Topic 6

"Noise, Vibration, Dust, Endotoxin, Microorganism"

Oral Presentation

A novel device for assessing the health risk caused by hand-arm vibrations in olives harvesting

Aiello G. [(2)], Catania P.[(1)], La Scalia G. [(2)], Pipitone F. [(1)], Vallone M. [(1)]
[(1)] *University of Palermo. Dept. SAgA, Mechanics Section*
Viale delle Scienze, edificio 4 – 90128 Palermo, ITALY.
Tel 0039 091 23865608, Fax 0039 091 484035
[(2)] *University of Palermo. Dept. DICGIM*
Viale delle Scienze, edificio 8 – 90128 Palermo, ITALY.
Tel 0039 091 23863763, Fax 0039 091 7025040
Email of the corresponding Author: pietro.catania@unipa.it

Abstract

The mechanization of olive harvesting is very important both to reduce the costs of production and to assure the oil quality because the manual harvest does not allow to operate at the right time and also need a long period to be completed. The use of portable shakers, that are spreading more than others typologies, can give a solution to the problem. However, the use of such equipment may involve risk of exposure to hand-transmitted vibration. The aim of this study was to assess the level of exposure to hand-arm vibration of the operators using portable shakers (reference standards UNI EN ISO 5349-1:2004, Italian Low Decree 81/2008). The research presented here concerns the definition of a test bench for the execution of laboratory tests and the experimental tests in the open field under real operating, in both cases by applying the hardware components and the related software development activities previously realized by the authors. The experimental tests were performed with shakers commonly used in olives harvesting in order to collect and characterize vibration data in terms of intensity. These information were afterwards used to real time monitor vibrations and consequently evaluate health risks. Total vibration values measured in the laboratory using the test bench and measured in the field were not statistically significant different. This allows to state that the test bench realized by the authors can be applied to measure the vibrations transmitted by handheld shakers to the hand-arm operator's system as a "standard system" for eventual certification of this type of machines for the defence of agricultural workers' health.

Keywords: safety, MEMS accelerometers, wireless sensors

Introduction

The mechanization of olive harvesting is very important both to reduce the costs of production and to assure the oil quality because the manual harvest does not allow to operate at the right time and also need a long period to be completed.

The use of portable shakers, that are spreading more than others typologies, can give a solution to the problem. However, the use of such equipment may involve risk of exposure to hand-transmitted vibration.

The exposure to prolonged vibration is a potential cause of pathologies such as muscular/skeletal pains in hand-arm system, or specific pathologies such as Vibration-Induced White Finger (VWF), Carpal Tunnel Syndrome (CTS), Hand-Arm Vibration Syndrome (HAVS) (Gerhardsson et al., 2005). Due to the potential hazardousness of such shakers, they are generally designed with the aim of transmitting maximum vibration to the branches in order to optimize fruit detachment while minimizing vibration transmission to the

operator and avoiding possible damages to the trees (Horvath and Sitkei, 2001; Gil et al., 2001).

In order to prevent health hazards, national and international institutions have issued laws and directives which establish recommended limits to the workers' exposure to vibration during operations. The reference standard, UNI EN ISO 5349-1:2004 gives the characterization of the vibration transmitted to the hand and a guide to the health effects. In Italy, the Low Decree 81/2008 defines the limit of daily exposure to a standardized reference period of 8 hours, at 5 m s^{-2}.

The research involves the definition of the hardware components of the system and the related software development activities, as well as experimental tests in real operating conditions. The experiments have been carried out on olive shaking tools commonly employed in olive harvesting operations and allowed to gather and characterize the vibration data, in terms of frequency spectrum and intensity. Such information has been subsequently exploited for real-time vibration monitoring and subsequent health hazard assessment.

The proposed system is based on Micro Electro-Mechanical Systems (MEMS) technology and involves the design of a compact wearable unit to be attached to the waist of the operator, and a fixed station for storing and analyzing the measured data. MEMS-based sensors are a class of devices constituted by very small electrical and mechanical components on a single chip. MEMS capacitive accelerometers, in particular, have several advantages for numerous applications including low cost, high sensitivity, good response and noise performance, low temperature sensitivity, and low power dissipation, as documented by several researchers (Yazdi et al., 1998 and Bernstein et al., 1999). Due to the versatility of MEMS sensors and their small size, they have been efficiently employed for monitoring vibrations in engines and mechanical equipments and facilities (Vogl et al., 2009) and in civil structures (Lynch et al., 2002). The possibility of employing such systems in vibration risk assessment is also a field of application recently approached and investigated by researchers (Koenig et al, 2008, Morello et al., 2010).

The aim of the research is the assessment of the operator's health risk using handheld shaker for olives harvesting. The study is based in the application of a MEMS system developed by the authors (Aiello et al. 2012), consisting in the application of a MEMS axial accelerometer during the operator's activity to real-time monitoring vibrations using wireless technology and communications.

Materials and methods

We examined two common portable shakers for olives and dried fruit harvesting, Cifarelli SC800, hereinafter named shaker A, and Tekna TK 650, hereinafter named shaker B (Fig. 1) whose technical features are given in table 1.

The machines are equipped with an anti-vibration patented system on the handles that isolates them from the rod, from the engine and from the gear box. The elastic elements interposed between the gripping means and the support body, compensate the reaction forces transmitted parallel to the drive axis of the movable shaft, allowing a prolonged use of the shaking device without causing heavy discomfort to the operator.

A   B

Figure 1. Cifarelli SC800 and Tekna TK 650 hand held shaker tools.

Table 1. Cifarelli SC800 and Tekna T650 technical features.

Engine	Cifarelli C5	Tekna T650
Engine displacement [cm^3]	52	52
Strokes [n]	2	2
Cooling	air	air
Tank capacity [l]	1.7	1.7
Total weight (filled up) [kg]	18.0	18
Length except the bar [mm]	1050	1000
Bar length/total length ratio	0.66	0.65
Length of the bar [mm]	2000	2000
Stroke of the bar [mm]	60.2	60.1
Hook width [mm]	40.5	42

The tests were first performed in the laboratory and after in the open field. The laboratory tests were carried out in idling mode with a 45° shaker rod angle (test 1) and subsequently on a "test bench" made by the authors (test 2), consisting of a wooden pole at the end of which a glass fiber rod has been inserted (Fig. 2).

Figure 2. Test bench realized for laboratory tests.

The test bench was designed to evaluate the values of the vibrations transmitted from the machines to operator's hand-arm system and then compare them with those recorded by the same machines in the open field. The objective of the test bench was to evaluate the vibrations transmitted to the operator by this type of shakers in the laboratory under standard conditions. This would allow to certify the machine according to the level of risk for the operator's health.

Field trials (test 3) were carried out in a plot with olive trees of the variety *Cerasuola*, aged 15 years, having layout of planting 6.00 x 6.00 m, with monocaule plants, whose average olive production was equal to 20 kg / plant (fig. 3).

Figure 3. Use of the shaker during field tests.

Particular attention was used during the fixing process of the accelerometers on the auxiliary and command handles, in order to have each axis oriented in the directions imposed by the provisions of UNI EN ISO 5349-1 (basicentric coordinate system): y_h axis parallel to the axis of the handle; x_h perpendicular to the axis of the handle oriented by the back towards the palm of the hand and, at last, the z_h axis perpendicular to the plan formed by the two previous axis as shown in figure 4. For practical measurements, the orientation of the coordinate system may be defined with reference to an appropriate basicentric coordinate system originating in vibrating handle gripped by the hand.
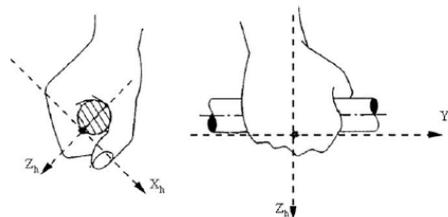

Figure 4. Accelerometer position and directions.

Frequency analysis on laboratory tests was performed in the range of 0-1250 Hz. Laboratory tests showed that The X-Axis of the main handle was characterized by the most significant vibrations levels, although the same considerations on the spectrum analysis can be done for all the other axes and measures. The first harmonic appears at 15-25 Hz, as the main vibration component, and corresponds to the rod oscillation occurring at maximum 1500 strokes/min (25 Hz), as declared by the manufacturer. The full-spectrum analysis allowed to conclude that the vibration range where the most risky vibration phenomena occur is 0-50Hz. It has also been considered the contribution of vibrations over 100 Hz are actually negligible for safety risk according to ISO weighting the curve. The results obtained are coherent with similar results obtained by other researchers (Pascuzzi et al., 2009).

The proposed system is based on Micro Electro-Mechanical Systems (MEMS) technology and involves the design of a compact wearable unit to be attached to the waist of the operator, and a fixed station for storing and analyzing the measured data. MEMS-based sensors are a class of devices constituted by very small electrical and mechanical components on a single chip. The wearable sensor unit has been designed taking into account that the unit must be lightweight, small and compact as possible in order not to hamper the operations and the movements of the worker. According to such specifications, the Freescale MMA7455 triaxial accelerometer device, based on Microelectromechanical systems technology, has been selected. The acceleration data collected by means of the previously described sensor are fed into a microcontroller and sampled via an analog digital converter. They have been processed in real time in order to evaluate the health risk the worker is exposed to, according to the guidelines for measuring and evaluating human exposure given in ISO 5349-1 and ISO 5349-2. In the ISO 5349 standard recommendations, the most important quantity used to describe the magnitude of the vibrations transmitted to the operator's hands is the root-mean square (rms) frequency-weighted acceleration, expressed in m/s². According to such guidelines, the vibration spectrum must be extracted from the raw acceleration data by means of Fast Fourier Transformation (FFT), and analyzed in 1/3 octave bands. Subsequently, in order to determine the effect of the vibrations on the human body the rms intensity in each band must be multiplied by a proper weighting factor.

The evaluation of vibration exposure in accordance with ISO 5349 is finally based on a quantity that combines all three axes. This is the vibration total value a_{hw} or weighted acceleration sum (WAS) and it is defined as the root-mean-square of the three component values:

$$a_{hw} = \sqrt{a_{hw(x)}^2 + a_{hw(y)}^2 + a_{hw(z)}^2}$$

where a_{hwx}, a_{hwy}, a_{hwz} are frequency-weighted acceleration values for the single axes. The vibration exposure depends on the magnitude of the vibration total value and on the duration of the exposure. Daily exposure duration is the total time for which the hands are exposed to vibrations during the working day. Each test consisted in 3 trials of 40 seconds with a polling frequency of 120 Hz.

Results

The experimental tests were carried out using the previously described shakers, named A and B. The experimental analysis involved the real-time acquisition and processing of the acceleration data collected by the device while the machines were used by the same operator. In Table 2 the values of total vibration a_{hw} are reported with reference to the different tests

performed A and B machines., A did not register statistically significant differences among the three test conditions, both in right and in left operator's handles. The values of total vibration obtained in laboratory using the test bench are very similar to those obtained in the field test. In machine B, however, statistically significant differences were found between idling mode test field test only on the right operator's handle.

Table 2. a_{hw} values [m s^{-2}]and statistical analysis for the two shakers and the three test conditions.

A1$_{right}$	20.23	±	0.60	ns	A1$_{left}$	22.25	±	0.23	ns
A2$_{right}$	20.50	±	2.49	ns	A2$_{left}$	22.31	±	0.67	ns
A3$_{right}$	19.16	±	2.21	ns	A3$_{left}$	20.89	±	0.87	ns
B1$_{right}$	15.17	±	4.29	b	B1$_{left}$	15.01	±	4.48	ns
B2$_{right}$	21.66	±	0.76	a	B2$_{left}$	19.13	±	0.84	ns
B3$_{right}$	20.22	±	0.34	ab	B3$_{left}$	17.60	±	1.41	ns

Data are reported as means and standard deviations of the three replicates (Tukey's test at the 95% confidence level, ns=not significant). A = Cifarelli; B = Tekna; 1 = idling mode; 2 = test bench; 3 = field test.

Comparing the two shakers, it emerges that the total vibration values obtained on the right operator's handle do not show statistically significant differences in the three test conditions (table 3). On the contrary, statistically significant differences were found in the left operator's handle between machine A and machine B. The values of total vibration are always higher in machine B, approximately 52% in the idling mode laboratory test, about 20% in the laboratory test bench and about 38% in the open field test.

Table 3. a_{hw} values [m s^{-2}]and statistical analysis comparing the two shakers used in the tests.

A1$_{right}$	20.23	±	0.60	ns	A1$_{left}$	22.25	±	0.23	a
B1$_{right}$	15.17	±	4.29	ns	B1$_{left}$	15.01	±	0.48	b
A2$_{right}$	20,50	±	2.49	ns	A2$_{left}$	22.31	±	0.67	a
B2$_{right}$	21.66	±	0.76	ns	B2$_{left}$	19.13	±	0.84	b
A3$_{right}$	19.16	±	2.21	ns	A3$_{left}$	20.89	±	0.87	a
B3$_{right}$	20.22	±	0.34	ns	B3$_{left}$	17.60	±	1.41	b

Data are reported as means and standard deviations of the three replicates (t- test at the 95% confidence level, ns=not significant). A = Cifarelli; B = Tekna; 1 = idling mode; 2 = test bench; 3 = field test.

Conclusions

The development of a test bench for the measurement of the vibrations transmitted to the hand-arm system from olives harvesting shakers provided very interesting results. Total vibration values measured in the laboratory using the test bench and measured in the field were not statistically significant different.

This allows us to state that the test bench realized by the authors can be applied to measure the vibrations transmitted by handheld shakers to the hand-arm operator's system as a "standard system" for eventual certification of this type of machines for the defence of agricultural workers' health.

The application of the test bench and a simple and inexpensive hardware can lead to a fairly accurate assessment of the risk profile, thus providing valuable information for the safe management of shifts and to improve planning and resource management.

The study presented here can certainly be supplemented and deepened by further investigation and opens new scenarios on intelligent systems for workers' safety management.

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Evaluation of human exposure to vibration according to a draft Tractor Testing Method

Capacci E., Rondelli V.
DEIAGRA, University of Bologna, Via G. Fanin 50, 40127 Bologna, Italy
Phone: +39051766632, Fax: +39051765318
enrico.capacci@unibo.it, valda.rondelli@unibo.it

Keywords: concrete track, seat suspension, comfort

Aim
The evaluation of human body exposure to vibration in agricultural tractor is the purpose of the ISO 5800:2002 standard. Nonetheless, this testing method requires the use of a dedicated track, quite expensive in terms of construction and mainly in the maintenance. The DEIAGRA of the University of Bologna in collaboration with UNACOMA and CNR-IMAMOTER developed a draft testing method to assess the whole-body vibration transmitted by the seat when the tractor is travelling on a smooth concrete surface. This method is dedicated to wheeled and rubber track agricultural tractor. The purpose of the work was to verify the effect of different seat adjustments and operators on the value of Whole-Body vibration measured. The comfort and perception of the operators was also evaluated.

Methodology
Wheeled agricultural tractors were tested according to the draft testing method. During the tests, the driver seat was adjusted at different suspension levels from maximum hard response to the end-stop impact of seat suspension system. The tests were repeated with different operators. The vibration effects on operators comfort and perception were recorded. The driver seats were equipped by using a dedicated accelerometer and a linear position sensor, in order to measure the vibration magnitude and the travelling of the suspension system until the end-stop impact event. The tests were performed in a smooth concrete surface at three fourth of the maximum speed of the tractors.

Results
The vibration magnitudes measured during the tests were influenced by the mass of the operators and the adjustment of the seat suspension system. The damping effect of the seat suspension influenced the comfort of the operator in particular if the end-stop impact of suspension seat occurred.

Conclusion and Perspectives
The testing method developed by DEIAGRA, UNACOMA and CNR-IMAMOTER was not oriented to simulate the tractor operative conditions. The aim of the testing procedure basically was to characterize in a defined and reproducible condition the seat response with respect to the tractor and platform system. The test results evidenced some lacks in the draft testing method. The procedure should be improved introducing some specific adjustments of the seat and operators of different mass.
The method evaluated represents an approach toward a WB vibration measurement based on tests performed on a testing surface easy to be recovered and with a repeatable methodology.

A device for dust reduction during mechanized harvesting of hazelnuts

Cecchini M.[1], Guerrieri M.[1], Colantoni A.[1], Monarca D.[1], Bedini L.[2], Cavariani F.[2], De Rossi M.[2], Fedrizzi M.[3], Pagano M.[3]
[1]*University of Tuscia, Dept. DAFNE*
Via S.Camillo De Lellis – 01100 Viterbo, ITALY.
Tel 0039 0761357357, fax 0039 0761357453, ergolab@unitus.it
[2] *Viterbo Local Health Unit, Laboratory of Industrial Hygiene*
Via Nepesina 1/a - 01033 Civita Castellana VT, ITALY.
[3] *Agricultural Research Council, Agricultural Engineering Research Unit*
Via della Pascolare 16 – 00016 Monterotondo RM, ITALY.

Abstract
One of the main risk factors for workers derived by the mechanized hazelnuts harvesting is the exposure to respirable dust. The harmful effects of airborne particles, which often contain chemicals used in pesticide treatments, are not to be neglected.
In the past the problem has been addressed through efforts as: use of machines equipped with cyclones; use of pick up machines instead of vacuum machines; substitution of tilled soil with grass covered ground; discharges of dust directed towards the ground rather than in the air. These interventions have not solved the problem.
Aim of the research is to develop a system to be applied directly to harvesters, who manages to give the soil adequate moisture, reducing the dust development.
The device is based on the use of sprayers with low volume pneumatic nebulization.
Sprayers are positioned in front of the machine and along the dust exhaust pipes. A first evaluation of the effectiveness of the proposed device was performed by measuring the concentration of dust that affect the operator and that persist in the environment.
The number of tests does not allow a statistical treatment of data. Given the high number of variables involved (e.g.: air speed/direction, planting distance, etc.) it does not seem reasonable to implement assessment protocols that can provide statistically acceptable regressions between, for example, hydraulic flow or number of nozzles mounted on the machine and dust concentration.
However, the first tests, conducted in the same fields and in the same days with the aim to reduce the influence of the several variables, show a decrease of dust concentration in tests with sprinklers mounted in front of harvesting apparatus of the machine (the area where dust is generated).
The results can still guide the research and development of new prototypes, which can make a significant reduction in dust emission.

