previous studies (Saraçoğlu, 2001; Çakmak et al., 2011). No study has been found on the noise level and effects of internal combustion engine driven machines, widely used in olive harvesting. The objective of this study was to determine the daily noise exposure levels of some machine types widely used in olive harvesting and to evaluate their effects on employees' health. For this purpose, sound pressure level (SPL) measurements were conducted during the olive harvests performed by hand-held, self-propelled, and tractor-driven machines, and the results were evaluated by considering the relevant regulations and various research results.

MATERIAL and METHOD

The study was conducted in the Marmara and Aegean Region of Turkey. The machines were selected in a variety to represent all the machines used in olive harvest and had different technical characteristics and different working principles according to the topography and tree form: hand-held types, self-propelled and tractor-driven (Figure 1).

Figure 1. Images of olive harvesting machines used in the research. a) hook, b) flap, c) self-propelled trunk shaker, d) and e) tractor driven trunk shaker, f) tractor driven rotated flap, g) the other employee, h) operator

Şekil 1. Araştımada kullanılan zeytin hasat makinalarına ait görseller a) dal sarsıcı, b) tarak, c) kendi yürür gövde sarsıcı, d) ve e) traktör tahrikli gövde sarsıcı, f) traktör tahrikli döner tarak, g) diğer çalışan, h) operatör

Hand-held type olive harvesters: the hand-held olive harvesters pick up the fruits by means of impacts produced by vibrational tools driven by small two-cycle engines or electric motors (Saraçoğlu, 2001). Two different types of hand-held machines were selected, which are commonly used in the semi-mechanized olive harvesting: *Hook type (branch shaker)* dropping the olives by shaking the branches, *Flap type (comb)* dropping the olives by combing and flapping the thin branches. SPL measurements were made on four hook type machines, and four flap type machines. In addition, measurements were also conducted for olive harvesting, where two machines are used together (Figure 1; Table 1).

Table 1. The technical characteristics of hand-held type olive harvesters
Çizelge 1. El tipi zeytin hasat makinalarına ait Teknik özellikler

Machine	Brand - Model	Year
Flap 1 (F1)*	Benza - BO12, (500 watt)	2017
Flap 2 (F2)	Olivgreen - Pro 500, (250 watt)	2018
Flap 3 (F3)	Zanon, (600 watt)	2016
Flap 4 (F4)	Benza - BO12, (500 watt)	2018
Hook 1 (H1)	Stihl - SP 481, (2,20 kW)	2018
Hook 2 (H2)*	Cifarelli - SC 800, (3,60 kW)	2017
Hook 3 (H3)	Stihl - SP 481, (2,20 kW)	2018
Hook 4 (H4)	Cifarelli - SC 800, (3,60 kW)	2017

**The machines used simultaneously together for harvesting*

Self-propelled olive harvester: these machines, driven by internal combustion engines, perform the harvesting by shaking the tree completely from the trunk or main branches (Deboli et al., 2014). The self-propelled trunk shaker (SPS) olive harvester had an operator cabin, but there was no door at the operator entrance of the cabin and operator worked with the front, back and right sides closed (Table 2; Figure 1).

Tractor driven olive harvesters: The study continued the sound pressure levels measurements of three tractor-driven olive harvesters, two of which are trunk shaker and the third one with a rotary comb. *Tractor driven trunk shaker (TDS):* these machines, driven by tractors, perform the harvesting by shaking the tree completely from the trunk or main branches (Table 3). *Rotary comb (RC):* while the shaker olive harvester falls out the olives by means of impacts or branches shaking, this machine combs the branches instead of hitting them (Deboli et al., 2014).

Table 2. The technical characteristics of self-propelled olive harvesters (SPS)
Çizelge 2. Kendi yürür zeytin hasat makinalarına ait teknik özellikler

Brand, Model	Sicma, speedy
Fuel	Diesel
Engine power	Iveco FTP 66,5 kW/4 cylinders
Controls	Joystick and steering wheel
Transmission	Hydrostatic
Diameter	6000-8000 mm
Height, Length	1860 mm, 5990 mm
Width, Weight	2200 mm, 3950 kg
Year	2018

Table 3. The technical characteristics of tractor driven harvesters and tractors
Çizelge 3. Traktör tahrikli zeytin hasat makinalarına ait teknik özellikler

