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The environmental noise level in the rejuvenation pruning on centuries-old olive tree

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Abstract. In the Italian agricultural economy, olive cultivation plays a fundamental role, and this is especially true for the southern regions where almost all cultivation is spread. In Calabria, in particular, olive cultivation has seen over the last few decades significantly improve the quality of production also as a result of investments aimed at the creation of new mechanizable plants and/or the modernization of existing ones; today some areas have got both PDO and PGI certification.
In the 'Piana di Gioia Tauro', located north-west of the Reggio Calabria metropolitan area, olive growing extends over 20,000 hectares and the presence of centuries-old olive tree is still widespread. The olive varieties mainly belong to the local cultivars of 'Sinopolese' and 'Ottobratica', characterized by a remarkable rusticity and high development, perhaps unique in the world; they reach 20–25 meters high, forming what is called a 'forest of olive trees'.
The pruning operations are carried out by means of chainsaws of different power and size whereby, in addition to the previously described difficulties, operators are exposed to prolonged periods of noise levels. The purpose of this study is precisely to assess the exposure of operators to this particular olive grove. The aim is to identify the acoustic levels generated by the two pruning and cross-cutting activities, the risk thresholds and the exposure to which the individual workers of the two work sites are subjected, giving indications on the appropriate safety distances to maintain (according to current regulations) compared to noise sources.

Key words: mechanized pruning, chainsaw, safety, dB, phonometer.

INTRODUCTION

The cultivation of the olive tree (*Olea europaea L.*) plays a fundamental role in the Italian agricultural economy, this is especially true in the southern regions where the highest share of olive oil production is concentrated.

Italy, in the world, is in second place among the producing and exporting countries of olive oil, after Spain, and the employed in the sector determine a commitment of about 30 million working days (CO.RE.R.A.S, 2007).

The olive tree is one of the most important crops in the Mediterranean region, where 97% of the world's olive oil is produced (IOOC, 2013). Calabria, in southern Italy, is the second region for olive production in Italy (ISTAT, 2016). The economic sustainability of olive groves necessarily implies the reduction of production costs especially those relating to manual harvesting, which accounts for approximately 40% of the total (Abenavoli & Proto, 2015; Abenavoli et al, 2016; Sorgonà et al., 2018).

Olive cultivation is therefore very widespread in the Calabrian territory and over the last few decades has seen a considerable improvement in the quality of olive oil production, following the introduction of new investments aimed at the implementation of agricultural mechanization. Therefore, new and more modern systems have been made or, where possible, existing ones have been modernized. Currently, some of these areas particularly suited, have had from European systems the recognition of the trademarks 'PDO' (Protected Designations of Origin) and 'PGI' (Protected Geographical Indications). Fruit picking and harvesting systems play an important role in the quality of drupes and olive oil (Mele et al., 2018).

Recent studies were conducted on olive and olive oil quality in Calabria in which the effects of cultivar, harvest date and harvest year on biometrics of fruits and on physico-chemical parameters of oil were evaluated (Abenavoli & Proto, 2015; Giuffrè, 2017; Giuffrè, 2018). In the territory of the 'Plain of Gioia Tauro', wide and fairly homogeneous area, composed of 33 municipalities and located in the North-West of the Reggio Calabria metropolitan area, where the olive growing covers over 20,000 hectares, still today, is widespread the presence of traditional planted trees, where the densities of planting varies from 50 to 80 plants ha^{-1} in the plains from 100 to 140 plants ha^{-1} in the hilly areas (Cavazzani & Sivini, 2001) and the distance between the plants, often irregular (due to the soil conditions), on average between 7–12 meters (Fig. 1).

The olive trees present, mostly centuries-old, belong mainly to the local 'Sinopolese' and 'Ottobratica' cultivars, which here assume a notable growth, perhaps unique in the world, with trees that reach 20–25 meters in height and that form a real 'forest of olive trees' (Fardella, 1995). Even if we find ourselves in a suggestive landscape, due to the majesty of these trees, the management of these plants is really problematic and not very rational due to the work overload that they require as well as the economic effort necessary for their maintenance (Proto & Zimbalatti, 2010; Abenavoli & Marcianò, 2013; Proto & Zimbalatti, 2015).