Keywords: particulate matter, work hygiene, harvesting.

Introduction

One of the main risk factors for workers derived by mechanized harvesting of hazelnuts is the exposure to respirable dust (Biondi et al., 1992; Monarca et al., 2005).

The harmful effects of airborne particles, which often contain chemicals used in pesticide treatments, are not to be neglected (De Rossi et al., 2008, De Rossi et al., 2009; Nieuwenhuijsen et al., 1999; Schenker, 2000; Schenker et al., 2005; Schenker et al., 2009; Swanepoel et al., 1999).

The problem becomes significant in those areas where the cultivation of hazelnut has spread. In some of these sites, harvesting was possible when the rainy season started,

especially for hazel trees close to residential areas. Even in 2011 (when tests were carried out), some local mayors have issued specific orders to shift the harvesting to the first rains arrival. The harvesting period (August and September 2011) was characterized by particularly high levels of drought (Table 1).

Table 1. Rain (in mm) in the municipalities delimiting the hazelnut area of cultivation (ARSIAL, 2011)

Month	Stations											
	Bassano R.		Corchiano		Vetralla		Soriano C. (Station I)		Soriano C. (Station II)		Viterbo	
	Year 2011	Monthly average 2004-2010	Year 2011	Monthly average 2004-2010	Year 2011	Monthly average 2004-2010	Year 2011	Monthly average 2004-2010	Year 2011	Monthly average 2004-2010	Year 2011	Monthly average 2004-2010
June	43.20	45.01	61.40	43.50	26.60	55.34	57.20	53.09	42.40	50.00	51.10	45.80
July	106.60	23.66	100.80	18.46	102.00	13.54	138.60	19.51	125.20	23.03	65.30	12.85
August	0.40	26.17	0.80	20.14	0.20	22.93	1.70	35.84	0.80	39.03	2.40	28.25
September	29.60	76.17	40.20	82.43	50.80	73.36	62.40	93.03	22.60	85.74	72.70	69.12

During the past years the problem was addressed through efforts that can be summarized as follows (Cecchini et al., 2005; Cecchini et al., 2010; Monarca et al., 2005; Monarca et al., 2008; Monarca et al., 2009; Monarca et al., 2010; Monarca et al., 2011):
• use of machines with cyclones;
• use of pick up machines instead of vacuum machines;
• grass covered ground instead of tilled soil;
• discharges of dust directed towards the ground rather than in the air.

The mentioned solutions could not overcome the situation which still recurs every year, especially during particularly dry summers.

The aim of this research is to test a device to be applied directly on the harvesters, that manages to give the soil suitable moisture, reducing the dust development.

Material and methods

The operations taken into account by the present study were tested on a self-propelled harvester (model Cimina 380 S) manufactured by the company FACMA S.r.l.. If compared with other machines produced by FACMA, Cimina 380 is characterized by a greater suction flow and the absence of cyclones used to reduce the dust.

The device is based on the use of sprayers, already experienced in agriculture for irrigation and pesticide treatments. It uses the principle of pneumatic nebulisation at low volume.

The operating principle is very simple: water is sprayed in tiny droplets and transported by air lowing over the ground. This condition is achieved by exploiting the physical principle of the "Venturi tube".

The device is composed of the following elements: a tank, a diaphragm pump, nozzles and nozzle holders, a spraying bar, valves and pipes for transporting water. The tank has been positioned within the carriage for the storage of the product. It is made of metal sheet, has a capacity of about 290 liters and is equipped with a discharge point located about 10 cm from the bottom. This is to avoid that any sedimented material can pass into the pipe connected to the pump (Fig. 1).
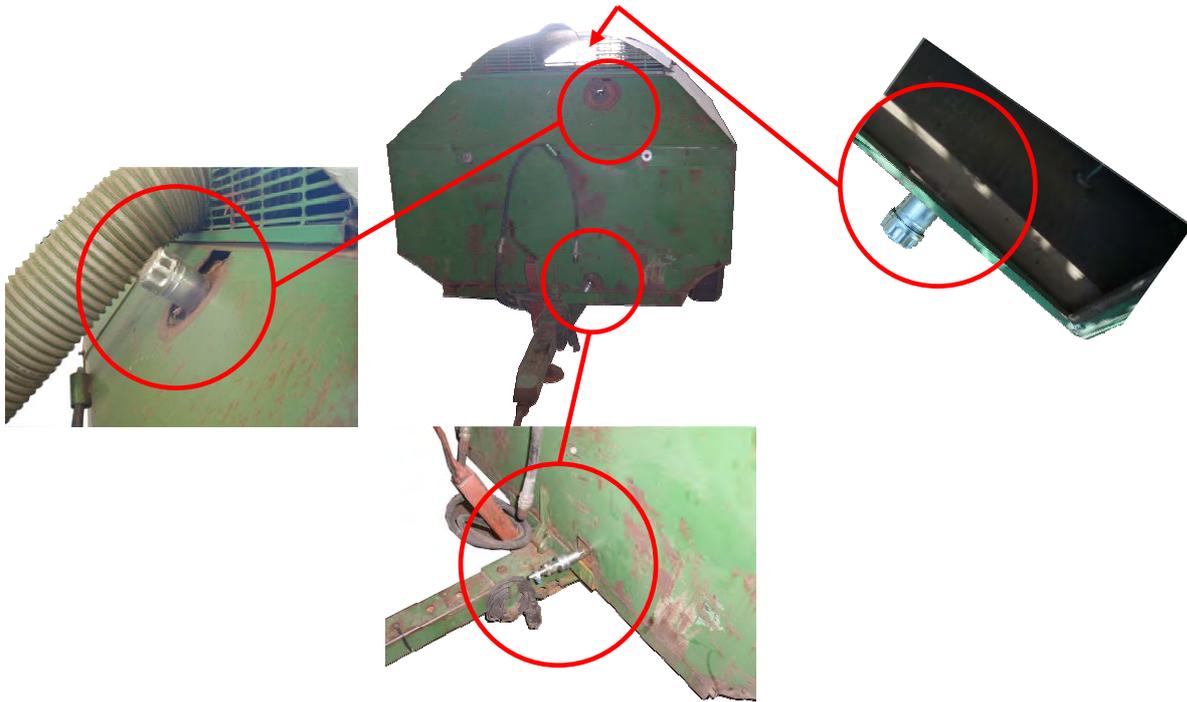
Figure 1. Positioning of the tank

The nozzles (four Lurmark 04 M110 and four Lurmark 02 M110 were tested) are positioned on a bar mounted on the harvesting head. The hydraulic circuit is made by an electric pump (SHURflo 2088-313-544) (Fig. 2).

Figure 2. Spraying bar and pump

The dust control is also achieved through appropriate devices, positioned along the exhaust pipes of the powder: water, delivered through nozzles to low volume sprayers, intercepts the flow of dust, leaves and twigs, before they're released outside (Fig. 3 and 4).

Figure 3. Sprayers positioned inside the suction fan cover

Figure 4. Sprayer positioned along the dust exhaust pipes

A first evaluation of the effectiveness of the proposed device was performed by measuring, with appropriate instrumentation, the concentration of dust which affects the operator and persists in the environment.

Six environmental samplings and six personal samplings on driver were performed, using portable analyzers for direct reading (DustTrak Aerosol Monitor TSI model 8520 for the environment and SidePak Aerosol Monitor TSI model AM 510 for worker). The instruments were equipped with a Door-Oliver selector for respirable fraction.

Results

Table 2 shows the first results of tests conducted on the device. The data obtained show differences between samples taken on the same day and on the same plot of land. This phenomenon can be due to the variability of external conditions (such as humidity, temperature, wind speed and direction, soil slope, etc.) that influence the results.
Looking at the table, the high maximum values in test nr. 2 are certainly caused by the lack of moisture along the pipes of the machine (because it was the first test of the device). Other tests carried out during the morning have certainly benefited humidification made in previous attempts. If we don't consider test nr. 5 since the spraying of the ground was not working because of high temperatures, lower values of dust concentration have been found in the tests nr. 3 and nr. 4.

Table 2. Test results

Time	Test nr.	Description of test	Environmental sampling (DustTrak Aerosol Monitor)			Personal sampling (SidePak Aerosol Monitor)			Device performance	
			min	max	avg	min	max	avg	Flow	Volume per hectare
			(mg/m^3)	(mg/m^3)	(mg/m^3)	(mg/m^3)	(mg/m^3)	(mg/m^3)	(l/min)	(l/ha)
morning	1	Hazelnut harvesting in standard conditions (dry soil)	0.215	7.41	0.695	0.026	2.852	0.308	-	-
	2	Hazelnut harvesting with 3 rear nozzle Lurmark 02 F110 on	0.063	5.071	0.167	0.028	6.328	0.370	3.00	143
	3	Hazelnut harvesting with 3 rear nozzle Lurmark 04 F110 on	0.164	0.219	0.201	0.035	2.573	0.185	5.70	243
	4	Hazelnut harvesting with 4 front nozzle Lurmark 02 F110 on	0.082	0.159	0.151	0.033	1.955	0.128	4.00	190
	5	Hazelnut harvesting after 30 min by moistening the soil with hand sprayer	0.798	0.940	0.878	0.030	5.273	0.316	5.45	588
afternoo	6	Hazelnut harvesting with 4 front nozzle Lurmark 04 F110 on	0.358	0.438	0.400	0.029	18.724	1.814	7.50	386
	7	Hazelnut harvesting after 15 min by moistening the soil with hand sprayer	0.201	4.09	0.773	0.025	4.312	0.256	5.45	588

More precisely, test nr. 4 shows the lowest concentration of dust in the environment (average = 0.151 mg/m^3) and near the worker (average = 0.128 mg/m^3). This may be due to the use of the nozzles Lurmark 02 F110, certainly more suitable than the model Lurmark 04 M110 that has a lower power to spray water. Test nr. 7 (after 15 minutes from the soil spraying) should be better than test nr. 5 (after 30 minutes from the soil spraying), but the maximum value does not confirm this statement. This anomalous value may be caused by changes in microclimatic conditions (higher temperature and relative humidity almost halved) but mostly to the wind direction that brought the outgoing dust from the exhaust pipe towards the machine. Test nr. 6 was influenced by the sloping path where the brushes of the machine "scraping" the ground created an anomalous condition if compared to previous tests.

As regards the water consumption, the nozzles Lurmark 02 F110 are more suitable for the present type of work, since at operating pressure (measured at the spraying bar) produce a jet with a low flow rate and fine droplets. The demand of 143 l/ha, necessary to drive the three rear nozzle, and that of 190 l/ha required by the four nozzles carried by the bar, do not represent small quantities, but still acceptable for the type of yard which characterizes hazelnuts harvesting. As a matter of fact, since each hectare of hazel produces an average of 2 t and each trolley contains a maximum of 1.5 t, the operator still has to stop to empty the carriage in the dryer or in larger trailer: that is the moment he can fill the tank with water.

Even if in test nr. 3 the use of the model Lurmark 04 M110 showed a discrete reduction of dust concentration, this type of nozzles (that can supply a greater flow and produce droplets of medium size) is to be discarded due to the high water consumption. The spraying of the soil under the conditions of test nr. 5 and nr. 7, at present does not seem feasible, both for the excessive amount of water required, both for the poor results of dust reduction.

Conclusions

The number of tests does not allow a statistical treatment of data. Because of the very high number of variables involved (e.g. air speed and direction, soil moisture, planting distance and so on), the implementation of assessment protocols - that can provide statistically acceptable regressions for instance between hydraulic flow/number of nozzles mounted on the machine and dust concentration - doesn't seem to be reasonable. However, the first tests show

a decrease of dust concentration with sprinklers mounted in front of harvesting apparatus of the machine (the area where dust is generated). The use of water as a method for reducing the concentration of dust during the harvesting of nuts seems an achievable goal. The use of the pump which sends the water to the nozzles has enabled progress in reducing the dust concentration. It can be improved as a result of tuning of the system. The water consumption can be decreased through the use of a pump that generates a greater pressure and by mean of nozzles which deliver a lower flow rate, but with drops properly sized in order to achieve dust reduction. With regard to the front of the machine, the ends of the bar will have to be equipped with asymmetrical jet nozzles, so that we can spray from the harvesting head to the side part of the land. This area is generally cleared of hazelnuts because they have been already aligned to the center of the row through a previous agricultural operation. Indeed a good percentage of dust raised in the site due to friction operated by rotating brushes.

The results of this study can help the research and development of new prototypes, in order to make significant reduction in dust emission.

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The contribution to the programming and executing of this research must be equally divided by the authors.

Main safety aspects of agricultural machinery: management of control tests on noise emitted according to EN ISO/IEC 17025:2005

Fanigliulo R., Fornaciari L., Vassalini G., Biocca M., Brannetti G., Cervellini C., Pochi D.
CRA-ING, Agricultural Research Council - Agricultural Engineering Research Unit
Via della Pascolare, 16 – 00016 Monterotondo (Rome), ITALY
Tel 0039 0690675233, Fax 0039 0690625591
Email corresponding Author: roberto.fanigliulo@entecra.it

Abstract

The aspects of functionality and safety of agricultural operating machines are being studied at CRA-ING, since about twenty years by Testing Centre of Agricultural Machinery (CPMA). According to ISO and EN standards and to comply with some provisions of the Machinery Directive 2006/42/EC, this activity includes control tests of pressure and sound power levels emitted by mounted, trailed and self-propelled machines, the values of which must be declared by the manufacturer in the user and maintenance manual. As example of CPMA test activity, accredited as Testing Laboratory (ACCREDIA no. 1141) in accordance with the requirements of the EN ISO/IEC 17025:2005 standard, this paper reports the results of tests on a pneumatic seed drill, aimed at verifying the noise emitted. The measurements of the sound pressure levels (according to EN ISO 4254-1:2010 and EN ISO 11201:2010) and of the sound power levels (according to EN ISO 3744:2010 and EN ISO 4254-1:2010) are among the tests accredited. The former are measured for frequency bands in $^1/_3$-octaves in the range 100 Hz to 10.000 Hz, as the latter are measured in 10 micro-phonic positions dislocated on an hemispherical measurement surface. A Brüel&Kjær instrumental chain is employed, consisting of a real-time frequency analyzer, a microphone and a sound level calibrator. The test results, provided with the associated measurement uncertainty, showed a sound pressure level of 90.6 dB (A) ± 1.4 dB, above the limit of 80 dB (A) indicated by the Machinery Directive, requiring to measure of the sound power level. This resulted of 106.5 dB (A) ± 3.2 dB.

Keywords: sound pressure, sound power, quality management system, pneumatic seed drill

Introduction

The aspects of functionality and safety of agricultural operating machines are being studied at CRA-ING, since about twenty years by the Agricultural Machinery Testing Centre (CPMA), a work-group provided up with specific equipments, test areas and updated instrumentations aimed at verifying the compliance of the machines with the standards in force and at studying proper solutions for improving the safety conditions and solving eventual non-conformity problems.

According to ISO and EN standards and to comply with the requirements of the Machinery Directive 2006/42/EC, this activity includes control tests of pressure and sound power levels emitted by mounted, trailed and self-propelled machines, the values of which must be declared by the manufacturer in the user and maintenance manual.

To ensure the quality of the results obtained, CPMA has been organized as a technical-scientific laboratory, in which the management of testing activities, tools and measures takes place according to criteria of procedural severity. The resulting Quality Management System in 2010 obtained, by ACCREDIA (Italian Accreditation Body), the official accreditation N° 1141 as a laboratory that operates in compliance with the severe requirements of ISO/IEC

17025:2005 "General requirements for the competence of testing and calibration laboratories". The accreditation achieved by the CRA-ING is the first application, in Italy, of the strict requirements of ISO 17025:2005 to the field of agricultural engineering.

As example of CPMA test activity, this paper reports the results of tests on a pneumatic seed drill, aimed at verifying the noise emitted. The measurements of the sound pressure levels (according to EN ISO 4254-1:2010 and EN ISO 11201:2010) and of the sound power levels (according to EN ISO 3744:2010 and EN ISO 4254-1:2010) are among the tests accredited in such a quality system. The former are measured for frequency bands in $^1/_3$-octaves in the range 100 Hz to 10.000 Hz, as the latter are measured in 10 micro-phonic positions dislocated on an hemispherical measurement surface, surrounding the noise source.

A Brüel&Kjær instrumental chain is employed, consisting of a real-time frequency analyzer, a microphone and a sound level calibrator. They periodically undergo calibration tests in an authorized centre.

Through the example of tests with a pneumatic seed drill, this work aims at describing how the CPMA laboratory works, with the purpose of providing reliable, accurate and reproducible results.

Materials and Methods

The tested machine was a Nardi rear-mounted pneumatic seed drill for in-line sowing, model Dora 400, normally used for autumn-winter cereals, with sowing width of 4.15 m and 29 sowing unit, each provided with row opener (Fig. 1).

Figure 1. The pneumatic seed drill during the sound power level tests.

As to the sound pressure levels tests, according to the EN ISO 4254-1:2010 and EN ISO 11201:2010 standards, the basic parameters to measure were: the level of the A-weighted sound pressure, L_{pA}, and the level of the C-weighted peak, $L_{pC,peak}$. The 1st standard specifies the points in which the microphone must be placed with reference to the characteristics of the machine.