Type	Brand	Technical features
Front-linkage Trunk shaker (FTDS)	Agromelca Z20	Turbo vibration system Hydrostatic PTO driven: 540 rpm Year: 2017
	Tractor New Holland 110-90	with cab 81 kW Year: 1998
Rear-linkage Trunk shaker (RTDS)	Tornado Spedo	Turbo vibration system Hydrostatic PTO driven: 540 rpm Year: 2018
	Tractor Same Explorer 95 T8	without cab 70 kW Year: 2016
Rotary comb (RC)	Viviani Z20	Hydrostatic PTO driven: 540 rpm Year: 2007
	Tractor Same Dorado 55	without cab 38.5 kW Year: 2016

It was observed that operators preferred to work with the door open during the harvesting operations with the front-mounted trunk shaker. Therefore, measurements were made separately while the door was closed and open. In this machine, the operator uses both the tractor and the harvester. As for the rear-linked machine, the harvesting operations were carried out by two operators (for harvester and tractor). The olive harvester operator directed the machine with a remote control about 10 m from the tractor and the harvester. Thus, measurements were made for both operators.

Measurement Procedure

All factors (work, production, process, organization, employees, working time) that can contribute to noise exposure were analyzed (OSHA, 1998), and it was determined that the task-based strategy was suitable for the study, According to the task-based measurement strategy, all tasks performed by the employees within a working day were defined, the working time of each task was determined precisely, and sound pressure level measurements were made for each task separately.

In the measurements, an SPL meter in Type-2 class (TESTO 816-1) complying with the requirements of IEC 61672-1: 2002 (IEC, 2002) was used. Calibration of sound level meter was performed by using Testo Schall IEC 60942 Class 2 calibrator complying with the of IEC 61672-1: 2002 (IEC, 2002), which defines the SPL as 94 and 114 dBA. A MASTECH brand MS6252B model wind meter was used to determine the wind speed. The measurements of A-weighted SPL (dBA) for all sub-tasks of the machine operators and other employees picking up olives were conducted for about 5 min with three replications. In all measurements, the microphone was located 20 cm to the right side of the center plane of the operator's head, in line with the eyes, with its axis parallel to the operator's line of vision (ISO, 2009). Besides, sound pressure levels of harvesters were measured at both idling and full loading conditions.

Equivalent SPL (L_{eq}) values were calculated by using the obtained SPLs dBA. Durations (Tm) for each task were determined by observing employees' occupational activities and interviewing them.

Equation (1) was used to calculate the relative contribution of each task to the daily personal noise exposure levels of operators and other employees according to the task-based measurement strategy specified in the EN ISO 9612 standard (ISO, 2009), using the L_{eq} values and effective duration of each task in the working day. Each activity, in which the machine is active or passive, was defined as a task such as lunch, maintenance, pick-up, refueling. The Leq values determined in the tasks when the machines were passive varied between 58-62 dBA.

$$L_{EX,8h,m} = L_{p,AeqT,m} + 10\lg\left[\frac{\bar{T}_m}{T_0}\right] \quad (1)$$

where;

$L_{EX,8h,m}$: L_{eq} for task m contributing to the daily noise exposure level, dB(A)

$\bar{T}_m$: effective duration of the working day for task m, h

T_0: reference duration, 8 h

m: task number

Daily personal noise exposure levels were calculated with Equation (2).

$$L_{EX,8h} = 10\log\left[\sum_{m=1}^{M}\frac{\bar{T}_m}{T_0}10^{0,1xL_{p,A,eqT,m}}\right] \quad (2)$$

$L_{EX,8h}$: daily noise exposure level normalized to nominal 8 h working day, dBA

M: total number of tasks

In the study, considering the noise parameters, the possible effects of daily noise exposure values on operators were evaluated and discussed by considering various research results and Directive 2003/10/EC (Directive, 2003) of the European Parliament and of the Council (minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents).

RESULTS and DISCUSSION

According to the data obtained, the operators of olive harvesters and tractors were exposed to higher noise parameters compared to the other workers during olive harvesting, as expected. The L_{eq} value determined in the operator ear level for all machines ranged from 74 to 88 dBA. The L_{EX} values of the operators were between 66-82 dBA, while the L_{max} values ranged between 85-109 dBA. For other workers, the ranges of L_{eq}, L_{EX} and L_{max} parameters were found to be 71-81, 65-75 and 79-99 dBA, respectively (Table 4; Figure 2).