The farms of the district are mainly small or medium-sized and therefore have a low investment capacity and, at the same time, a high need for labor due to low levels of mechanization. In these conditions all the cultivation operations are more complex, but in particular the pruning of the trees, as the operators, as real 'climbers', with the only help of ropes must climb to make the cuts of the branches at high height. So this operation, which in other places and conditions falls within the normal routine of agricultural management, in the 'Plain of Gioia Tauro', due to the particular conditions of danger in which it is performed and its high cost, takes on an extraordinary character, so it is averaged every 7-8 years (Abenavoli & Marcianò, 2013).

The extraordinary pruning, depending on the purpose that is proposed, is distinguished in: pruning of rejuvenation, reform, transformation, rehabilitation and preparation for grafting. They are all based on a common principle, the ease with which the olive tree emits the suckers in every part of the tree, whatever its age (Morettini, 1972).

As a result, pruning in the 'Plain of Gioia Tauro' is particularly complex and involves the removal of large masses of wood, because the cuts are made on large diameter branches (Morettini, 1972).

At a later time, other operators making the sawing of the branches, left on the ground from the previous yard, up to the preparation of logs and their transport to different destinations based on their use (Abenavoli & Marcianò, 2013). While pruning residues and cuttings, which were previously left on the ground today, given the high calorific power they possess, are reduced to pellets and used as a source of energy or, alternatively, they can be transformed into high quality biochars, such as they have shown recent studies (Abenavoli et al., 2016).

To perform this type of pruning mechanical cutting equipment (chainsaws) of different powers and sizes are used and the operators, in addition to dealing with the difficulties described above, are also exposed to high and prolonged noise levels.

The purpose of the work was precisely to evaluate the exposure to noise of operators, who work in this particular Italian olive growing area. Moreover, we have proposed to identify the acoustic levels generated by the two activities (pruning and cross-cutting), the risk thresholds and the exposure to which the individual workers of the two work sites are subject, giving the indications (according to current regulations) on the appropriate safety distances to be maintained with respect to noise sources (Proto et al., 2016).

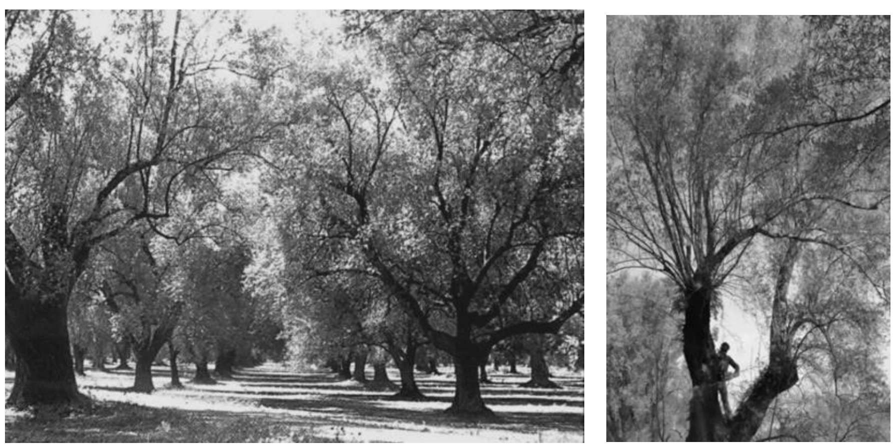

Figure 1. Typical olive-grove in 'Plain of Gioia Tauro' and an example of traditional pruning.

Noise is a relevant risk factor to be taken into account in evaluating health and safety of workers in agriculture (Vallone et al., 2017). Many studies have demonstrated that noise has serious effects (psychological and physiological) on humans, such as loss of concentration, difficulties to speak, loss of reflexes, reduced speech intelligibility, irritation, permanent hearing loss to permanent deafness, among others (Türker et al., 2011; De Souza et al., 2012; Proto et al., 2016; Grigolato et al., 2018). In particular, the process of mechanization in agricultural sector has led to an increase of the noise sources and, as a result, of an increase of the percentage of workers exposed to this risk. This study focuses on the assessment of workers' exposure to noise and was tested in compliance with the Italian legislation. The objective of this study was to evaluate the daily personal noise exposure of the underserved workers during pruning operations.

MATERIAL AND METHODS

The legislation reference

In Italy, Law Decree 81/2008 defined the requirements for assessing and managing noise risk, identifying a series of procedures to be adopted at different noise levels to limit workers exposure. Excessive noise, in fact, is a global occupational health hazard with considerable social and physiological impacts, including noise induced hearing loss (NIHL) (Deborah et al., 2005). The Italian Occupational Safety and Health legislation, in agreement with the EU Directive and ISO standard, establishes that both the worker's exposure time and instantaneous peak exposure must be considered, defining both the peak sound pressure level (L_p,C_{peak}), that is, the highest instantaneous sound pressure weighted through the 'C' ponderation curve, and the daily A-weighted noise exposure level, $LE_{X,8h}$, that is, the average value, time-weighted, of all the noise levels at work concerning an eight-hour working day (Pascuzzi & Santoro, 2017).