The tests for the relief of the sound power levels were carried out according to EN ISO 4254-1:2010 and EN ISO 3744:2010 standards in order to provide the measurements of time-averaged sound pressure levels of the tested machine, $L_{pi(ST)}$ (A-weighted or in frequency band). The 2nd standard requires 10 micro-phonic positions dislocated on an hemispherical measurement surface, $S = 2 \Pi r^2$, surrounding the noise source. The test surface and the 10 points are schematically shown in Fig. 2 and their coordinates are reported in the Tab. 1. The measurements must be done on an acoustic free field over a reflecting plane, for frequency bands in $^1/_3$-octaves in the range 100 Hz to 10 kHz. A Brüel & Kjær instrumental chain was

used (Fig. 3), consisting of a real-time frequency analyzer (mod. 2260), a microphone (mod. 4189), a sound level calibrator (mod. 4231). They periodically undergo calibration tests in an authorized centre (DANAK CAL, n. 307). Before and after the tests, the deviations from the initial calibration value have been verified by means of the sound calibrator.
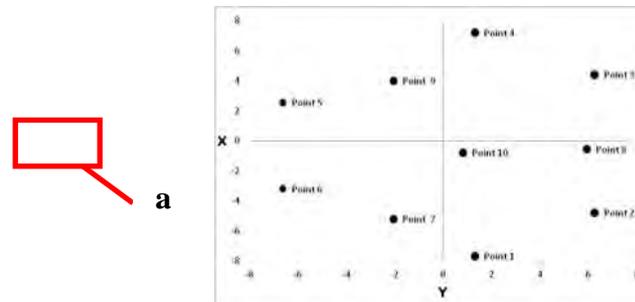

Figure 2. Top view of the hemispherical measurement surface surrounding the sound source (a) and of the 10 micro-phonic positions.

Table 1. Coordinates of the 10 micro-phonic positions.

Micro-phonic positions	X (m)	Y (m)	Z (m)
1	1.28	-7.68	1.76
2	6.24	-4.80	1.60
3	6.24	4.40	2.50
4	1.28	7.20	3.28
5	-6.64	2.56	3.60
6	-6.64	-3.20	3.04
7	-2.08	-5.20	5.68
8	5.92	-0.56	5.36
9	-2.08	4.00	6.64
10	0.80	-0.80	7.92

Instead of a tractor power take off, the tested machine was operated by an external power source consisting of a three phase electric engine, with a power of 15 kW at 50 Hz, fed by a 15 kW inverter that, through a potentiometer, allows the adjustment of the rotation speed.

Such an engine is mounted on a special single-axle trolley equipped with a three-point linkage supporting the machine to be tested that is connected to the electric engine by means of an extended drive-shaft. The trolley is pulled by a 47 kW tractor, the hydraulic system of which operates its three point linkage used to keep the tested machine off the ground during the tests. Such a solution, compared with direct drive of the machine by the tractor, reduces the background noise due to the tractor's engine, thus enabling much more accurate measurements of the noise emitted by the machine under test, even with low noise.

Figure 3. Real-time frequency analyzer, microphone and sound level calibrator used in the tests.

For the measurement of sound pressure levels, the requirements for the test environment are within the degree of accuracy 1 (precision), as required by EN ISO 11201:2010. For the relief of sound power these requirements meet the degree 2 (engineering), as required by EN ISO 3744:2010. The following tests have been conducted:

- Measurement of the environmental background noise;
- Determination of the background noise produced by the external power source, represented by the trolley and the electric engine, working at a P.T.O. speed of 1000 min^{-1} without load;
- Determination of the A-weighted sound pressure, L_{pA} and, for the sound power, of the sound pressure levels $L'_{pi(ST)}$, on the 10 microphone positions, produced by the trolley-electric engine-seed drill system working at the same P.T.O. speed without load.

The power- take-off speed has been measured by means of an optical revolution counter (accuracy: 1%). For the determination of both pressure and sound power, the correction factors K_1 (relative to the correction of the background noise), and K_2 (on the environmental correction) have been examined. In both cases the results were equal to zero. Five repetitions, with a sampling time of 60 s, were performed in order to reduce the degree of uncertainty associated with the measurement of sound pressure and power levels.

Results

The measurement uncertainty, $u(Lp)$, in decibels, associated with the emission of sound pressure level, determined in accordance with the EN ISO 11201:2010 standard, is estimated by the total standard deviation, σ_{tot}, in decibels:

$$\sigma_{tot} = \sqrt{\sigma_{Ro}^2 + \sigma_{omc}^2}$$

where:

σ_{RO} represents, in decibels, the standard deviation of reproducibility of the method;

σ_{omc} describes, in decibels, the uncertainty due to the instability of the operating and mounting conditions of the source under test.

Derived from σ_{tot}, the expanded uncertainty, U, shall be calculated from:

$$U = k\ \sigma_{tot}.$$

The expanded uncertainty depends on the desired degree of confidence. For a normal distribution of measured values, and for a confidence level of 95 %, the confidence interval is $[Lp - U]$ to $[Lp + U]$. This corresponds to a coverage factor of $k = 2$. Applying the previous equation, the uncertainty, in decibels, associated to the emission sound pressure level, is equal to 1.4 dB.

The measurement uncertainty, associated with the emission sound power level is estimated with the same procedure. If the sound emission does not vary or varies only a little with time and the measuring procedure is properly defined, a value of 0,5 dB for σ_{omc} can be applicable. As regards the determination of σ_{RO}, it can be taken as valid the upper limit values referred to the precision of degree 2, which cover the majority of machines and equipment set in the standard. It is equal to 1.5 dB, with a coverage factor k=2. Therefore, the expanded uncertainty, in decibels, associated with the emission sound power level, is equal to 3.2 dB.

The results of the tests of measurements of the sound pressure levels are reported in the Table 2.

Table 2. Results of the sound pressure level measurements.

Replication		$L_{pC,peak}$ dB(C)	L'_{pA} dB(A)	Correction f	ΔL dB(A)	K_1 dB(A)	L_{pA} dB(A)
1	A*	76.5	57.89				
	B*	103.2	90.65	0.07	32.76	0.0	**90.6**
2	A*	80.8	58.17				
	B*	103.8	90.59	0.07	32.42	0.0	**90.5**
3	A*	79.3	58.57				
	B*	103.4	90.60	0.07	32.03	0.0	**90.5**
4	A*	78.9	58.65				
	B*	75.9	90.41	0.07	31.77	0.0	**90.3**
5	A*	70.6	57.99				
	B*	103.2	90.46	0.07	32.46	0.0	**90.4**

*A - Background noise with tractor, trolley and electric engine; *B - Noise under working conditions without load.

It can be noticed that the L_{pA} values are always higher than the reference value of 80 dB(A) indicated by the Machinery Directive. As consequence, the maximum L_{pA} observed value, equal to 90.6 dB(A) and its associated measurement uncertainty ($\pm$ 1.4 dB) must be indicated on the user manual of the machine and it has been necessary to determine the corresponding sound power. Finally, the data collected during the tests for the determination of the sound pressure underwent frequency analysis in $^1/_3$ –octaves that provided the behaviour of Fig. 4: the contribution of the seed drill to the sound pressure level is given by the difference between grey and black bars. It is more significant within the interval 200 to 630 Hz and shows a peak at 500 Hz, characteristic of the tested equipment.
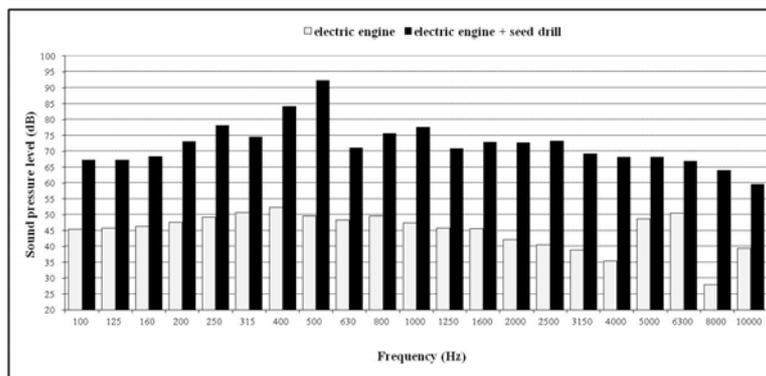

Figure 4. Frequency analysis in $^1/_3$ –octaves.

The results of the measurements of the sound power level are reported in the table 3, showing a maximum of 106.5 dB(A). Such a value and its associated measurement uncertainty (± 3.2 dB) must be reported in the user manual as well.

Table 3. Measured levels of the sound power.

Replication	$\overline{L_p}$ dB(A)	K_1 dB(A)	K_2 dB(A)	Surface (m^2)	L_w dB(A)
1	80.44	0.0	-0.09	401.92	**106.5**
2	80.00	0.0	-0.09	401.92	**106.0**
3	79.79	0.0	-0.09	401.92	**105.8**
4	79.64	0.0	-0.09	401.92	**105.7**
5	79.45	0.0	-0.09	401.92	**105.5**

According to the results of the two types of test, carried out according to the quality criteria, it seems possible to apply the described quality system even to a sector characterized by considerable environmental variability, as that of agricultural engineering.

Conclusions

Through the example of the tests conducted on a seed drill for in-line sowing, this work aims at showing how the CPMA laboratory works in order to provide valid, accurate and reproducible results, testifying that the Quality System is in compliance with an international standard. The objective of CPMA tests activity is the study of the safety characteristics of the machines under operative conditions.

As a consequence of the relevance assumed by the aspects of safety and prevention of accident and diseases in the work environment, the importance of such an activity is continuously increasing. In particular, when it is conducted in an accredited testing centre, it represents a guaranty for both the users, that can orientate their choices towards the most safe machines, and the manufacturers, often small manufacturers that could find, in the test results, suggestions for modifications and adaptations aimed at improving the quality of the machines.

At the end of each test, the CPMA provides the Official Report of the tested machine that illustrates in detail all the requirements, measurements and actions taken to perform the test. As a member of EA (European co-operation for Accreditation) ACCREDIA is one of the signatories of the Multilateral Mutual Recognition of International Laboratory Accreditation Cooperation (ILAC-MRA), and, consequently, the reports issued by the CPMA, bearing the combined brand ILAC-MRA ACCREDIA, are recognized and internationally accepted.

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Self-propelled prototype for harvest of hazelnut fruits *(Corylus avellana* L.*)*: analysis of particulate matter emitted into the atmosphere

M. Fedrizzi[1], M. Pagano[1], C. Perrino[2] , P. Recchi[1] , P. Gallo[1]

[1] *CRA-ING, Agricultural Research Council - Engineering Agricultural Research Unit*
Via della Pascolare, 16 – 00016 Monterotondo (Rome), ITALY.
0039-06 90675230 Fax 0039-06 90625591
[2] *CNR-IAA: Italian National Research Council, Institute of Atmospheric Pollution Research*
Via Salaria Km 29.300 – 00016 Monterotondo (Rome) Italy
Email corresponding Author: marco.fedrizzi@entecra.it

Abstract

The paper aims to point out the characteristics of a new pick-up type harvesting machine used in hazelnuts cultivation, the dust emission in the air and the productivity of mechanized harvesting operation. The paper reports the results of a first trial in the field. The prototype "Semek 900", manufactured by FACMA s.r.l., uses a mechanical harvesting pick up and it was tested in hazelnuts cultivation. The hazelnut fruits present on the ground had been previously moved in windrows using a hand blower. Work time measurements in according to the C.I.O.S.T.A. method. Each sample of harvested hazelnut was analyzed to measure the presence of shell damages and impurities. The environmental monitoring of dust was carried out both in ambient air and close to the machine driver. The dust samples were analyzed for the mass concentration and chemical composition of inorganic species. Therefore a theoretical working capacity was obtained with an operating efficiency level of 71%. The harvesting losses referred to the product in the windrows were 20% of the total production. The average concentration of dust was 7.5 mg m^{-3} in ambient air and 38.6 mg m^{-3} close to the machine driver. Most of the dust consisted in organics and soil components. The concentration of dust appears similar to that produced by other existing machines and therefore other solutions have to be studied.

Keywords: particulate, pollution, reduction

Introduction

This paper would point out the possibility of using a self-propelled hazelnuts mechanical harvester, which performs its harvesting action through mechanical action without pneumatic suction, limiting the emission of dust in the ambient air. The dust emitted from vacuum machines (sometimes containing high levels of pesticides and herbicides) may cause a high environmental pollution during the harvest period and constitute a serious risk to the worker's health (Biondi et al., 1992 b). To reduce health hazards, a useful solution may be represented by the employment of the pickup type machines for gathering the fruits form the orchard floor (Ghiotti, 1989). In fact pickup models use a rotating brush to lift the fruits that are then carried forward in the machine passing through succeeding mechanical cleaning and sieving devises. When using these harvester models the crop may be harvested even if the orchard floor is covered with grass and in this case dust emission is even more reduced (Fanigliulo et al., 2009). Being aware of this issue the FACMA, a company based in Vitorchiano (Viterbo - Italy), leader in the production of harvesting machines for the shell fruit sector, designed and developed a new model of a self-propelled pickup harvester, at present in the prototype stage, having some technical innovations with the aim of replacing its own vacuum technology. The aim of this work was to evaluate the technical solutions applied to the machine construction

and to appraise with specific harvesting tests, done in a hazelnut orchard near Viterbo, the operative performance (working time and working capacity) of the prototype and work quality (ground losses and product cleanness). During the harvesting tests, were acquired the main informations regarding the functional aspects of the harvester.

Methods
The prototype of pickup harvester, model "SEMEK 900", is a self-propelled machine developed for harvesting shell fruits (hazelnuts, walnuts and almonds) from the orchard floor that can work either on bare ground or with a grass covering. In addition to product harvest, the machine performs mechanical cleaning and sieving steps on the product, that is afterwards either delivered for storage to sacks held on a tractor-mounted platform or conveyed to a storage trailer hauled by the tractor. The "SEMEK" prototype is powered by a VM brand engine, an inline four cylinder supercharged Diesel engine, rated 64 kW (86 cv) at 2600 RPM, and complying with the EC/EPA Step 3A emissions standards. The total mass of the prototype is 2.3 tons. The machine has 3 drive wheels, of which the steering one is placed in the rear end of the frame. Power transmission from the engine to the wheels is hydrostatic with differential valve lock on the hydraulic motors coupled to the wheels. This locking device gives the possibility to operate also when working conditions are unfavourable: the differential lock assures the machine's continuous adherence, avoiding slippage and automatically stabilizing the vehicle, guaranteeing thus higher safety to the operator when working on sloping land and on rugged areas. Two hydraulically operated circular sweeps, placed in front of the harvester head, gather the product, previously fallen to the ground, into a windrow aligned with the intake opening (ENAMA 2002.). The sweeps have different diameters and are equipped with freely swinging flexible rubber paddles, hinged on a circular frame, the larger sweep carrying 25 elements and the smaller one 17. The pivoting movement allows the paddles to follow the soil's profile, reducing the number of fruits left on the ground when not intercepted by the sweeps. The harvesting unit has a total theoretical working width of 2.8 m. A horizontally rotating cylindrical brush, provided with rubber paddles, is placed in the header perpendicularly to the forward direction, in a position immediately following the sweeps. The brush, rotating in a direction opposite to the wheels, lifts the nuts from the ground (fig. 1). The product is so tossed behind and loaded onto an inclined conveyor belt, placed aligned with the longitudinal centre axis of the machine, that carries the fruits from the front to the back of the machine. The metallic conveyor belt, moved by an hydraulic motor, is assembled with cross rods having an appropriate pitch between the rods for accomplishing the first cleaning step for removing the debris from the material lifted by the brush. At the upper end of the belt (rear end) the fruits fall onto an inclined metal plane, that on the other end is linked to a revolving cylindrical sieve apparatus for a further sorting of the product, separating all the debris that has a diameter different from that of the hazelnuts. Finally an air stream carries the fruits to sacks held on a tractor-mounted platform or otherwise the nuts are transferred for the final storage, through a flexible tube connection, to a towed trailer with a pantograph lift system for unloading the material. The horizontal cylindrical brush is inserted in an enclosing cylindrical frame, which in the front half holds a metal grid wall. The fine soil passes through the grid form the beginning, while the fruits are lifted from the ground. A particular "dust cut-down" device is linked in front of the grid, on the outer side of the cylindrical carter, for accumulating the dust particles separated by the grid in this first step. Dust falls into a collect chute, holding an auger that pushes the material to the right hand side of the header (fig. 2). From the opening there placed the dirt is discharged on the ground to one side along the row. The rotation of the auger is powered by a specific hydraulic motor.

The grid helps remove the soil picked along with the fruits, before it is broken up into smaller particles, so producing lighter dust particles that are more difficult to separate. The use of this innovative device reduces the amount of light dust particles raised in the air, that are very dangerous to the health of the operator driving the machine. The tests were carried out in a 2 ha orchard planted with "Tonda Gentile Romana" cultivar, the landscape was quite level and the orchard floor covered by a natural grass. The plants had an average age of 23 years, a multi-stemmed training system, a 4.5 x 4.5 m plant spacing. Crop management adopted the controlled fine mown turf technique, carried out by making 3-4 passes for each year with a flail mower (starting from spring up to September, just before harvesting time) depending on the seasonal rainfall trend.