The lowest L_{eq} value (74 dBA) was determined for the harvester operator of RTDS and the highest L_{eq} value (88 dBA) was determined for the H2+F1 operator among all the evaluated machines (harvesters and tractors). The use of remote control (5-10 m distance) in olive harvest carried out with RTDS was an important factor in the reduction of noise parameters determined for the harvester operators. As for L_{EX} values, the lowest value (66 dBA) was found in FTDS (door closed), the highest value (82 dBA) in H2+F1 combination. The closed-door position in the FTDS harvester provided approximately 4.5 dBA lower L_{eq} and L_{EX} values compared to the door open position.

L_{eq} values and L_{EX} values measured at the ear level of operators of hook type machines were found to be higher than those of other larger and higher power machines. The reasons for this result are that the hook type is a hand-held machine driven by a two-cycle engine with insufficient exhaust muffler and therefore the operator works very close to the noise source. The lowest (85 dBA) and the highest (109 dBA) L_{max} values were measured for operators of T2 flap type and D4 hook type machines, respectively.

The other employees, in olive harvesting activities, carry out olive picking up and loading into the crates, approximately 5-10 m away from the machines. In these activities, the lowest L_{eq}, L_{EX} and L_{max} values were determined for the T2 harvester as 71, 65 and 79 dBA respectively, while the highest L_{eq}, L_{EX} and L_{max} values were determined for the SPS harvester with 81, 75 and 99 dBA. The fact that a flap type machine was electrically driven caused lower noise parameters, while the highest parameters determined for SPS harvester could be explained with working at closer distances to the noise source (3-6 m) compared to those carried out with other harvesters. (Table 4; Figure 2; Figure 3).

Considering the load and idle position of all machines, it was determined that the highest difference for the two conditions occurred in hook types and the lowest difference was in flap types. Average difference was 22.4 dBA for hooks and 4.9 dBA for flaps. The differences of drive mechanisms of the machines (electric and two-cycle engine) can be shown as the reason for this result (Table 5; Figure 4).

Table 4. L_{eq}, L_{max} and L_{EX} values of olive harvesters
Çizelge 4. Zeytin hasat makinaları için belirlenen L_{eq}, L_{max} and L_{EX} değerleri

Harvester	Noise parameters, dBA							
	Operator			The other employees			Working mode	
	L_{eq}	L_{max}	L_{EX}	L_{eq}	L_{max}	L_{EX}	L_{eq} Loading	L_{eq} Idling
F1	76.30±0.77	87.33±3.94	69.93±0.76	70.84±1.01	81.63±1.96	64.54±1.43	78.93±0.31	74.38±0.31
F2	78.99±0.31	84.73±0.67	72.99±0.30	70.37±1.47	78.97±4.30	64.51±1.54	80.76±0.37	76.89±0.28
F3	79.67±0.44	88.33±0.32	73.66±0.43	71.60±1.55	80.77±5.88	65.66±1.68	83.10±0.26	76.02±0.84
F4	76.95±0.46	89.17±4.93	70.95±0.45	71.37±1.30	82.17±1.62	65.43±1.27	79.44±0.87	75.23±0.21
H1	85.52±0.61	107.40±0.70	77.75±0.60	74.25±1.21	82.93±3.92	66.65±1.20	96.69±1.61	76.24±0.84
H2	85.88±1.34	105.10±1.04	78.11±1.33	74.78±0.88	83.07±2.23	67.14±0.87	98.35±1.36	74.37±0.58
H3	83.31±0.95	103.70±0.58	75.55±0.94	73.21±1.71	88.20±3.63	65.68±1.70	98.41±0.77	73.10±0.13
H4	86.34±1.06	108.53±0.95	79.95±1.05	75.35±0.90	90.00±0.10	69.00±0.89	97.59±0.63	77.76±0.61
H2*+F1	87.53±1.38	106.33±1.34	81.51±1.37	76.37±1.94	93.40±2.97	70.37±1.93	97.24±1.01	75.33±0.92
F1*+H2	80.19±1.79	96.20±2.78	74.18±1.78				96.25±0.91	76.17±0.81
SPS	83.72±0.76	101.67±2.37	77.91±0.75	80.87±1.42	99.17±1.06	74.86±1.41	88.05±1.30	79.76±0.23
FTDS(C[1])	73.84±0.38	87.63±1.50	65.55±0.37	75.71±1.60	91.37±0.12	67.40±1.59	76.69±0.76	71.04±0.25
FTDS(O[2])	77.40±0.45	91.50±0.26	69.07±0.44				80.80±1.22	73.81±0.28
RTDS(HO[3])	73.72±1.92	95.73±1.08	68.41±1.91	72.85±1.59	88.60±4.31	67.55±1.58	76.95±0.85	66.85±1.93
RTDS(TO[4])	81.07±1.22	91.80±1.37	70.54±1.21					
RC	82.93±0.91	90.77±2.46	76.06±0.90	78.92±0.53	88.27±3.21	72.54±0.52	84.36±0.85	81.04±1.16