Instrumentation and test parameters

The noise exposure assessment during the pruning phase has been done with the use of integrator phonometer Class 1, by which were recorded sound pressure levels at ear of exposed workers and using 26 sound level data logger Class 2 (IEC 61672-1) to recorded acoustic levels located in a geometric scheme to assess the noise propagation in the area test. Before and after each series of measurements a field calibration with appropriate adjustment has been performed using a sound calibrator.

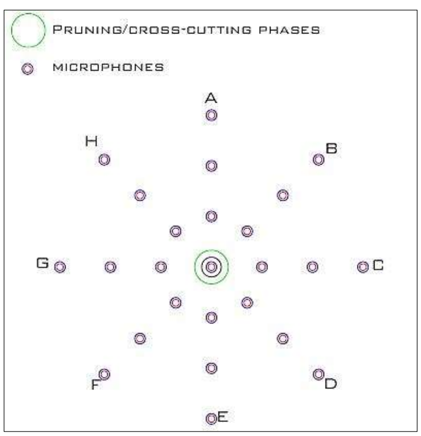

Figure 2. Locations of the sound level data logger for the noise measurements.

Figure 3. Sound level data logger for the noise measurements.

In order to measure the sound level at the ear level of the operator, the microphone was properly attached on a helmet and the operator was told to look continuously at the direction of movement during the measurements. Each data logger was mounted at 2 meters above the ground and positioned at 3, 6 and 9 meters away from the operator; the area was subdivided into 8 cardinal directions (Fig. 2). The measurements were taken in an open field using a properly set measurement system without any obstacle that might have caused sound reflection. During the sound level measurements the relative humidity and temperature of the experiment environment was measured by electronic thermo-hygrometer. During the noise measurements the environmental noise were ignored when the difference between the chainsaw sound levels and environmental noise levels were more than 10 dB (Brüel & Kjaer, 2001). Nine measurement periods were considered at each of the measuring points and these observations pointed out that the stated time interval T (measurement duration).

The collected data were processed in order to calculate the levels of personal noise exposure of workers involved in the pruning and cross-cutting operations.

The A-weighted equivalent continuous sound pressure level, $L_{p,A,eqT}$ was calculated by the following equation (ISO, 2013; Pascuzzi & Santoro, 2017):

$$L_{p,A,eqT} = 10lg\left[\frac{\frac{1}{T}\int_{t1}^{t2} p_A^2(t)dt}{p_0^2}\right] \text{dB} \qquad (1)$$

where p_a is the A-weighted sound pressure during the stated time interval T starting at t_1 and ending at t_2; p_0 is the reference pressure value (20 µPa).

On the other hand, the C-weighted peak sound pressure level, $L_{p,Cpeak}$ was calculated by the following equation (ISO, 2013; Pascuzzi & Santoro, 2017):

$$L_{p,Cpeak} = 10lg\frac{p_{Cpeak}^2}{p_0^2} \text{dB} \qquad (2)$$

where p_0 is the reference pressure value (20 µPa).

Work sites

The trials were conducted in the municipality of Cosoleto, metropolitan area of Reggio Calabria (Calabria region, Italy), typical olives-oil district. Two workers were monitored during the pruning phase and cross-cutting operations conducted on centuries-old olive trees. The plant density was very low and the average diameters of the crown was 14 m (Fig. 3), with a planting density of 73 plants for hectare (Table 1).

Table 1. Characteristics of the olive grove that has been subject to pruning (pre-intervention)

Biometric data	*Mean*	*SD*
Tree density (trees ha^{-1})	73.0	4.0
Tree height (m)	18.6	0.4
Crown diameter (m)	14.0	0.5
Trunk diameter (cm)	80.9	5.5

In the studied farms the pruning is usually done every ten years, so the cuts made are necessarily very drastic, and the wood mass removed is very significant. The first worker used a chainsaw Stihl, Ms-261C-BM model, for pruning operations and an assistant operator helped during this phase. The assistant was engaged like work place cleaning, accessories carrying, moving the branches away after delimbing, producing and stacking of fuel wood, etc. The second chainsaw operator used a Jonsered, CS-2188 model, and another operator was an assistant. The chainsaws' weight, guide bar length, and chain type are shown in Table 2.