To determine the unitary fruit yield of the test site, various samples where harvested in five sampling areas of the test field casually scattered throughout the orchard. The data achieved allowed us to estimate a unitary hazelnut yield of 2.50 t ha^{-1}. The fruits so gathered showed a unitary average weight of 2.7 g. The field tests were carried out in accordance with the protocol, proposed by E.NA.M.A., for determining functional characteristics of machines used for picking shell fruits from the ground (E.NA.M.A., 2002). Field measurements were made for establishing the harvester's fuel consumption, the driving speed, working time and working width. The C.I.O.S.T.A. (Commission Internationale de l'Organisation Scientifique du Travail en Agriculture) methodology was used for the computation of working time. The machine's fuel consumption was measured using the method based on multiple weighing: the trial started with the tank filled up to the rim and, at the end of the trial, the fuel level was resumed weighing the quantity added. Before the tests all the hazelnuts fallen to the ground, scattered on the whole area included between the tree lines (about 4,50 m), were concentrated in the middle of the row, into a single windrow, by a worker using a blower carried on the back. Therefore the harvest was completed making only one pass over each row and consequently the working width taken into account for calculating the related work capacity and productivity was exactly that between the rows, specifically 4.5 m and not the 2.8 m width given by the circular sweepers of the SEMEK 900 harvester. The work time (only in this case) was therefore related to the whole area and not only to that occupied by the windrow (Colorio et al., 2009).

To evaluate the harvest quality, samples were gathered from the harvested product conveyed in the trailer, at regular intervals. The samples were visually analyzed in the laboratory at CRA-ING with the aim of identifying the level of product cleanness and the quality of the fruits. In each sample the sound appearing hazelnuts were separated from the debris picked up by the machine (i.e. pebbles, pieces of wood and empty shells) and the different parts were weighed for establishing the percentage of fruits actually gathered. Following the machine's passage in the field, other samples were gathered on the ground to evaluate the amount of eventual fruit losses to the ground. The machine settings best suited for an optimal working configurations were made by F.A.C.M.A.'s technical personnel. These regarded mainly: working speed, circular sweep speed, conveyor belt speed. Particulate matter (PM) released during the harvesting was sampled both in ambient air, at about 30 m from the machine, and on the operator (personal sampling). Sampling in ambient air was carried out by means of Tecora mod. Bravo, operating at the flow rate of 6 l min^{-1}; personal sampling was carried out by means of a *SKC* worn by the driver of the machine. The instrument operated at the flow rate of 2 l min^{-1} and was equipped with a Dorr-Oliver cyclone for the collection of particles having aerodynamic diameter below 10 micrometers (PM10). Main meteorological parameters (temperature, R.H., wind speed, wind direction) were monitored during the experiments. During all the samplings, PM was collected on Teflon membrane filters. The

first step of the analytical phase consisted in the gravimetric determination of the collected PM mass, after 48-h conditioning at $20\pm1°C$ and $50 \pm 5\%$ relative humidity. Then the filters were analyzed by energy dispersion X-ray fluorescence (ED - XRF, Spectro, Germany, mod. X-Lab 2000), a non-destructive technique, for their elemental content (Al, As, Br, Ca, Cd, Cl, Cr, Fe, K, Mg, Mn, Na, Ni, P, Pb, S, Si, Sr, Ti, V, Zn). The third analytical step consisted in the filter extraction in deionised water and ion chromatographic analysis (IC, Dionex, Dionex, S. Donato Milanese-MI, mod. ICS 90) of anions and cations (chloride, nitrate, sulphate, sodium, ammonium, potassium, magnesium, calcium).

Results

The specific trial conditions and the amount of fruits actually present on the ground required the testing of different forward velocities, to avoid eventual overfilling problems, causing the harvester to malfunction. The average forward speed in the test was 1.5 km h^{-1} in opposition to the 2.0 km h^{-1} maximum speed that the machine can hold in the work phase, while the machine's maximum road travel speed reaches the value of 17.5 km h^{-1} (data given by the manufacturer). The working capacity of the pickup harvester was 0.64 ha h^{-1} with an hourly productivity of 1.25 t h^{-1}. In these working conditions the operative efficiency was 71% (other data provided by the tests are indicated in table 1). These results of course are not intended as absolute, but must be necessarily referred to the way the harvester was employed in the specific test, that followed the accumulation of the product in a windrow. If the harvest is done going over the whole orchard surface, without a previous windrowing, machine performances would decrease considerably. This fact was established by other studies carried out with different harvesters employed for gathering shell fruits from the ground. The resulting hourly productivity turned out to be satisfactory and anyways the prototype proved to be able to work even when the grass cover was overgrown. The tests showed a fuel consumption per hour of 6.8 kg h^{-1}, while fuel consumption per surface unit was 10.6 kg ha^{-1}. Regarding the evaluation of the harvester's work quality it is possible to assert that the cleanness level of the gathered fruits is comparable that obtained using other commercial models of shell fruit harvesters: sound hazelnuts amount to 90% of the total mass gathered, while the remaining 10% consists of debris, broken, damaged and undersized fruits. The product analysis results are shown in table 2. The analysis highlights that the machine's working mechanisms, in particular the rotating sieving apparatus, do not cause damages to the fruits during the different work steps, giving almost 1% percent of broken hazelnuts. Fruit losses to the ground, due to fruits that are not intercepted by the pickup apparatus, was 20% percent of the total production. The picking efficiency was 80% of the total product gathered in the windrow. This result is not completely satisfactory if compared to the other commercial harvesters, either vacuum or pickup models, produced by FACMA itself and by other firms. It is necessary to check harvester settings for a better fine tuning of the pickup apparatus. But it's appropriate to note that the level of fruit losses observed are due, in part, to the condition of the field that was not appropriately levelled. To obtain the harvester's maximum efficiency it is important to perform an accurate superficial soil tillage, leaving the orchard floor evenly levelled.

Average PM concentration in ambient air was 7,5 mg m^{-3}, while the average concentration close to the operator (personal sampling) was 38,6 mg m^{-3}; the data show a 5-fold increase in PM concentration with respect to the position where the environmental sampling was carried out, about 30 m a part. The analysis results are shown in table 3.

The results of the chemical analyses on the collected dust did not show any significant difference in PM composition between ambient and personal samplings. The results of the

ED-XRF analysis show that the elemental composition of the collected samples was typical of soil: silicon (32%), calcium (28%), iron (13%), aluminum (10%), potassium (6%) and sodium (5%). Other elements that can include a relevant contribution from the soil (S, Cl, Ti, Mn, Sr, Cd) accounted for about 1% (range 0.6 – 1.2 %), while elements of main anthropogenic origin accounted for 0.2 – 0.3% (V, Cr, Ni, Pb) or were below the detection limit (As, Zn). All together, the elements constituted around 10% of the collected PM mass. As these species are generally in the form of oxides, we can estimate that their contribution was around 15, the remaining PM mass has to be attributed to organic matter and to water.

Figure 1 – SEMEK 900: powder reduction device the lateral opening for soil discharging and circular sweepers

Figure 2 - device of dust expulsion

Table 1. Results obtained with the self-propelled hazelnuts mechanical harvester Semek 900 during the test harvesting (average values).

Parameters	Performance
Theorical working width (m)	2.80
Actual working width (m)*	4.50
Actual working time (h ha^{-1})	1.56
Operative efficiency (%)	71
Operative working capacity (ha h^{-1})	0.64
Average actual working velocity (km h^{-1})	1.5
Hourly productivity (t h^{-1})	1.25
Fuel consumption per hour (kg h^{-1})	6.8
Fuel consumption per surface unit (kg ha^{-1})	10.6
Fuel consumption per hourly productivity (kg t^{-1})	5.4

* width corresponding to the distance between the rows of plants

Table 2. Analysis of impurities presence in harvested hazelnuts.

Parameters	Performance	
	%	**Avarage weight (g)**
fruits	89.75	5564
wood	0.18	11
full cupules	0.81	50
empty cupules	0.34	21
broken shells	1.08	67
leaves	0.85	53
soil	5.60	347
small unmarketable fruits	1.39	86
Total	**100**	**6199**

Table 3. Dust concentrations measured in ambient air and the operator during the harvesting test (average of 4 trials lasting 30 minutes each).

Harvester	Sampler position	Average dust concentration [mg m^{-3}]
SEMEK 900	AMBIENT	7,5
	OPERATOR	38,6

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Noise operator exposure in olive oil mills

Manetto G., Cerruto E., Emma G.

University of Catania, DiGeSA, Section of Mechanics and Mechanisation
Via Santa Sofia, 100 – 95123 Catania, ITALY
Tel. ++39 0957147515, Fax ++39 0957147600
Email corresponding Author: gmanetto@unict.it

Abstract
Noise in work environment is among the major causes of concern for safety and health of the industrial workers, as it causes annoyance and hearing loss. As with most occupational diseases, recognition and assessment of noise exposure are the foundations on which preventive measures and treatments are based. Aim of this study was to identify the predominant noise sources in the workrooms of two small olive oil mills in the South-East of Sicily and to measure the extent of noise exposure of the workers. The two mills differ essentially for the crushing system: based upon a millstone in the former and upon a steel-hammer type in the latter.
The results showed quite high sound pressure levels, especially in the second mill (average of 93.7 dB(A)). In the first mill, sound pressure levels ranged from 75.2 up to 94.4 dB(A), depending from the machines running contemporarily. The main sources of noise were the leaves remover and the washing machine in both mills, as well as the steel hammer-type crusher in the second mill.

Key words: occupational disease, safety, health.

Introduction

The olive growing has a fundamental role in the Italian agro-industrial economy, especially in the Southern Italy, where it is concentrated the greatest national production of olive oil. Moreover, this sector generates a job application of about 30 million of working days and classifies Italy at the second best world olive oil both as producer and exporter, after Spain. In particular, Italy is the first olive oil supplier for the USA (CO.RE.R.A.S., 2007).

In this national contest, Sicily is one of the leading regions both for invested surface (158 502 ha) and for olive production (313 705 t). However, despite the presence of 8 protected origin denominations (DOP) for the Sicilian olive oil production, less than 1% of product is certified. This is due to the high incidence of small olive farms: in fact, only 6.2% of these have an extension greater than 10 ha. Moreover, most of the olive oil production is destined to self-consumption or direct marketing, without any packaging (CO.RE.R.A.S., 2007).

Due to this organization, a great number of small oil mills (about 687 during the olive year 2004–2005) are active. Frequently, they have a family management and the working day duration is much longer than 8 hours, because of the limited period per year during which the plants are functioning.

Noise in oil mills is among the main sources of risk for safety and health of the workers, as it causes annoyance and hearing loss (Landström *et al*., 1995; Middendorf, 2004; Prasanna

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The Authors equally contributed to the present study.

Kumar *et al*., 2008). On the other hand, the Italian regulation in force (Government Decree 9th April 2008, no. 81) states that the risk evaluation report must be carried out also for the family management activities. Therefore, it is necessary to carry out the recognition and the assessment of noise exposure on which preventive measures and safety interventions can be based.

This research intends to evaluate the noise level in two small oil mills with different crushing systems and similar oil separation systems. The paper reports the noise levels measured in each oil mill near each working position so to identify the machines mainly involved in causing high sound pressure levels.

Materials and Methods
The oil mills

Measurements of the sound pressure levels were carried out in two small olive oil mills: the first located in Regalbuto, in province of Enna, and the second in Noto, in province of Syracuse. The two oil mills have different period of installation, the same extraction system, but different crushing system. In fact, the former adopts a traditional millstone crusher, while the latter uses a steel hammer-type crusher. Therefore, the first one has mostly a batch functioning and the second a continuous one. In practice, also the second oil mill has a batch functioning, because during the same working day several small olive consignments of different farmers are milled and the oil must be separated for each of them.

The plant layout is different too due to the greater space taken by the millstone crusher system and to the shape of the workroom: almost square for the older oil mill (Figure 1) and rectangular for the most recent one (Figure 2).

Figure 1. The oil mill in Regalbuto (province of Enna).

In detail, the two oil mills have the same feeding system consisting in a hopper followed by an elevator belt and a leaves remover based on a very fast airstream produced by a radial fan. After there is the washing machine; only in the first oil mill it is preceded by a second hopper that permits to stock the olives before the crashing, so allowing its activation in different times with respect to the leaves remover and improving the batch functioning. Then the olives reach the crushing system by means of an inclined screw elevator in both oil mills. Differently from the first oil mill, in the second one leaves remover, washing machine, and crushing system are always activated contemporarily.

Figure 2. The oil mill in Noto (province of Syracuse).

At the exit, the olive paste is pumped inside the kneading machines; in the older oil mill, the crushing phase is finished by means of a rotating cutter with three blades installed at the end of the feed pipe. The kneading machines in the first oil mill consist in three modules and each module can be bisected so that its volume can be adequate to the amount of the worked batch. In the second oil mill they consist in six modules, equipped with an automatic pressurised washing system.

Finally, in both oil mills, oil extraction is performed by means of a horizontal centrifugal extractor, and water separation is carried out by means of two vertical centrifugal separators.

Measuring equipment

The measurements of the sound pressure levels were carried out by using a microphone RION, model UC-53A, screwed on a pre-amplifier RION, model NH-17A, connected to an amplifier MESA, model R31. A sound pressure calibrator NORSONIC mod. CAL1251, which provides a sinusoidal pressure signal of 10 Pa (114 dB) at the frequency of 1000 Hz, was used to calibrate the measuring chain. The microphone signals were recorded on the hard disk of a notebook by using a PC based recording and analysis system made up of a four-channel USB-II data acquisition unit (dB4), a PC, and the dBFA Suite software (01 dB-Metravib). With the software it is possible to configure the measuring chain, to carry out the calibration of the microphone by fixing its sensitivity and to start or stop the signal acquisition. Moreover, it allows for several post-processing analyses, among which narrow band analysis (FFT), 1/3 and 1/n octave analysis. The frequency weighting according to the different sound weighting curves provides the continuous equivalent sound pressure level L_{eq} for each signal analysed. Finally, the software allows studying both the full signal recorded, but also its fractions, so to analyse singular events.

The research activity

Noise measurements were carried out under ordinary working conditions in several points of both oil mills (Figure 3 and 4). As the oil mill in Regalbuto did not work at full capacity, noise signals were recorded in two different days.

The microphone was fixed to a tripod at the height of 1.5 m above the ground. In the first oil mill, due to the different plant layout and the irregular free space, the measurement points were preferably selected near the machines (Figure 3), but three points (R1, R4 and R7) were chosen in correspondence of the area where the workers operate and are more influenced by two or more machines.
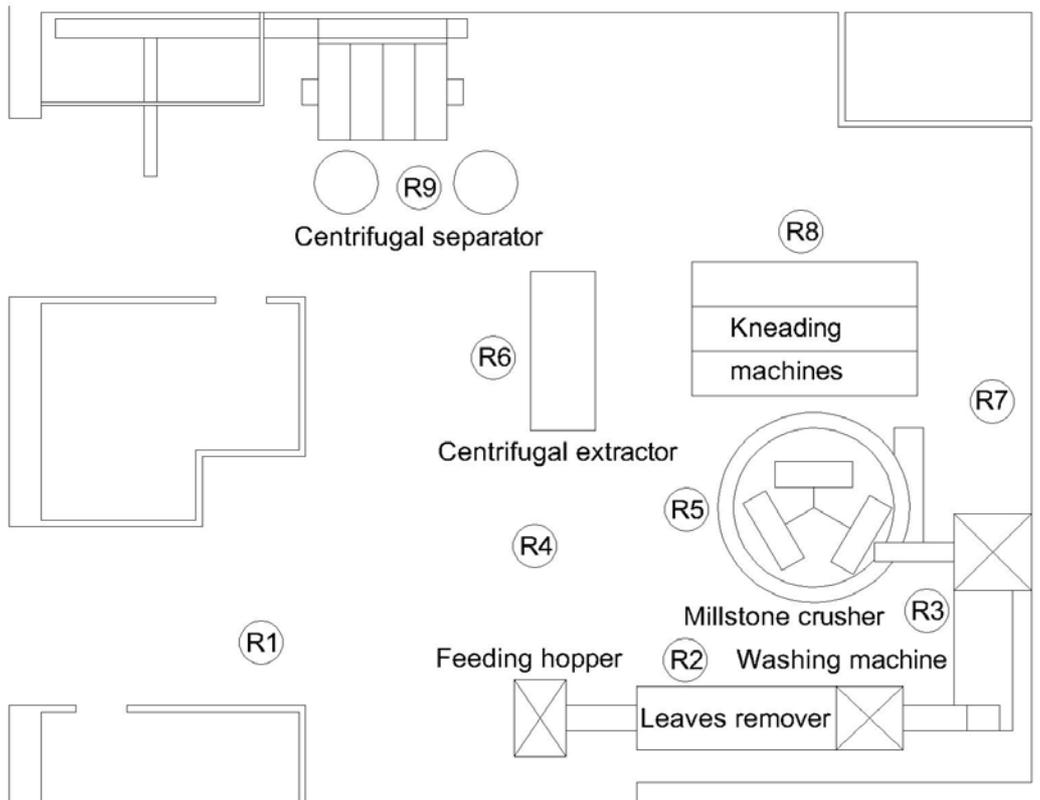
Figure 3. Plant layout and measurement points in the oil mill in Regalbuto.