*[1]Door open, [2]Door closed, [3]Harvester operator, [4]Tractor operator. *Measurement at the ear level of the operator H2 and F1 with both machines running.*

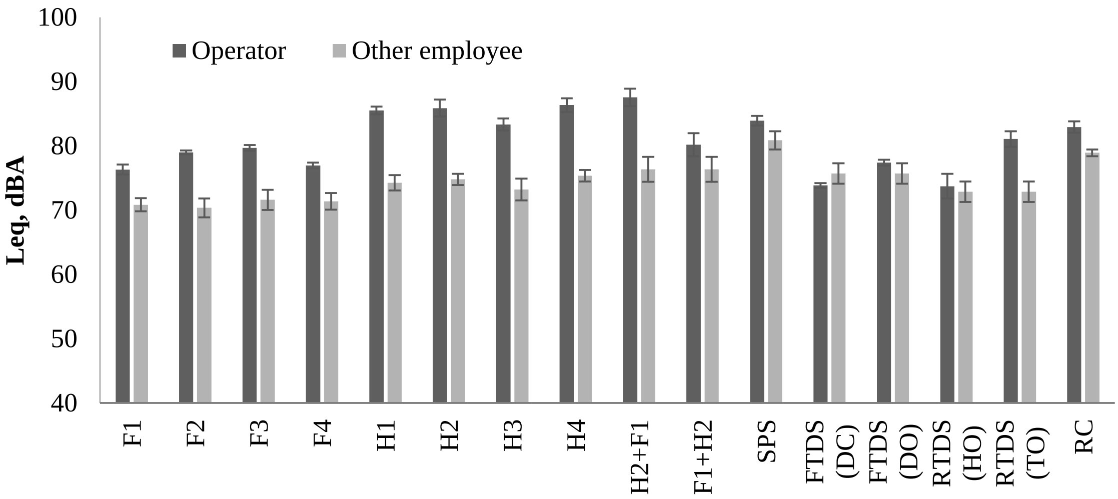

Figure 2. L_{eq} values of operators and other employees for all machines tested in the study
Şekil 2. Tüm hasat faaliyetlerinde operatörler ve diğer çalışanlar için L_{eq} değerleri