Table 2. Description of the chainsaws

Sites	*Pruning*	*Cross-Cutting*
Chainsaw Type	Jonsered	Stihl
Model	CS 2188	Ms-261C-BM
Displacement (cm^3)	87.9	50.2
Power (kW)	4.8	4.1
Weight (Kg)	7.1	5.0
Guide bar (cm)	60.0	45.0
Specific power (kW kg^{-1})	1.8	1.4

RESULTS AND DISCUSSION

Daily exposure values were also calculated with the maximum daily time and each measurement was added with the uncertainty (ε) related to the level of daily personal exposure, to define if a specific limit of exposure is, or can be exceeded. In particular, uncertainties are a quantitative indication of the reliability of the result. In the case of environmental acoustic noise measurements, exceeding thresholds may cause health risks for the public and then it becomes essential to find the relationship between measurement uncertainty and acceptable risk (Russo, 2015). Analysis of noise levels are exceeded in first 6 meters from the area of operations (Fig. 4). In no station the value of L_{peak}(C) came out higher to135 dB(C), so the verification of the respect of the action values and the exposure limits has been carried out exclusively on the base of the values of the daily personal exposure $L_{EX,8h}$. Values in this case varied from 92.8 and 91.0 dB(A) during pruning phase while the operator is exposed at an equivalent noise pressure levels between 92.0 and 89.6 for cross-cutting operation. Another important factor to considered is the different daily personal exposure; in fact during the pruning phase the operator typically used a chainsaw for less time respect the cross-cutting. In the Tables 4 and 5 are reported the daily personal exposure in a period of eight hours, distinct for phase and distances. This confirms that a chainsaw is one of the most critical machines in terms of noise level (Proto et al., 2016; Grigolato et al., 2018).

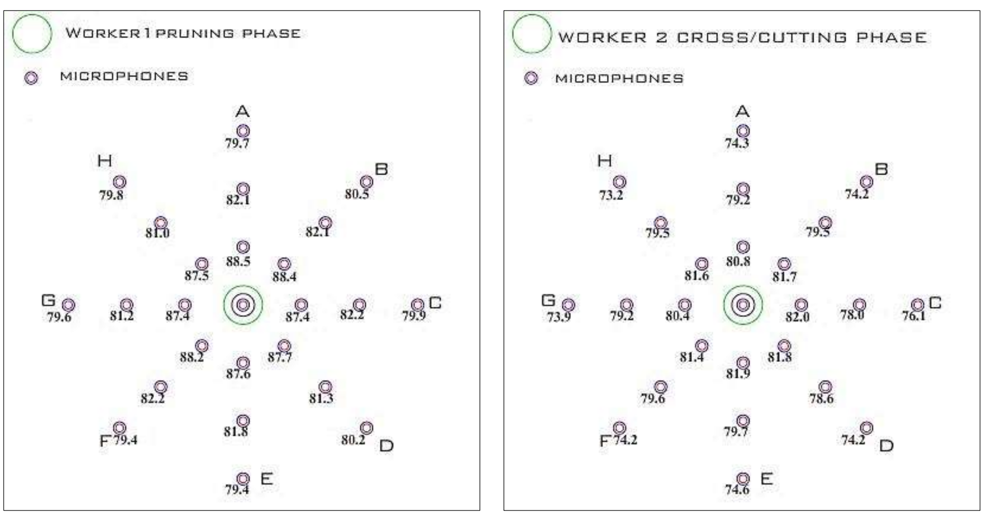

Figure 4. Noise levels – dB(A) – at the studied operations following the eight directions (A – H): during pruning phase (left) and cross-cutting phase (right).

This management of work tasks exposes all workers to acoustic levels, which are always higher than the maximum exposure limit, and obliges them, in the same way, to the use of PPE, that are however appropriate to reduce these levels. The second worker, assistant for each phase monitored, at the level of the ear, the equivalent continuous sound levels of the machines used, were measured between 81.6 and 79.6 dB(A) for the pruning operation, and between 73.8 and 71.2 dB(A) for the cross-cutting operation, with an average level varied from the 5 measurements carried out for both operations of 80.8 and 72.6 dB(A), respectively.