In the second oil mill, ten measurement points were selected, disposed on a rectangular grid made by two lines 2 m apart and five columns 2.5 m apart (Figure 4). Another point (N11) was chosen near the general electric panel, where the operators may remain to start or stop a machine or to verify the regular functioning of the plant.
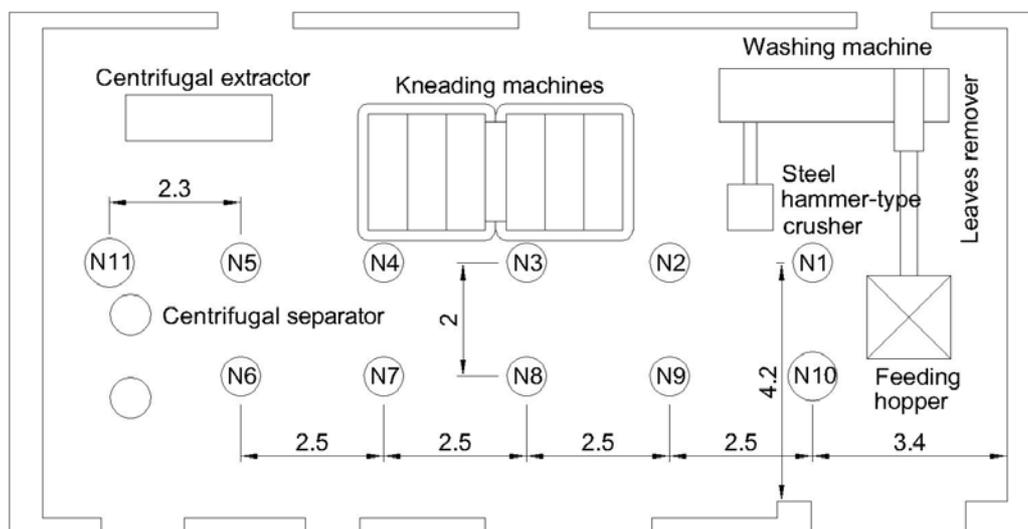

Figure 4. Plant layout and measurement points in the oil mill in Noto.

Each measuring session ranged from about 7 up to 37 minutes in the first oil mill and from about 5 up to 15 minutes in the second one, so to ensure the recording of a signal representative of the ordinary working conditions. During the measures all the significant variations (activation or deactivation of machines) were noted.

Data analysis

The signals were analysed in the range 0–20 000 Hz (third of octave bands from 12.5 Hz to 20 kHz) by applying the FFT and the 1/3 octave analysis and by computing the frequency weighted sound pressure levels (RMS values) and the continuous equivalent sound pressure levels weighted A L_{Aeq}. Then the exposure times T_e need to reach the superior action value of 85 dB(A) and the exposition limit value of 87 dB(A) of the daily personal exposition level $L_{EP,d}$, established by the Government Decree no. 81/2008, were computed by applying the equation:

$$L_{EP,d} = L_{Aeq,T_e} + 10\log_{10}\frac{T_e}{T_0},$$

being T_0 a reference exposure time of 8 hours.

To put in evidence the effect of single machines, first of all each signal was analysed in its entirety and then several sub-signals, concerning constant working conditions, were extracted from it and analysed separately.

Graphical representations were carried out by using the open source software *R*.

Results and Discussions

Looking at the signals recorded and taking into account the activations and deactivations of the machines noted during the measurement sessions, it was possible to easily identify the correspondent variations in the sound pressure levels. For example, in figure 5, concerning a measurement carried out in position N2 inside the second oil mill, during the first 35 s the signal was influenced by the pressurised system to clean the kneading machines; the peaks showed at around 180 s were due to the empting of a bin into the feeding hopper; at last, the new increasing of pressure after 225 s was caused by the activation of the leaves remover, the washing machine and the steel hammer-type crusher.
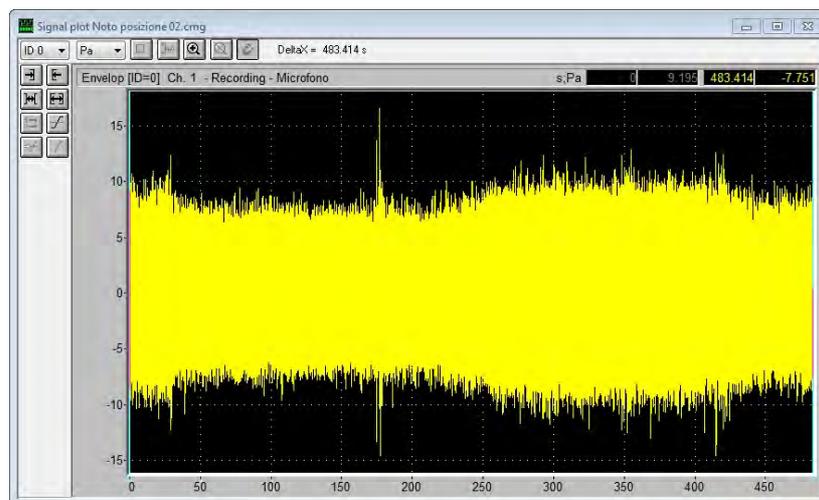

Figure 5. A signal recorded into the second oil mill.

The results of the analysis carried out on the full signals are showed in figures 6 and 7 for the two oil mills respectively. In the same graphs are reported the minimum and maximum values of the sound pressure level computed with reference to the sub-signals recorded in constant running conditions. Where the minimum and the maximum values are missing, it means that did not happen significant variations in the running conditions during the acquisition of the signal.
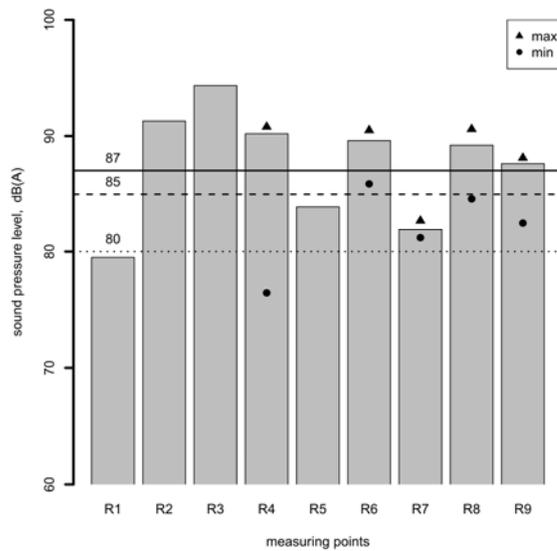

Figure 6. Sound pressure levels recorded in the oil mill in Regalbuto.
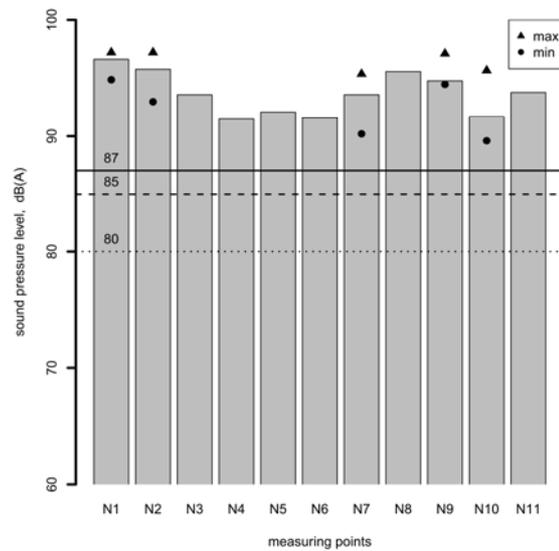
Figure 7. Sound pressure levels recorded in the oil mill in Noto.

In the first oil mill (Figure 6), the continuous equivalent sound pressure levels in each position were always higher than the threshold value of 80 dB(A), with the only exception of the position R1, the access area of the mill and the furthest by the plant, where, nevertheless, 79.5 dB(A) were measured. In R5 and R7 the continuous equivalent sound pressure levels were 83.9 and 81.9 dB(A) respectively, but during the recording the leaves remover was turned off. Furthermore, in R7 it was possible to detect the contribution of the transfer pump for the olive paste together with the crushing finisher (maximum value) and of the millstone crusher (minimum value), that was turned off for 14 minutes. In all the other measurement points the level was always exceeding the exposition limit value of 87 dB(A). In R4 it is possible to valuate the effect of the only millstone crusher (minimum value) and a difference of around 6 dB between maximum and minimum values in correspondence of R6, R8 and R9, mainly due to the leaves remover and the washing machine, in the proximity of which (R2 and R3) the highest values were recorded.

Looking at the second oil mill (Figure 7), that during the measuring sessions had a more continuous running with respect to the first one, values higher than 90 dB(A), with a mean of 93.7 dB(A), were recorded in all the points. Also in this case the main sources of the sound pressure level were the leaves remover and the washing machine, to which must be added the steel hammer-type crusher, noisier than the millstone crusher. Their contribution was again valuable by observing the difference between maximum and minimum values in all the measurement points. It ranged from 4 up to 6 dB in function of the activation of the leaves remover and the washing machine. Also the pressurised washing system of the kneading

machines had some effect, but it was active only few seconds and can not provide a significant increase in the sound pressure level. The background level was associable to the centrifugal extractor, but it was not possible to determine its effect.

The higher sound pressure levels recorded in the second oil mill can not be explained with the different crusher system only and/or the running conditions of the mills (the first oil mill did not operate at full capacity and therefore the machines were always started and stopped). A great contribution was due to the size of the workroom and, above all, to its height, very larger for the first one. This circumstance could induce more reverberation in the second oil mill, so increasing the pressure level.

Given this working condition, the use of personal protection equipment (PPE) is absolutely mandatory. In fact, with the mean equivalent sound pressure level of 93.7 dB(A), the two limits of 85 and 87 dB(A) fixed by the regulation in force are achieved after only 1.7 and 1.1 hours respectively. These times are absolutely incompatible with the duration of the ordinary working day. Moreover, especially with a family management, the PPE are refused in order to hear anomalous sounds and preserve the plant. A solution could be found in covering the walls with sound absorption material and/or in shielding leaves remover, washing machine and crushing area.

Conclusions

The study allows for the following conclusions:

- The continuous equivalent sound pressure levels were quite high in both oil mills analysed. That located in Regalbuto showed a sound pressure level lower than the oil mill in Noto but, due to its running conditions, other measuring sessions should be carried out.
- The machines that more contributed were the leaves remover, the washing machine and the steel hammer-type crusher, but also the centrifugal extractor with its continuous noise can provide a high background sound pressure level.
- The size and the height of the workroom can have high influence due to the reverberation of the walls. To limit this effect could be necessary to cover the walls with sound absorption material.
- The mean value of 93.7 dB(A) recorded in the second oil mill causes the achievement of the limits fixed by the regulation in very short times: 1.7 and 1.1 hours respectively. The use of PPE is then essential, but they are refused by operators because of the necessity to hear immediately anomalous sounds to preserve the plant. It follows that more effective information on the effect of the noise on safety and health is absolutely necessary.

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Vibration operator exposure during olive harvesting

Manetto G., Cerruto E., Schillaci G.

University of Catania, DiGeSA, Section of Mechanics and Mechanisation
Via Santa Sofia, 100 – 95123 Catania, ITALY
Tel. ++39 0957147515, Fax ++39 0957147600
Email corresponding Author: gmanetto@unict.it

Abstract

The paper reports the results of some experimental tests aimed at measuring the vibrations transmitted to the hand-harm system by electric portable harvesters for olives. One flap-type harvesting head was applied to three bars, different for diameter (35 and 40 mm), length (2010 and 2210 mm) and material (aluminium and carbon fibre), so assembling three harvesters. The vibrations were measured in two points, next to the hand-grips. Measurements were carried out both in laboratory, during idle running, and in field, during the harvesting of "Nocellara Etnea" olive variety, under ordinary working conditions.

The results of the laboratory tests showed that the bar material had the greatest influence in reducing the vibration level: the average RMS value was about 12 m/s^2 for the carbon fibre bar and about 21 m/s^2 for the aluminium ones, without significant differences between the two diameters. The in field tests proved that the tree canopy had a negative effect on the vibrations transmitted to the hand-arm system: in fact, the average RMS value increased from 16 (laboratory) up to 20 m/s^2 (in field). The greatest difference between laboratory and in field tests was observed when using the 35-mm aluminium bar.

Key words: safety, electric portable harvesters, hand-arm system.

Introduction

The use of hand-held portable harvesters for olives is very widespread to increase the work productivity, mainly when full mechanisation is not possible (Famiani *et al*., 2008). Unfortunately, they expose operators to several sources of risk, as noise, vibrations, and fatigue (Iannicelli and Ragni, 1994; Blandini *et al*., 1997; Deboli *et al*., 2008), that only after proper design or optimal selection of the operating parameters can be reduced (Monarca *et al*., 2007; Pascuzzi *et al*., 2008; Mallick, 2010). A significant reduction in noise level exposure has been achieved by using machines powered by electric motors (Biocca *et al*., 2008), so increasing in the same time the operator's comfort.

Vibration is probably the most important risk connected with the use of these portable harvesters. The effects of vibrations on the hand-harm system can lead to the well-known Raynaud syndrome, a disease which requires attention from the medical point of view (Chetter *et al*., 1998). Moreover, workers, when operate with hand-held power tools, in most of the cases do not perceive acceleration levels as being too high, so increasing the exposure risk (Vergara *et al*., 2008). This aspect is often underestimated by agricultural farmers, mainly interested at the harvest capacity.

The factors influencing the biodynamic response of the hand-arm system are multiple, depending on the vibration (acceleration, direction, frequency), the operator (mass, posture,

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The Authors equally contributed to the present study.

grip force), the operating tool (mass, material, handle sizes), and the use of anti-vibrating equipment (Buström, 1997; Monarca *et al*., 2003; Dong *et al*., 2005; Aldien *et al*., 2006; Dewangan and Tewari, 2008; Tewari and Dewangan, 2009).

This research intends to evaluate the vibrations transmitted to the hand-arm system by electric portable harvesters at varying bar features (material, diameter and length), but keeping the same harvesting head. First studies, presented in (Cerruto *et al*., 2009) and (Cerruto *et al*., 2010), dealt with laboratory tests only, while in this paper the results of both laboratory and in field tests, under ordinary working conditions, are reported.

Materials and Methods

The portable harvesters

Experimental tests were carried out by using three portable harvesters, assembled by applying the same flap-type harvesting head to three bars, different for material, diameter, length and mass as reported in Table 1. The use of carbon fibre is mainly aimed at reducing the weigh of the equipment and then the fatigue of the operators, but it is expected to have influence on vibrations too.

The harvesting head presents an aluminium-made box and 12 teeth (the small bars that beat branches and olives during the harvest). The teeth, all in carbon fibres and of the same size (diameter = 5 mm, length= 370 mm), are connected to a 36-centimetre arm parallel to the motor shaft, and are arranged in the classical flap-type shape (Figure 1), widely used in pneumatic harvesters.

Table 1. Portable harvester features.

Harvesting head		Bars			
			B1	B2	B3
Mass, kg	1.365	Material	Aluminium	Carbon fibre	Aluminium
Teeth:		Diameter, mm	35	40	40
Number	12	Length, mm	2010	2210	2210
Material	Carbon fibre	Thickness, mm	2	2	2
Diameter, mm	5	Mass, kg	1.356	1.342	1.416
Length, mm	370				

The harvesters are powered by an electric motor (maximum power of 900 W and rotating speed of around 6000 rpm, fixed by an electronic card), feed by means of an external 12 V battery. The motor shaft is connected to a gear that, with a gear ratio of 10:58, gets the arm carrying the teeth moving with frequency of around 18 Hz.

Measuring equipment

Vibrations were measured by using three mono axial accelerometers DJB, model A/123/S, screwed on to the mutually orthogonal faces of a small cube tied to the bar by means of a metallic clamp (Figure 2). The reference axes were selected according to the basicentric coordinate system defined by the UNI EN ISO 5349-1:2004 regulation: *x*-axis perpendicular to the palm surface area, *y*-axis parallel to the longitudinal axis of the grip, and z-axis directed along the third metacarpus bone of the hand.

Figure 1. The harvesting head.

Figure 2. Positioning of the accelerometers on the bar.

The accelerometer signals were recorded on the hard disk of a notebook by using a PC based recording and analysis system made up of a four-channel USB-II data acquisition unit (dB4), a PC, and the dBFA Suite software (01 dB-Metravib). The software allows for several post-processing analyses, among which narrow band analysis (FFT), 1/3 octave analysis, and frequency weighting according to the ISO 5349 regulation.

The research activity

The experimental activity was aimed at evaluating the vibrations transmitted to the hand-arm system at varying bar features (material and geometry) and operating mode (idle and harvesting running). To this end, the research was developed in two steps, the former in laboratory and the latter in field.

Laboratory tests were conducted by operating the three portable harvesters idle running by the same person. To take into account possible influences of the bar angle, three inclinations (vertical, inclined at about 45 degrees, and horizontal), were considered. Vibrations were measured, at different times, in two points, next to the hand positions in working conditions (Figure 3). Each measuring session lasted about 5 minutes.
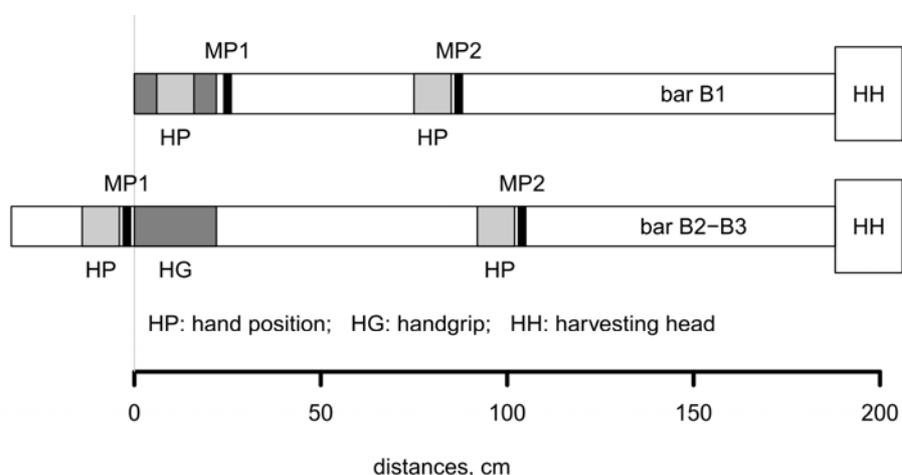
Figure 3. Measurement point position (MP1 and MP2).