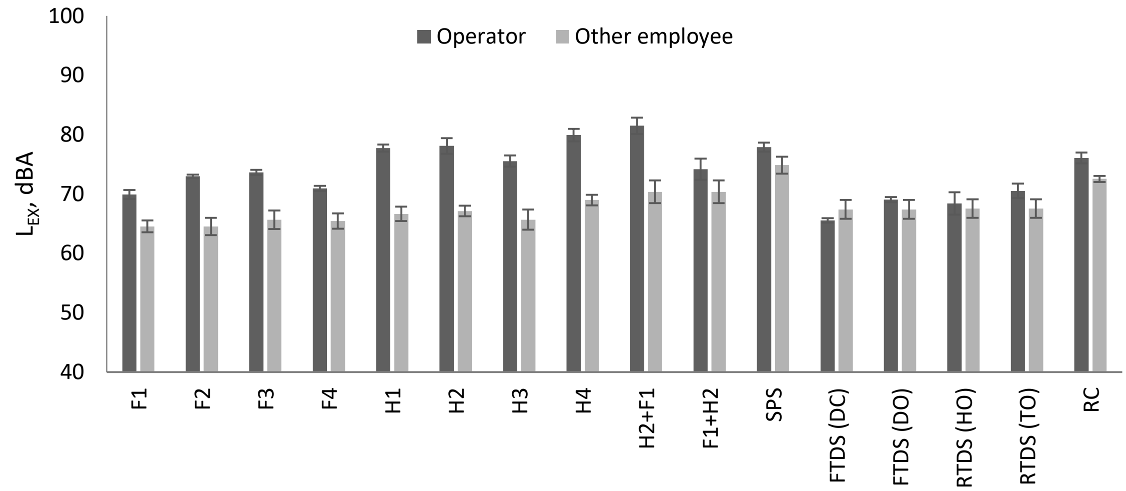

Figure 3. L_{EX} values of operators and other employees for all machines tested in the study
Şekil 3. Tüm hasat faaliyetlerinde operatörler ve diğer çalışanlar için L_{EX} değerleri

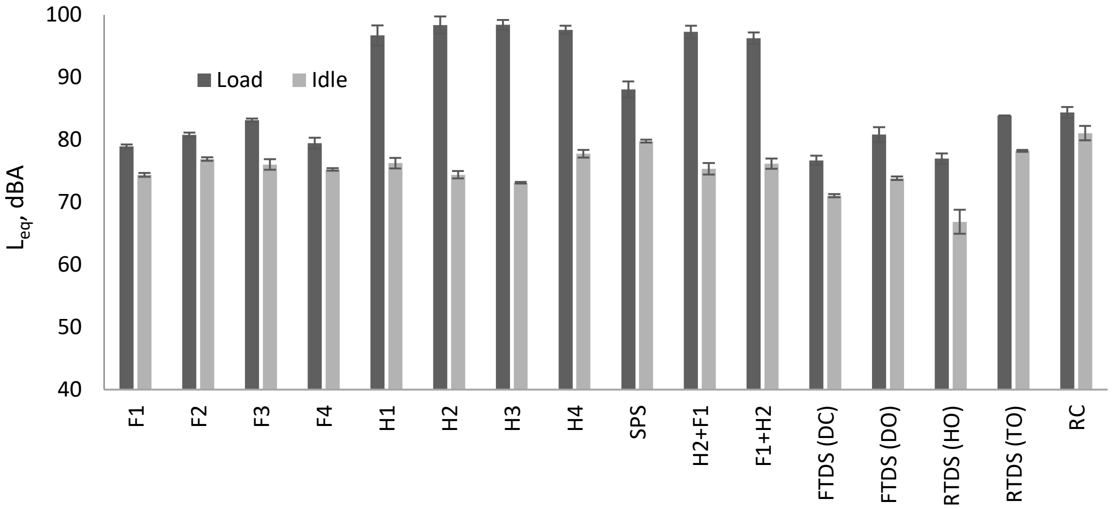

Figure 4. L_{eq} values in the load and idle positions of all machines tested in the study
Şekil 4. Makinaların yük ve rolanti pozisyonları için L_{eq} değerleri

When the number of employees and working durations in the harvesting activities are examined, it is seen that two operators worked as the machine and tractor operator in RTDS harvester, and only one operator worked in all other harvesters. As for other employees, while there have generally been fewer employees in small olive orchards with fewer trees, harvesting was carried out with more employees in large enterprises (Table 5).

The olive harvesting activities have differed in terms of daily, active, and passive working hours. Machine performance and the number of other employees accompanying the operator could be considered as influencing factors on these durations. For example, the hook type harvester with higher performance had lower active hours compared to the flap type. Active durations for all employees and the duration of breaks, such as lunches and the others, had an impact on the employees' daily personal noise exposure levels. The increase in the share of passive time in daily working hours had a remarkable effect on the decrease of L_{EX} values.

When the literature is examined, it is possible to come across many studies in which the effects of personal noise exposure are evaluated only by determining Leq and Lmax values. In order to assess whether the employees work in accordance with the noise regulations, it is necessary to determine the L_{EX} value, which also takes into account working times. Although the 8-hour shift is standard in many workplaces, farmers are known to work longer or shorter hours for a given task. Some researchers stated that depending on the type of farm and time of year farmers can work up to 11-15 hours per day (Solecki, 2000; Winters et al., 2005).