Table 4. Acoustic levels of pruning phase

	Worker 1 $L_{eq,i}$ (ε)	Assistant 1 $L_{eq,i}$ (ε)	Distance 3 m $L_{eq,i}$ (ε)	Distance 6 m $L_{eq,i}$ (ε)	Distance 9 m $L_{eq,i}$ (ε)
Test 1	92.8 (± 0.2)	81.0 (± 0.4)	87.4 (± 0.5)	85.2 (± 0.3)	79.0 (± 0.6)
Test 2	91.9 (± 0.4)	79.6 (± 0.2)	86.6 (± 0.3)	84.2 (± 0.4)	78.2 (± 0.3)
Test 3	92.6 (± 0.2)	81.4 (± 0.5)	87.3 (± 0.6)	85.1 (± 0.6)	79.6 (± 0.4)
Test 4	92.9 (± 0.3)	81.6 (± 0.3)	87.6 (± 0.2)	85.4 (± 0.5)	79.8 (± 0.2)
Test 5	91.0 (± 0.5)	80.2 (± 0.6)	86.4 (± 0.4)	84.6 (± 0.2)	78.1 (± 0.5)
Mean	92.3 (± 0.6)	80.8 (± 0.4)	87.0 (± 0.2)	84.9 (± 0.4)	78.9 (± 0.2)

Table 5. Acoustic levels of Cross-Cutting phase

	Worker 2 $L_{eq,i}$ (ε)	Assistant 2 $L_{eq,i}$ (ε)	Distance 3 m $L_{eq,i}$ (ε)	Distance 6 m $L_{eq,i}$ (ε)	Distance 9 m $L_{eq,i}$ (ε)
Test 1	90.9 (± 0.6)	73.8 (± 0.3)	81.7 (± 0.4)	79.6 (± 0.5)	74.7 (± 0.2)
Test 2	91.3 (± 0.3)	72.9 (± 0.6)	80.7 (± 0.6)	79.6 (± 0.2)	74.7 (± 0.4)
Test 3	90.4 (± 0.6)	73.5 (± 0.5)	80.9 (± 0.2)	79.2 (± 0.4)	73.6 (± 0.6)
Test 4	92.0 (± 0.3)	71.2 (± 0.6)	80.6 (± 0.5)	78.2 (± 0.6)	73.4 (± 0.3)
Test 5	89.6 (± 0.4)	71.4 (± 0.2)	80.7 (± 0.3)	78.3 (± 0.3)	74.0 (± 0.2)
Mean	90.8 (± 0.2)	72.6 (± 0.4)	80.9 (± 0.4)	79.0 (± 0.5)	74.1 (± 0.6)

In relation to the equivalent continuous sound levels in the work environment, the measurements monitored during the pruning operation with sound data logger, positioned at 2 3, 6 and 9 meters respectively from the operator number 1, reported levels between: 86.4 and 87.6 dB(A), 84.2 and 85.4 dB(A), 78.1 and 79.8 dB(A) with averages of 87.0 dB(A), 84.9 dB(A) and 78.9 dB(A). Instead the measurements carried out, during the cross-cutting operation, with microphones positioned at same distances from the operator number 1, reported levels between: 81.7 and 80.6 dB(A), 78.2 and 79.6 dB(A), 73.4 and 74.7 dB(A), with averages of 80.9 dB(A), 79.0 dB(A) and 74.1 dB(A) respectively. The differences were observed in the acoustic levels both at the operator's ear level and at the work environment level, depending on the type of chainsaw used, the speed of the equipment's progress and the diameter of the trunks.

CONCLUSIONS

This study has enabled to widen our understanding of the general picture whose many criticalities in terms of work safety have not only been highlighted and observed, but also analyzed. During the use of chainsaw with an equivalent acoustic level higher than 85.0 dB(A), it would be important to adopt specific balancing measures or precautionary interventions, and limit the access only to the employers with appropriate personal protective equipment, as well (earphones or auricular insets) (Zimbalatti et al., 2008). The phonometric data processing has enabled to outline a typical representation, even though approximate, of the acoustic conditions during the rejuvenation pruning on centuries-old olive tree. Unfortunately, it has turned out that the non-reception and non-application of the present legislation endangers the safety of workers, who, in most cases, are unaware of the risks they run. In the work stations where there is an equivalent acoustic level higher than 85 dB(A), the results of this work should be interpreted as being indicative as they only account for a descriptive case study which can prove its utility and replicability in similar conditions (Cheta et al., 2018). The noise reduction, at the source or on the run, should be one of the main management programs of this risk factor. This activity must take into account both the facilities and planning, as well as maintenance to control acoustic pollution. In the future new measurement sessions will be conducted to study the reduction of the noise levels and to define possible interventions with low technical and economic impacts.

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