The in field tests were conducted while harvesting "Nocellara Etnea" olive variety. The tree were irregularly spaced, vase pruned, and with canopy diameter of about 4 m. Again, vibrations were measured in two points as during the laboratory tests and the harvesters were operated by the same person, but different by the previous one. Each measuring session ranged from about 4 up to 13 minutes, so to complete the harvesting of one tree during each run.

All considered, laboratory tests required 18 measuring sessions (3 harvesters × 3 bar angles × 2 measurement points), whereas those in field 6 (3 harvesters × 2 measurement points).

Data analysis

Sub-samples lasting 1 minute (4 from the laboratory tests and ranging from 4 to 13 from the in field tests) were extracted from each signal recorded during the measuring sessions, so to simulate pseudo-replications. They were analysed in the range 5.6–1400 Hz (third of octave bands from 6.3 to 1250 Hz) by applying the FFT and the 1/3 octave analysis, computing the frequency weighted accelerations (RMS values) for each axis (a_{hwx}, a_{hwy}, and a_{hwz}). Finally, the global acceleration a_{hw} was calculated according to:

$$a_{hw} = \sqrt{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2} \ .$$

All a_{hw} acceleration values were statistically analysed to ascertain significant differences related to bar type and/or bar inclination (laboratory tests) and/or operating mode (idle and harvesting running). The 1-minute sub-sample signals, being pseudo-replicates only, selected without a true randomisation, were analysed via the more robust Kruskal-Wallis non parametric test rather than the analysis of variance. Statistical analyses and graphical representations were carried out by using the open source software *R*.

Results and Discussions
Global weighted acceleration

Comparing global weighted acceleration values for bar type, bar inclination, measurement point, and operating mode, the plot design reported in Figure 4 was obtained. It shows that the mean value of the global weighted acceleration is quite high (17.7 m/s^2) and comparable with that measured when using mechanic or pneumatic machines (Blandini *et al.*, 1997; Çakmak *et al.*, 2011). Moreover, the Kruskal-Wallis test shows that there are statistical significant differences among the levels of the factors included in the experimental design.

In detail, the in field tests were more stressing than the laboratory ones: in fact, the global weighted acceleration values increased from 16.3 up to 19.6 m/s^2, so denoting that the tree canopy had a negative effect on the vibrations transmitted to the hand-arm system.

Looking at the bars, the lowest acceleration was measured when using the carbon fibre (B2) bar: 12.0 m/s^2 vs. 20.1 m/s^2 (B3) and 21.1 m/s^2 (B1). These first results show a positive effect of the carbon fibre in reducing the vibrations transmitted to the hand-arm system with respect to the aluminium, keeping constant bar diameter and material thickness. However, different results could be obtained when using carbon fibre of different features and/or aluminium with different alloy and thickness. Therefore, other bars of other manufacturers should be tested in order to study more in depth the effect of the material on the vibrations.

When comparing the measurement points, it emerged that the acceleration values were higher in MP2 and lower in MP1: 21.1 m/s^2 vs. 14.5 m/s^2. Therefore, the hands are differently stressed: that which holds the bar in MP2 is more exposed to the vibrations than that in MP1. Probably the lower vibrations measured in MP1 are due to the greater distance from the

source of vibration (the harvesting head) and/or to the vibrating mode with a node near the measurement point MP1.
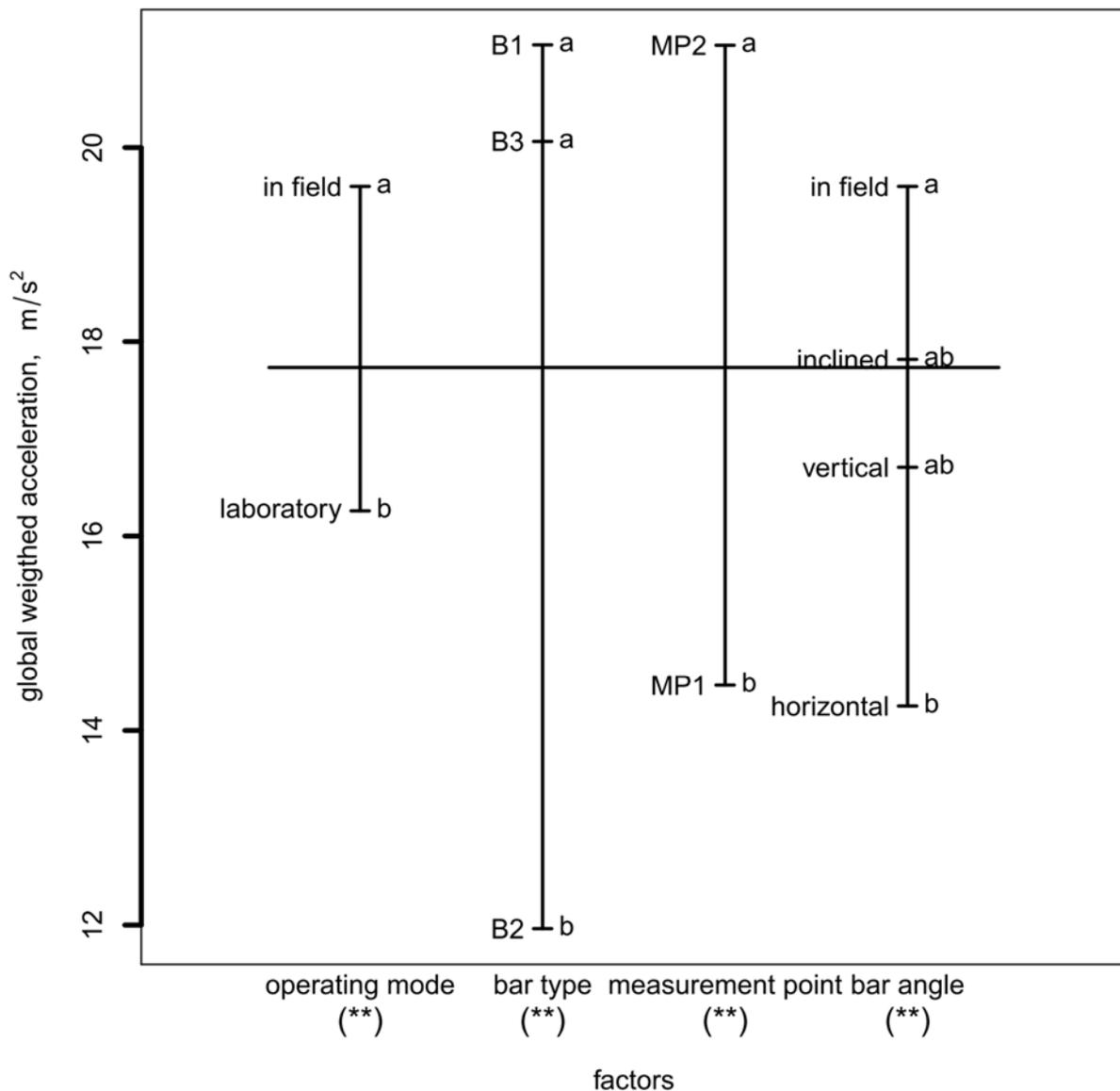

Figure 4. Plot design (mean values) of the global weighted accelerations (group separation by Kruskal-Wallis test at p=0.05).

Finally, the differences among the bar angles during the laboratory tests were not statistically significant: the acceleration values ranged from 14.3 (horizontal) up to 17.8 m/s^2 (inclined).

These acceleration values lead to daily exposure levels much higher than the daily limit value of 2.5 m/s^2 and the daily action value of 5.0 m/s^2 established by the European directive 2002/44/CE. With reference to the mean value of acceleration (17.7 m/s^2) and supposing a daily exposure of 4 h (obtained considering a work-day of 7 h and that operators attend also to

positioning of nets on the ground and to the recovery the olives), the corresponding A(8) values becomes:

$$A(8) = \sqrt{\frac{T}{T_0}} a_{hw} = \sqrt{\frac{4}{8}} 17.7 \text{ m/s}^2 = 12.5 \text{ m/s}^2 .$$

Conversely, by imposing $A(8) = 5.0$ m/s^2 or $A(8) = 2.5$ m/s^2, the daily exposure times should be 0.64 h and 0.16 h respectively, clearly incompatible with the length of a standard work-day in agriculture, so the use of appropriate personal protection equipment should be mandatory.

The first order interactions involving the operating mode (operating mode × bar and operating mode × measurement point), are reported in Figure 5. They show that the carbon fibre bar (B2) produced the lowest accelerations both in field and in laboratory and that the differences between laboratory and in field tests were progressively increasing when going from carbon fibre bar (B2, 11.7 vs. 12.3 m/s^2), to 40 mm aluminium bar (B3, 19.1 vs. 21.1 m/s^2), to 35 mm aluminium bar (B1, 18.0 vs. 25.7 m/s^2).

These results lead to the conclusion that, keeping constant the harvesting head, the bar material plays the most important role in reducing the acceleration values, both during idle and harvesting running.
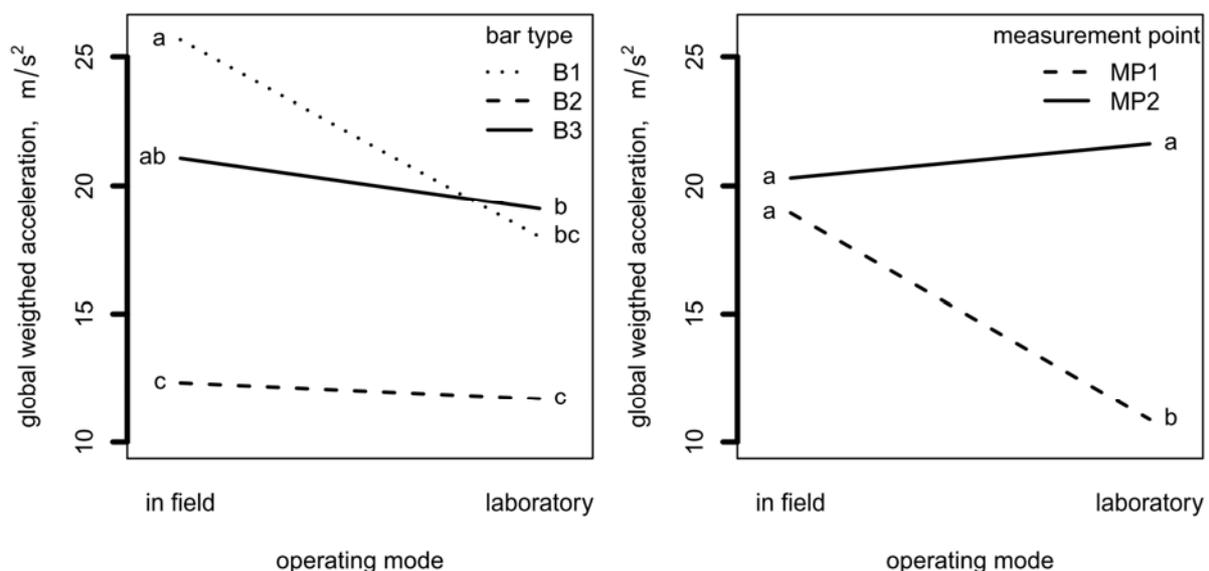

Figure 5. Interaction plot (mean values) of the global weighted accelerations (group separation by Kruskal-Wallis test at p=0.05).

When comparing the measurement points, it emerges that the differences between MP1 and MP2 were not statistically significant in field, whereas they were in laboratory. This result could be due to the fact that the tree canopy, differently from the idle running, interferes with the flap oscillations and requires a greater force from the operator, so modifying the transmission of the vibrations through the bar.

Acceleration components

The box plots of the weighted acceleration values for each axis and operating mode are reported in Figure 6. They show that the lowest accelerations were measured along the bar axis (*y* direction) in both operating modes (laboratory and in field). Moreover, during the laboratory tests, carried out in controlled conditions, the highest vibrations were always measured along the *x* axis: they were 2–3 times those measured along the other two axes. On the contrary, during the in field tests, due both to the canopy reaction and the necessity to move and rotate the bar according to the harvesting needs, it was observed a large increase in the *z* component, mainly for B1 and B3 bars.

This implies that, given the influence of canopy and operating mode, laboratory tests are need to characterise materials and machines in standard and controlled conditions, while operator's exposure should be evaluated in field.
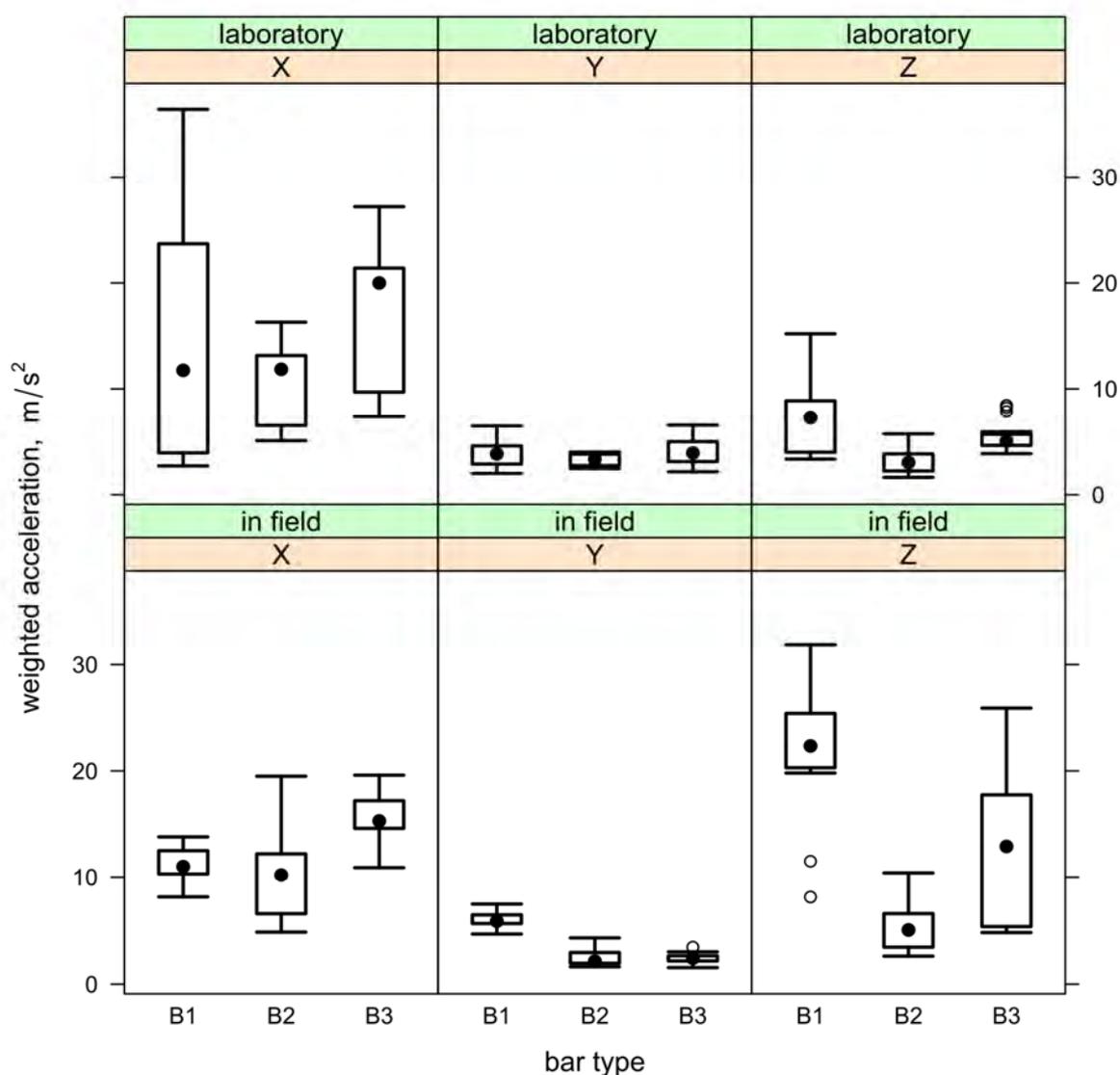

Figure 6. Weighted acceleration components for bars and operating modes.

Conclusions

The study, even if preliminary, allows for the following conclusions, to be integrated by further investigations:

- The measurement procedure proved to be effective in ascertaining the vibration level of the portable harvesters. Global weighted accelerations were quite high for all the harvesters: this means that the vibration level is mainly affected by the kinematic system that activates the harvesting head. Probably this is the key aspect to be investigated to reduce vibrations at the source. Actually, electric systems increase the operator's comfort by reducing weight and noise with respect to mechanic or pneumatic systems.

- Comparisons between laboratory (idle running) and in field tests (harvest in ordinary working conditions) showed that the tree canopy had a negative effect in vibration transmission. Acceleration values, in fact, increased from 16.3 up to 19.6 m/s^2 (from 18.0 to 25.7 m/s^2 for the aluminium low diameter bar). This implies that laboratory tests are need to characterise materials and machines, ensuring standard and controlled conditions and keeping constant all the external factors (operator's influence, operating modes, load parameters), whereas the effective daily operator's exposure should be measured during harvesting tests.

- Carbon fibre ensured a significant reduction in the vibrations transmitted to the hand-arm system with respect to the aluminium: 12.0 m/s^2 vs. 20.1 m/s^2, keeping constant the bar diameter (40 mm). This has also a positive effect on the comfort of the operators as reduce the global weight of the machinery. However this result should be investigate more in depth, as different results could be obtained when using carbon fibre of different features and/or aluminium with different alloy and thickness, so other bars of other manufacturers should be tested to evaluate the effect of the bar material on the vibrations.

- Given the quite high vibration level, operators should take into great consideration not only the harvest capacity of the portable harvesters, but also the health and safety aspects and take all the precautions to reduce vibration exposures.