Table 5. The number of employees and working durations
Çizelge 5. Hasat faaliyetleri için çalışan sayıları ile çalışma süreleri

Harvester	The number of Operators +other	Working duration h/day	Working duration distribution, h/day					
			Operator			Other employees		
			Active*	Passive*	Breaks	Active*	Passive*	Breaks
F1	1+10	7.0	5.5	0.5	1.0	6.0	1.0	1.0
F2	1+2	8.5	6.0	2.0	0.5	6.0	2.0	0.5
F3	1+6	7,5	6.0	1.0	0.5	6.0	1.0	0.5
F4	1+10	7.5	6.0	1.0	0.5	6.0	1.0	0.5
H1	1+14	8.5	4.0	3.5	1.0	4.0	3.5	1.0
H2	1+3	8.0	4.0	3.0	1.0	4.0	3.0	1.0
H3	1+1	9.0	4.0	4.0	1.0	4.0	4.0	1.0
H4	1+10	7.5	5.5	1.0	1.0	5.5	1.0	1.0
H+F	1+5+10	7.5	6.0	1.0	0.5	6.0	1.0	0.5
SPS	1+10	8.0	6.0	1.0	1.0	6.0	1.0	1.0
FTDS	1+1	5.0	3.5	1.0	0.5	3.5	1.0	0.5
RTDS(HO)	1+10	8.5	5.0	2.0	1.5	5.0	2.0	1.5
RTDS(TO)	1+10	8.5	2.0	5.0	1.5	5.0	2.0	1.5
RC	1+15	7.5	5.5	1.0	1.0	5.5	1.0	1.0

**Working duration under conditions that the harvester is active or passive*

In the present study, it was determined that the L_{max} value increased up to 109 dBA and the L_{eq} value reached 88 dBA. However, a more effective parameter for evaluating the effect of noise on the employee, the highest L_{EX} value was 82 dBA. Currently, regulations are focused on hearing loss, which is a physical effect, when controlling occupational noise, and this limit varies between 85-90 dBA across countries. This effect has been emphasized in the majority of scientific studies conducted, moreover it has also been reported that sound pressure levels below the limit values specified in the regulations may cause hearing loss. In the EU noise regulation (Directive 2003), there are two main action levels that guide these steps: lower exposure action value and upper exposure action value. The lower one is a daily average noise exposure level of 80 dBA, at which the employer has to provide information and training and make hearing protection available. The upper one is set at a daily average noise exposure of 85 dBA, above which the employer is required to take reasonably practicable measures to reduce noise exposure, such as engineering controls or other technical measures. The use of personal protective equipment (PPE) is also mandatory if the noise cannot be controlled by these measures (Directive, 2003). In the hearing loss classification of WHO (World Health Organization), it was reported that prolonged exposure at 41-60 dBA intervals causes hearing loss, and 61-80 dBA intervals can cause severe hearing loss. Although the results of present study were mostly below the action values, according to WHO's classification, they showed that olive harvesting employees work under risk of hearing loss (WHO, 1991).

Many acoustic studies report that the noise will continue to adversely affect human health not only physically, but also in a physiological and psychological context, unless necessary precautions are taken. Ragni et al. (1999) reported that noise exposures between 66-85 dBA cause physical and autonomic nervous system disorders. Serin and Akay (2008) stated that noise exposures in the range of 66-85 dBA have disturbing psychological effects in addition to hearing loss. Noise exposure was also identified as a risk factor for cardiovascular disease (Basner et al., 2014). Several acoustic studies report that these effects of noise negatively affect cognition, decision-making, learning, calculation, and hand-eye coordination of employees, and thus have an effect on reducing work efficiency (Sabancı and Sümer, 2015; Thatcher and Yeow, 2018).

Considering the literature review regarding the effects of noise on employees, it was concluded that noise exposures (L_{EX}) determined for 12 olive harvesters of three types in olive harvesting may have not only physical effects but also physiological and psychological effects on the health of employees. These effects may also reduce the work efficiency of the operator and other employees. Therefore, the noise control measures are of great importance in olive harvesting to protect the health of employees. According to EU regulation, employers are required to take certain steps to reduce the harmful effects of noise on hearing. According to the results of the present study, operators and other employees work at noisy conditions below the upper exposure action value in all olive harvest operations examined while the lower exposure action value was exceeded only in "hook+flap" (82 dBA, L_{EX}) application. These results should not mean that there is no need to take measures against noise. Considering the literature review on the effects of noise, olive harvest lasting about 5 months (average 8 hours daily duration), should be considered an activity that affects the health and work efficiency of the employees.