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The heat stress for workers during vegetable grafting in greenhouses

Marucci A., Pagniello B., Monarca D., Colantoni A., Biondi P., Cecchini M.
University of Tuscia, Dept. DAFNE
Via S.Camillo De Lellis – 01100 Viterbo, ITALY.
Tel 0039 0761357357, fax 0039 0761357453, ergolab@unitus.it

Abstract
The use of grafted plants on resistant genotypes is now widely widespread in the Mediterranean horticulture. Plants with greater resistance to infections by soil-borne pathogens and increased tolerance against abiotic stresses are obtained by the different grafting techniques. The vegetable grafting is carried out in controlled environments, the most used are greenhouses, in order to adjust the main climatic factors that affect the healing: temperature, relative humidity and solar radiation. The values of air temperature recommended in literature for the healing are at least 24÷27°C although some authors indicate higher values, the relative humidity must be close to 95% and shade cloths must be used to reduce the radiation on plants. The total automation of grafting operations is difficult due to no perfect uniformity of the plant but some phases of the grafting can be automated to increase labour productivity. In this context, the presence of the operator cannot be eliminated and he is subject to heat stress beyond make over repetitive tasks. The aim of this study is to assess the heat stress for workers employed in Mediterranean greenhouses for vegetable grafting.

Keywords: microclimate, work hygiene, controlled environments.

Introduction

Vegetable grafting, introduced in Western countries only in the early 90's, is a widespread method in Mediterranean area and it is performed on various horticultural species (watermelon, melon, tomatoes, eggplant, etc...) using mainly local scion cultivars on imported rootstocks (Lee et al, 2010).

The rapid diffusion of this practice is mainly due to the plants' greater tolerance to attack from soil-borne pathogens (Morra and Bilotto, 2006; Blestos et al., 2003; Rivard and Louws, 2008), to their increased vigour due to their larger roots that increases the efficiency of absorption of water and nutrients (Lee and Oda, 2003) and their increased tolerance to abiotic stress such as heat stress, water stress and organic pollutants (Rouphael et al., 2008; Venema et al., 2008; Schwarza et al., 2010).

Some studies shown that this practice can increase the crop yield with good results in quantitative and qualitative (Lee and Oda, 2003; Chung and Lee, 2007) and in addition can minimize the use of chemical fertilizers and synthetic pesticides making vegetable grafting an environmentally friendly practice (Rivard and Louws, 2008).

Statistics related to the yield of the grafted plants indicate that the first manufacturer in Europe is Spain with about 130 million plants grown in 2009, followed by Italy and France with 47 million and 28 million plants grown respectively in 2008 (Lee et al, 2010). Especially in Italy production increased by 89% from 2005 to 2008 (Morra and Bilotto, 2009).

Usually the vegetable grafting is performed in a climate controlled environment such as greenhouses, where you can control the different climatic conditions: air temperature, relative humidity and solar radiation. In these environments the air temperature must not fall below

the values of 24-27°C, the relative humidity must be close to 100% and solar radiation must be reduced by using shade cloths (Leonardi and Romano, 2004). In the healing phase plants must be put into environments with an air temperature of 28-30°C and a relative humidity of 95% (Kubota et al., 2008; Oda, 2002).

Since the nineties robots were introduced to carry out grafting in order to increase production. These robots have a production capacity of 600 grafts/hour but still require the experienced operators.

In Italian horticulture this practice is still carried out manually because of the high cost of the machinery. The manual graftig also enables us to use most of the vegetables which is the opposite of what happens in the fully automated processes where the plants that do not have a homogeneity and compliance to the level required are discarded (Morra and Bilotto, 2009).

From this it follows that the presence of the worker cannot be eliminated and he is subject to some risk factors such as heat stress and repetitive tasks.

Studies on environments with elevated temperatures and humidity show that the cardiovascular system and the thermoregulatory system of workers can be affect (Chad and Brown, 1995). In this condition the aggression, distraction, sweating and tremor of the worker can be increase with adverse effects on productivity but also on the safety of the worker (Zhao et al., 2009) .

A research carried out on risk assessment of heat stress in Mediterranean greenhouses shows that the risk of exposure occurs as early as April even if for a limited number of hours (Cecchini et al., 2010).

It is therefore necessary to analyze these working conditions in the hot season, to assess the impact on the workers' health and identify appropriate technical, organizational and procedural measures to be taken in order to improve staff working conditions.

The risk assessment of thermal stress is evaluated with microclimatic indices (Alfano et al., 1998; Moran et al., 2001; Perez-Alonso et al., 2011; Callejon-Ferre et al., 2011) taken from the safety regulations and that take into account the climatic factors, operators' activities and the type of clothing worn by the workers (Budd, 2008).

The aim of this research was to assess the microclimate risks for workers employed in vegetable grafting in Mediterranean greenhouses in the hot season.

Material and methods

In a farm, located in the north coast of the Lazio Region, climate data were recorded in a greenhouse used for vegetable grafting (tomato, watermelon, melon) in the hot period from April 2011 to October 2011 in order to calculate the main indices used to assess the heat stress (WBGT, PMV and PPD under the law, ESI as alternative to WBGT).

The workers are usually women (figure 1) who work from 8.00 a.m. to 6.00 p.m. with a lunch break.

The measurement system used was the following:

1. multi-acquiring LSI BABUC M instrument with 6 inputs;
2. probes for measuring micro-climatic parameters;
3. support for probes;
4. tripod.

A LSI BABUC M unit (serial number S/N BSA020/V.4.04) with six inputs was used

Figure 1. Manual grafting

Figure 2. Instrument used to measure climatic parameters

for analyzing the environmental parameters which was connected to 4 probes: a psychrometric probe BSU102 (2 x Pt100-1/3DIN) with forced ventilation and a distilled water tank, with a measuring range from -20°C to +60°C, range of humidity measurements from 0% to100%, humidity accuracy (t_a: +15°C to +45°C) equal to 2% used for measuring the air temperature (t_a) and the temperature of the damp bulb (t_w); an anemometric probe with hot wire BSV101, to measure the speed of the air (V_a) with average air speed range from 0 ms^{-1} to 50 ms^{-1} and accuracy (t_a: +10°C to +30°C; V_a: 0 m/s to 1 m/s) 0.04 m/s and acquisition rate every 12 s; a global thermometric probe BST131 in black opaque copper (reflection < 2% ASTM 97-55), measurement range from -10°C to +100°C, sensor: Pt100 with 4 wires, precision 1/3DIN; average diameter of the globe 50 mm, for measuring the average radioactive temperature (t_r); a natural ventilation wet bulb temperature probe BSU121 (S/N AF 711 157) ranging from 0 to +80°C, sensitive element Pt100 DIN-A, in compliance with the ISO 7243 standard used for measuring the partial vapor pressure (pa) (all probes are in compliance with ISO 7726 standards, as declared by the manufacturer).

All the instruments used were calibrated in 2007 at a specialized calibration centre. The measurements were taken in a homogeneous environment where the probes were carrying out a constant and repetitive activity with samples spread out all over the work surface throughout the working hours. The probes were put into position on a tripod at a height of 1.50 m from the ground (figure 2).

The assessment of risk from heat stress was performed using the ISO standards:

-EN ISO 7730:2006 Ergonomics of the thermal environment. Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria;

-EN ISO 27243:1996 Hot environments. Estimation of the heat stress on the working man, based on the WBGT index (wet bulb globe temperature);

-EN ISO 8996:2005 Ergonomics of the thermal environment. Determination of metabolic rate;

-EN ISO 9920:2009 Ergonomics of the thermal environment. Estimation of thermal insulation and water vapour resistance of a clothing ensemble;

-EN ISO 7726:2002 Ergonomics of the thermal environment. Instruments for measuring physical quantities.

The PMV and PPD were determined in the first phase of the study.

The PMV (Predicted Mean Vote) is the average rating from a large sample of people present in the same environment and is a mathematical function (1) that depends on several factors:

$$PMV = f (M, W, I_{cl}, f_{cl}, t_a, t_r, v_{ar}, pa, h_c, t_{cl}) \qquad (1)$$

where:
M is the metabolic rate (W/m^2);
W is the effective mechanical power (W/m^2);
I_{cl} is the clothing insulation (m^2 K /W);
f_{cl} is the clothing surface area factor;
t_a is the air temperature (°C);
t_r is the mean radiant temperature (°C);
v_{ar} is the relative air velocity, in metres per second (m/s);
pa is the water vapour partial pressure (Pa);
h_c is the convective heat transfer coefficient (W /m^2 K);
t_{cl} is the clothing surface temperature (°C).

The different factors listed above were calculated on the basis of climatic data collected in the greenhouse while the metabolism rate (M) and clothing insulation (I_{cl}) of workers have been determined on the basis of current legislation as listed in Table 1.

Table 1. Metabolic rate and clothing insulation applied for workers

Factors	Value	Units	Standard
M	75	W/m^2	ISO 8996
I_{cl}	0.6 (from May to September) 0.75(March, April, October and November) 0.9 (January, February and December)	Clo	ISO 9920

The PMV scale of values is between +3 (very hot) to -3 (very cold), the 0 is the neutrality and the range between -0.5 and 0.5 corresponds to the thermal comfort like given in ISO 7730.

When -2 < PMV <-0.5 and 0.5 < PMV < 2 the thermal environment is moderate while the PMV value less than -2 and greater than +2 the thermal environment is severe.

The PPD is the percentage of thermally dissatisfied people and it is calculated by the function (2):

$$PPD = 100 - 95 \cdot e^{-\left(0.03353 PMV^4 - 0.2179 PMV^2\right)} \qquad (2)$$

In thermal comfort (-0.5 < PMV < 0.5) the PPD is 10% while the thermal environment becomes severe when the PPD is greater than 80%.

To determine heat stress in the months in which the thermal environment is warm the WBGT index was applied. The equations are (3) and (4):

WBGT $= 0.7t_{nw}+0.3t_g$ for internal and external exposition without exposure to sun   (3)

WBGT $=0.7 t_{nw} +0.2 t_g +0.1t_a$ for external condition with exposure to sun   (4)

Where t_{nw} is natural wet-bulb temperature (°C), t_g is globe thermometer temperature (°C) and t_a is dry-bulb temperature (°C).

In this study, where the greenhouse roof is covered with shade cloths, the equation for internal and external exposition without exposure to sun was applied.

In addition the ESI (Environmental Stress Index) (5) was calculated as alternative to the WBGT index:

$$ESI = 0.63t_a - 0.03RH + 0.002SR + 0.0054(t_a \cdot RH) - 0.073 (0.1 + SR^{-1}) \qquad (5)$$

Where t_a is air temperature (°C), RH is relative humidity (%) and SR is solar radiation (W/m^2).

Results

The measured data are processed in order to calculate hourly values of the average day of the month to which microclimatic indices are applied.

The monthly average values of air temperature and relative humidity measured in the greenhouse during the grafting period are reported in figure 3. The maximum air temperature is about 29°C in June and September. The relative humidity measured in the greenhouse is almost always over 60%.
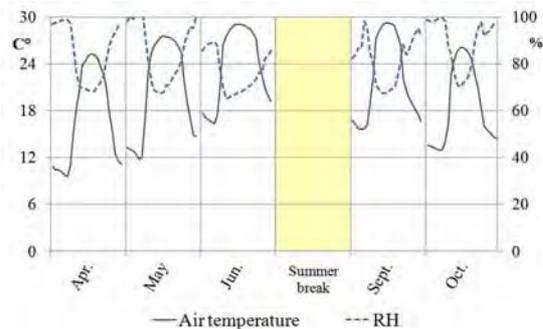

Figure 3. Air temperature and relative humidity in greenhouse.
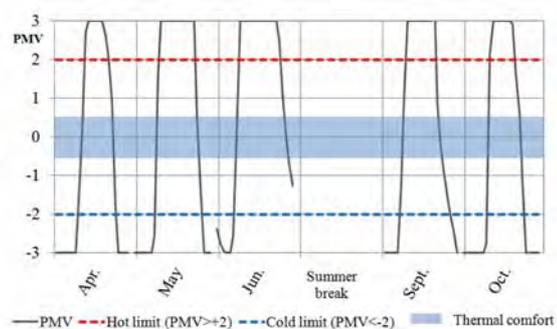

Figure 4. Predicted Mean Vote PMV

The indices calculated on average monthly data collected in the greenhouse are the PMV (figure 4) and PPD, the WBGT and ESI (figure 6).

Figure 4 shows that the PMV is grater than +2 and the environment is hot from April to October, months in which the maximum daily air temperature exceeds 25°C.

For each average day of the month the number of working hours are calculated in different classes of PMV(figure 5).

The PMV classes are: -0.5 < PMV < 0.5 (thermal comfort), -2 < PMV < -0.5 and 0.5 < PMV < 2 (moderate thermal environments), PMV < -2 and PMV > +2 (severe thermal environments).

The hours of exceeding of +2 (hot environment) varies from about eight hours in April and October (from 10.00 to 18.00) to a maximum of ten hours in May and June (from 8.00 to 18.00), for the entire working time.

In order to reduce this risk of heat stress we can intervene on factors that characterize the PMV such as the clothing insulation (I_{cl}) or air velocity (v_{ar}). In such environments however a reduction of clothing insulation from 0.6 to 0.3 at least, as any changes in relative humidity do not allow to reduce significantly the PMV.
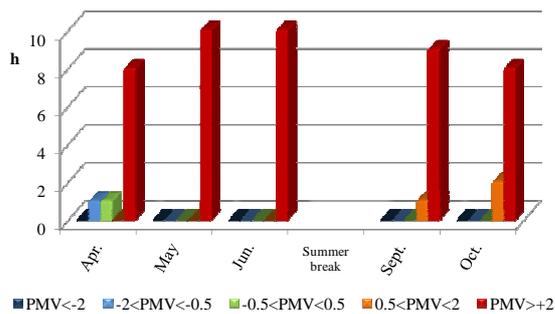

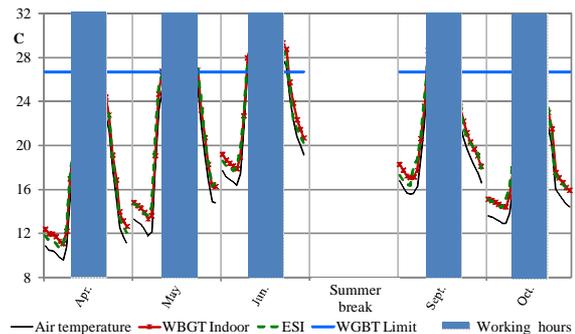**Figure 5. Number of working hours for PMV classes**

Figure 6. Temperature, WBGT and ESI comparison

During the months with the risk of heat stress (figure 6), the WBGT index application shows that the threshold of 26.7°C for acclimated individuals is overcome since April.

This limit is exceeded in April at 12.00 o'clock and for about an hour, in May and June in all working hours, in September and October respectively for nine and seven working hours. The ESI index shows a similar trend to the WBGT. The ESI exceeds the threshold of 26.7°C during working hours in May, June and September.

The PMV, WBGT and ESI calculation, for the average day of the month, shows that the workers employed in vegetable grafting in Mediterranean greenhouses are exposed to heat stress risk.

The air temperature is the parameter that affects the PMV and its decreasing of 5°C would reduce the value of the PMV by 75%. Similar effects would be on WBGT for which an air temperature decrease of 4°C would obtain values of less than 26.7°C (limit acclimated) even during the hottest hours of the day.

The natural ventilation is not sufficient to achieve these reductions in temperature and it is necessary using specific cooling systems for greenhouses in accordance with the requirements of the plants. Alternatively, you can reduce heat stress decreasing the exposure time and increasing the number of pauses that must be carried out in areas with favorable climatic conditions.

Conclusions

The research carried out on the thermal discomfort of workers employed in vegetable grafting in Mediterranean greenhouses, trought PMV index and WBGT index, showed that the workers are subject to significant risks of heat stress despite the widespread use of shade cloths on the roofing of the greenhouse. The months in which risk of heat stress was higher were April, May, June, September and October.

The results show that in the greenhouses the average value of thermal sensation is closely related to the climatic parameters, particularly the indoor air temperature.

The use of these indices results fundamental to assess the possible exposure to risks of heat stress and in addition is a valuable help in the selection of technical and procedural decisions to be taken for working conditions improvement.

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Prediction of whole body vibration through a multibody model of a tractor seat

Mattetti M. [(1)], Molari G. [(1)], Guarnieri A. [(1)]
[(1)] *University of Bologna. Dept. DEIAGRA*
Viale Fanin, 50 – 40127 Bologna, ITALY.
Tel 0039 0512096191, Fax 0039 0512096178
Email corresponding Author: giovanni.molari@unibo.it

Keywords: safety, acceleration, damper

Objectives

The vibrations transmitted to the driver induce permanent and temporary damage to the body. The agricultural tractors are characterized by a vibration level that can be higher than the exposition level fixed by the 2002/44/EC, in some conditions. The vibrations on tractors have a high intensity and a low frequency with the consequence of difficulties in the project of suspension systems able to reduce the intensity of the level. The numerous innovative suspension systems studied in the recent years, as the active and semi-active seats, did not introduce significant improvements.

In the present paper a multibody model of a seat suspension system to an agricultural tractor with a 170 kW power, has been defined with the goal to predict the seat acceleration and evaluate the reduction of the vibration level transmitted to the driver.