Measures to be taken to reduce the noise affecting employees in olive harvest may vary depending on the machine type. Engineering noise controls, very common in the agricultural setting, can be an effective application for tractor-driven and self-propelled machines. Retrofitting the cabs of self-propelled and tractor-driven olive harvesters with enclosure is the priority choice in reducing noise exposure. The window and door of the cab must be completely closed during harvesting. As for hand-held type machines, where it is not possible to apply engineering control, it seems that the operators should use PPEs for protection against noise. Çakmak et al. (2011) determined the noise levels in flap-type olive harvesters (56-73 dBA, L_{eq}) while and Saraçoğlu et al. (2011) determined the noise levels in the hook-type harvesting machines (56-73 dBA, L_{eq}), and in both studies, using the PPEs were recommended to protect the operators.

Using PPE for other employees in all olive harvests would be the best way to protect them from noise, but the effectiveness of these devices for preventing noise-induced hearing loss depends on the consistent use of the PPEs. Therefore, the operators and other employees should be encouraged to use PPE and increased their awareness through trainings. In the present study, besides the noise, it was observed that the precautions taken for employees' health and safety are almost nonexistent. In addition, the awareness of employees regarding occupational health and safety is quite low and they are uneducated in this regard. So, the work is done by the operators with very low risk perception.

CONCLUSION

It was concluded that the health and work efficiency of the operators and other employees were adversely affected in olive harvesting mechanization. The duration and conditions of the breaks in the daily activities of the employees had an impact on the LEX values. The operators of the olive harvest machine with thermic engine face higher risks of noise than those working on the other machines due to higher exposure levels. The directives on noise control state that accurate and adequate noise control measures must be effectively taken. However, it was observed that no measures were taken in the olive harvest activities evaluated in this study. Therefore, it is likely that hearing loss will occur in employees. Moreover, physiological and psychological effects may cause serious disturbances. Along with the effects of noise on human health, effects such as preventing speech and masking warning signals will not only decrease the work efficiency of employees but also increase the risk of accidents. Control methods to be applied in order to reduce the noise affecting employees in olive harvest should be selected and applied in accordance with the type of machine used.

ACKNOWLEDGMENT

This paper was produced from the project supported by The Scientific Research Projects Coordination Unit (Project no: FYL-2018-2717) of Canakkale Onsekiz Mart University. The authors also wish to thank to Ahmet Çelik who helped us in the fieldwork and to Prof. Dr. Cem Ömer Egesel for his valuable discussions and critical reading of this manuscript.

Statement of Conflict of Interest

Authors have declared no conflict of interest.

Author's Contributions

The contribution of the authors is equal.

REFERENCES

Aybek A, Kamer HA, Arslan S 2010. Personal noise exposures of operators of agricultural tractors. J Appl Ergonomics, 41(2):274-281.

Basner M, Babisch W, Davis A, Brink M, Clark C 2014. Auditory and non-auditory effects of noise on health. Lancet, 1325-1332.

Bernardi B, Falcone G, Stillitano T, Benalia S, Stranoa A, Bacenetti J, De Lucca AI 2018. Harvesting system sustainability in Mediterranean olive cultivation. Science of The Total Environment, 625;1446-1458.

Bilski B 2013. Exposure to audible and infrasonic noise by modern agricultural tractors operators. J Appl Ergonomics, 44:210-214.

Çakmak B, Alayunt FN 2009. Vibration and noise characteristics of two different types of trimmers. Journal of Agricultural Machinery Science, 5(2):167-173.

Çakmak B, Saraçoğlu T, Alayunt F, Özarslan C 2011. Vibration and noise characteristics of flap type olive harvesters. J Appl Ergonomics, 42:397-402.

Calvo A, Deboli R, Preti C 2016. Operators' exposure to noise and vibration in the grass cut tasks: comparison between private and public yards. Agric Eng Int: CIGR Journal, 18(1):213-225.

Çiçek G, Sümer SK, Çay A 2015. Determination of the number of trees to be harvested by shaking olive harvesting machine by the equivalent cost analysis method. In: the 29th National Agricultural Mechanization and Energy Congress. Conference proceedings, 348-352.

Deboli R, Calvo A, Gambella F, Preti C, Dau R, Casu EC 2014. Hand arm vibration generated by a rotary pick-up for table olives harvesting. Agric

Eng Int: CIGR Journal, 16(1):228-235.

Directive 2003/10/EC, 2003. of the European parliament and of the council of 6 February 2003 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise). Available from: https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32003L0010

Franzinelli A, Maiorano M, De BC, Masini M 1988. Annual dose of noise absorbed by machine drivers in wine and cereal growing. G Ital Med Lav., 10(3):131-134.

IEC 61672-1:2002. The international electrotechnical commission, Electroacoustics – Sound level meters – Part 1: Specifications.

ISO 9612 EN 2009. Acoustics - Determination of occupational noise exposure - Engineering method. Available from: https://www.iso.org/obp/ui/#iso: std:iso: 9612: ed2: v1: en

Jahanbakhshi A, Ghamari B, Heidarbeigi K 2016. Effect of engine rotation speed and gear ratio on the acoustic emission of John Deere 1055I combine harvester. Agric Eng Int: CIGR J., 18(3):106-112.

Matthews J 1968. Measurements of environmental noise in agriculture. Journal of Agricultural Engineering Research, 13(2):157-170.

Meyer RE, Schwab CV, Bern CJ 1993. Tractor noise exposure for bean bar riders. Trans ASAE, 36(4):1049-1056. Available from: https://doi.org/10.13031/2013.28433

OSHA 1998. Occupational safety and health administration. Regulations (Standards–29 CFR) Occupational noise exposure. 1998(1910.95). Available from: https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.95.

Ragni L, Vassalini G, Xu F, Zhang LB 1999. Vibration and noise of small implements for soil tillage. Journal of Agricultural Engineering Research, 75:403-409.

Reinvee M, Luik M, Kliimak P 2013. Noise emission from grain dryers and potential noise pollution. Agronomy Research, 11(2):457-462.

Sabancı A, Sümer SK 2015. Ergonomics (in Turkish). Nobel Academic Publishing, Ankara. Second edition, 472.

Saraçoğlu T, Çakmak B, Özarslan C, Alayunt FN 2011. Vibration and noise characteristics of hook type olive harvesters. African Journal of Biotechnology, 10(41):8074-8081.

Saraçoğlu T 2001. The determination of some handy type olive harvest machines performances (in Turkish). Uni. of Adnan Menderes. MSc. Thesis.

Sauk H, Beyhan M 2016. Determination of noise level during hazelnut harvesting with the pneumatic hazelnut harvester. International Journal of Agriculture and Wildlife Science (IJAWS), 2(1): 23-27.

Serin H, Akay AE 2008. Analysis of noise level resulting from logging. In: The 14th National Ergonomics Congress. Conference proceedings, 412-418.

Sola-Guirado RR, Castro-Garcia S, Blanco-Roldan GL, Jimenez-Jimenez F, Castillo-Ruiz FJ, Gil-Ribes JA 2014. Traditional olive tree response to oil olive harvesting Technologies. Biosystems Engineering, 118:186-193.

Solecki L 2000. Duration of exposure to noise among farmers as an important factor of occupational risk. Ann Agric Environ Med., 7(2):89-93.

Stangl GA, Porterfield JG, Lowery RL 1973. Tractor exhaust noise evaluation technique. Transact. ASAE, 16(4): 601-605.

Sullivan NW, Schnieder RD, Von Bargen K 1980. Annual noise exposure patterns of agricultural employees. Chicago, IL, USA, ASAE, St. Joseph, Mich, USA.

Sümer SK, Çiçek G, Say SM 2016. Determination of the potential of olive oil production residues and investigation of possibilities for utilization in Çanakkale. J Agri Mach Sci., 12:103-111.

Sümer SK, Say SM, Ege F, Sabancı A 2006. Noise exposed of the operators of combine harvesters with and without a cab. J Appl Ergononomics, 37:749-756.

Thatcher A, Yeow PHP 2018. Ergonomics and human factors for a sustainable future, current research, and future possibilities. Part of Springer Nature, (eBook).

WHO, 1991. Report of the informal working group on prevention of deafness and hearing impairment programme planning, Geneva, 18-21 June 1991. Available from: https://apps.who.int/iris/handle/10665/58839?mode=full

Winters M, MacIntyre E, Peters C, Thom J, Teschke K, Davies H 2005. Noise and hearing loss in farming. Farm and Ranch Safety and Health Association, Available from: https://doi.org/10.14288/1.0048187