Methods

The tractor has been fitted with transducers able to measure the roll, the pitch and the acceleration level on the three axles, also the acceleration on the seat has been measured. During the driving on the road the vibration levels have been measured in different conditions. The geometry of the seat has been defined and a multibody model has been designed using an analytical model of the air spring and the oil damper. The model was defined by five different components: the seatbase, two elements of the scissor linkage, the seat top, the ballast (figure 1). The components were defined as rigid and the joints as ideal. The ballast was added to represent the mass of the driver and was fixed at 75% of the driver's mass. The damper was connected between the two elements of the scissor linkage and was defined with a linear equation, while the air spring was located between the seatbase and an element of the scissor linkage and defined by an equivalent not linear mechanical model (Oda & Nishimura, 1970). The model was excited applying a displacement time history to the seatbase derived through the numerical integration of the measured accelerations. The non linear parameters of the suspension were defined by an optimisation routine (Miller, 2000), with an object function represented by the minimisation of the sum square residual of the Power Spectrum Density (PSD) between the vertical acceleration measured on the seat and that calculated from the model in function of the damper and air spring parameters.
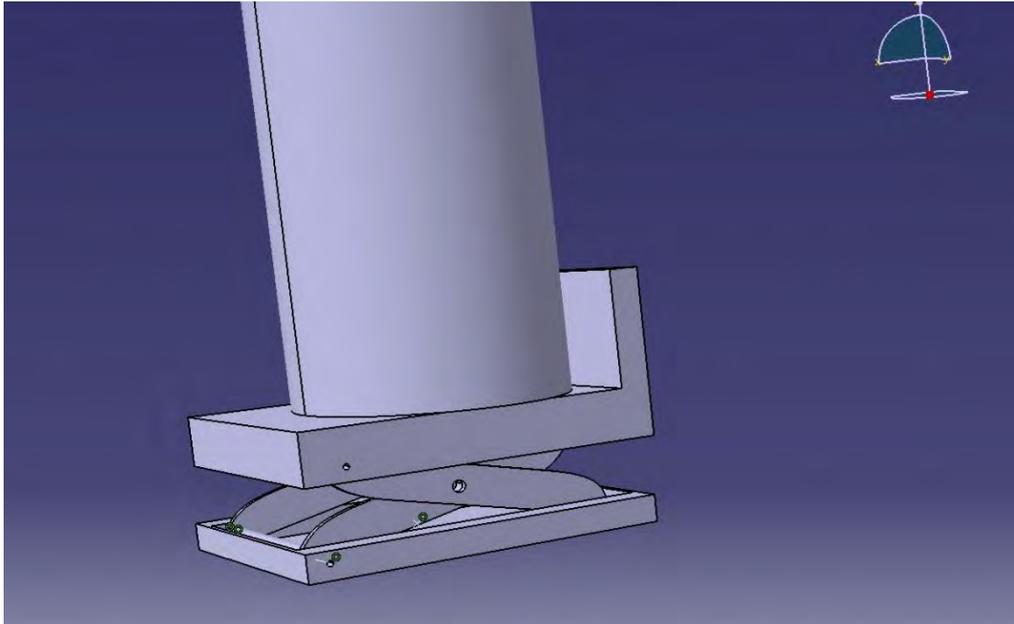
Figure 1: Multibody model developed to predict the vertical accelerations

Results

The PSD of the simulated and measured vertical accelerations are reported in figure 2. The peaks with a frequency between 1.5 and 2.5 Hz are reproduced faithfully. However the peaks lower than 1 Hz were not reproduced faithfully due to the reduced time of the measures as the peaks with a high frequency due to the non linearity of the system caused by the bushing elements and the driver movements. In any case the peaks with a frequency higher than 3 Hz can be neglected because they are lower than the maximum value of the PSD of two orders of magnitude.
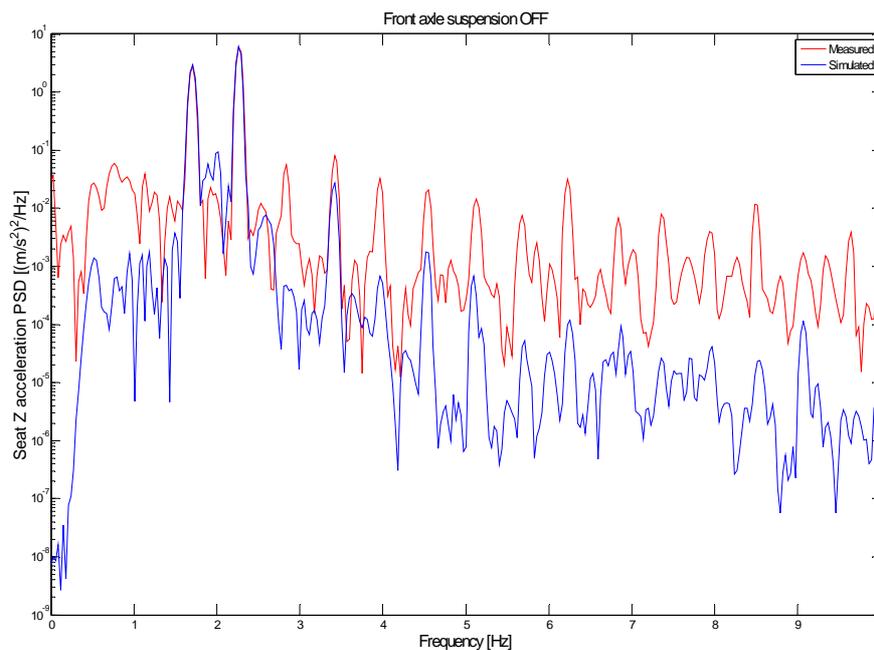

Figure 2: Simulated and measured PSD accelerations

Conclusion

This model can be easily used by the tractor designer and integrated in the multibody models of the whole tractor to optimize the behavior of the seat suspension. Finally, the model could allow to design new types of dampers able to reduce the whole body vibrations.

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Risk due to noise during the olive harvest: the electrical and pneumatic harvesters

Nardini G.[(1) *], Lori V.[(1)], Paroncini M.[(1)], Candido D.[(2)], Della Pasqua M.[(2)]
[(1)] *DIISM, Dipartimento di Ingegneria Industriale e Scienze Matematiche*
Via Brecce Bianche -60100 Ancona, ITALY
[(2)] *INAIL Direzione Regionale Marche*
Via Piave, 25 -60100 Ancona, ITALY
corresponding author: Tel 0039 071 2204876, Fax 0039 071 2204770, g.nardini@univpm.it

Abstract

The review of trends in farm practices and machinery development suggests that noise problems are still prevalent in agricultural situations. The aim of this study is to assess the noise exposure for workers during olive harvest in Azienda Agraria Didattico-Sperimentale of Università Politecnica delle Marche. A monitoring of noise levels is conducted in some days of the years 2010-2011.

Noise samplings were carried out on electric and pneumatic harvesters. For sound pressure levels measurements an integrating-averaging sound-level meter, B&K2250 type, was used and the measurement procedure was set up in accordance with ISO 9612:2011. The tests have been carried out during the regular working activity with all the shakers operated by the same worker expert in the use of this machines.

The results allowed to evaluate noise exposure during the olive harvest. Every machine has been analyzed to establish the level of noise produced according to the laws in force. With the collected data it was possible to establish noise exposure for every instrument. The measured sound pressure levels ($L_{p,A,eq,T}$) for all the harvesters under test are included between 70,2 db(A) and 83,5 dB(A). Noise pressure levels are higher for pneumatic type harvesters compare to electric type harvesters. The highest C-weighted peak sound pressure level ($L_{p,Cpeak}$) measured is equal to 109,8 dB(C), widely below the limits value. The daily noise exposure level determined respects the limitations in D.Lgs.81/2008 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise).

Keywords: agriculture, noise exposure

Introduction

Occupational exposure to noise is one of the most significant health risk for workers being able to determine irreversible hearing damages. 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 auditory system, such as the damage of the Corti's cells, and can involve psychosomatic diseases (Cosa, 1990). The current regulation in the European Union regarding protection of workers is based on the Directive 2003/10/CE. In Italy the safety act D. Lgs. 9 April 2008, n°81 and the following reviews are in force. This directive and the national decree state a set of minimum disposals with the aim of protecting workers from the risks for their safety and health, caused or that may be caused by the noise exposure.

The review of trends in farm practices and machinery development suggests that noise problems are still prevalent in agricultural stages, even though there has been a steady increase in the availability of materials and equipment for noise control over recent years.

In parallel to the technology development the use of machines in mechanization processes of agricultural production resulted in an increase of potential noise sources in the farm.

In recent years the use of hand-held vibrating type olive harvesters has become very common in small farms due to the high cost and time consumption of manpower in hand harvesting of olive which made mechanical harvesting convenient. However, hand-held olive harvest machines, such as pneumatic or electric harvester, can represent sources of health risk for workers in terms of noise exposure. Blandini G. has compared noise and vibrations produced by hand-held pneumatic type harvesters (Blandini G. et al., 1997). Biocca M. Has compared the noise levels of five different electrical powered machineries and one model powered by a two stroke engine; the study highlighted that noise levels of four of the five electric machines remained under the minimum limits specified in the European Directive 2003/10/CE while ear protection and/or other risk limiting procedures were required for the use of the two strokes engine model (Biocca et al., 2008). Bulent S. Has measured and evaluated the characteristics of five different electrical flap type olive harvesters pointing out that noise values at operator's ear were below risk level compared with the international standard recommendations (Bulent S. et al., 2010).

The aim of this study is to assess the noise exposure for workers during the olive harvest with hand-held type olive harvesters in Azienda Agraria Didattico-Sperimentale of Università Politecnica delle Marche. The Azienda Agraria performs the olive harvest between October and December using an electrical handheld vibrating machine. With the aim of compare noise levels of electric and pneumatic olive harvesters eight different commercial models were tested. The models tested represent a sample of machines used in small farms for the olive harvest. With the collected data it was possible to evaluate the noise exposure for every instrument. The measured data respect the D.Lgs.81/2008 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise). Measurements were carried out by using an integrating-averaging sound level meter, B&K 2250 type, during the regular working activity with all the shakers operated by the same worker expert in the use of this machines. The measurement procedure was set up in accordance with the method of UNI EN ISO 9612:2011. Microphone have been held at a distance of 0,1 m from the entrance of the external ear canal at the side of most exposed ear.

Material and Methods

All the noise sampling were performed in the years 2010 and 2011 during olive harvesting. Different campaign of measurements were carried out in the same farm during the regular working activity. Measurements have been performed on electric and pneumatic harvesters: five electric harvesters (A1 – A5), powered by 12 V d.c. motors, and three pneumatic harvesters (B1 – B3) operated by the compressed air produced by engine-driven compressors were tested.

The electric harvesters tested have different harvesting heads and bars. Harvesters A1, A2, A5 have similar harvesting capacity; harvesters A3 and A4 have a smaller harvesting capacity. The pneumatic harvesters tested have different heads but the same bar. Harvester capacity of this machines (B1, B2, B3) are comparable. The main characteristics declared by the manufacturers of the harvesters analyzed in the study are depicted in Table 1.

Table 1 Technical characteristics of the tested harvesters declared by the manufacturers

Harvester	Description	Weight (kg)	Bar lenght (m)	Working cycle $(60\ sec^{-1})$	Bar material	Rod/Rakes Material
B 1 Pneumatic	Low working pressure (max 6 bar) Short stroke system which reduces the rake opening in order to increase beat rate. Diapason-shaped rake teeth.	2,7	2,0	1800	Aluminium	Techno polymere
B 2 Pneumatic	Working pressure 4/5 bar (max 7 bar) The rakes move sideward, each on opposite side and crossing each other. 0,2 m long teeth with rounded shape and very flexible	2,7	2,0	1600	Aluminium	Techno polymere
B 3 Pneumatic	Max working pressure 7 bar Special rakes structure 0,2 m long teeth with rounded shape and very flexible	2,7	2,0	1600	Aluminium	Techno polymere
A 1 Electric	350 W powered unit placed on the handle of the tool. The rakes move sideward	3,2	1,2-2,0	800	Carbon fiber	Carbon fiber
A 2 Electric	12 V brushless motor positioned in the lower part of the tool. Double movement of the rakes. Double length of the teethes	3,6	1,8-2,7	1080-1150	Aluminium	Thermo plastic resin
A 3 Electric	12 V power unit positioned on the handle of the tool. Oscillating motion of the teethes	2,2	2,0	750	Thermo plastic	Thermo plastic resin
A 4 Electric	12 V power unit positioned at the top of the tool. Carbon fiber rods with anti-breaking system	1,65	1,7-3,1	N.D.	Aluminium	Carbon fiber
A 5 Electric	12 V power unit positioned at the top of the tool.	2,7	2,0-3,0	1150-1250	Aluminium	Thermo plastic resins

Measurements were carried out by using an integrating-averaging sound level meter, B&K 2250 type, meeting the requirements for class 1 compliance of IEC61672-1:2002 and IEC61672-3:2006. Before and after each series of measurements a field calibration with appropriate adjustment has been performed using a sound calibrator, B&K 4231 type, meeting the requirements of IEC 60942:2003, class 1. The integrating-averaging sound level meter and the sound calibrator had a valid periodic verification report (not exceed 2 years).

The tests have been carried out during the regular working activity with all the shakers operated by the same worker expert in the use of this machines. During the test the telescopic bars of the shakers have been setted at 2 m length.

The measurement procedure was set up in accordance with the method of UNI EN ISO 9612:2011. Microphone have been held at a distance of 0,1 m from the entrance of the external ear canal. Three measurements at least for each position in right and left worker's ear and for each olive-harvester under test were performed. It has been set a measurement time of five minutes after a preliminary analysis of the noise emitted by olive-harvesters during the harvesting task. Weather and climatic condition in measurement area have been monitored during each series of measurements. Measurements with wind speed up to 4 ms^{-1} have been avoided. Airflow-induced noise has been minimized by using a windscreen of 60 mm diameter on the microphone in accordance with Technical Standards. Errors due to mechanical impacts on the sound level meter have been avoided by ensuring that both microphone and windscreen have not been touched or hit by anything.

A-weighted and C-weighted equivalent continuous sound pressure level ($L_{p,A,eq,T}$, $L_{p,C,eq,T}$), C-weighted peak sound pressure level ($L_{p,Cpeak}$) and one-third octave bands sound pressure level RMS spectrum has been simultaneously recorded for each measurement.

The A-weighted daily noise exposure level, $L_{EX,8h}$ (1) for workers involved in olive harvesting was defined using the information provided by an appropriate work analysis, selecting a task-based measurement strategy .

$$L_{EX,8h} = 10 \lg \left(\sum_{m=1}^{M} \frac{\overline{T_m}}{T_o} 10^{0,1 \times L_{p,A,eqT,m}} \right) dBA \qquad (1)$$

Where: $L_{p,a,eqT,m}$ is the A-weighed equivalent continuous sound pressure level from task m, $\overline{T_m}$ is the arithmetic average duration of task m, T_0 is the reference duration ($T_0 = 8h$) and M is the total number of tasks m contributing to the daily noise exposure level.

Results

A-weighted equivalent continuous sound pressure level ($L_{p,A,eq,T}$), C-weighted equivalent continuous sound pressure level ($L_{p,C,eq,T}$) and C-weighted peak sound pressure level ($L_{p,Cpeak}$) measured at the side of most exposed ear for the eight olive harvesters under test are given in Figure 1 respectively along with the standard deviation values.

The measured sound pressure levels at each one third octave band center frequencies for all harvesters are depicted in average in Figure 2.
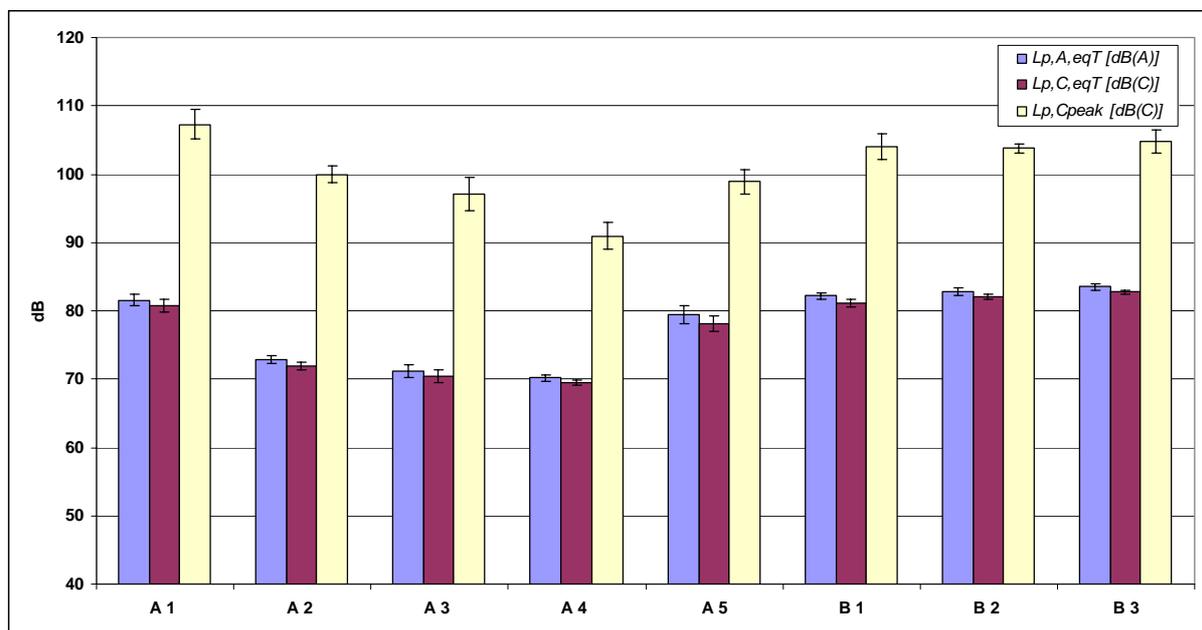

Figure 1 Sound pressure level ($L_{p,A,eq,T}$, $L_{p,C,eq,T}$, $L_{p,Cpeak}$) of olive harvesters under test

The measured A-weighted equivalent continuous sound pressure levels ($L_{p,A,eq,T}$) for all the harvesters under test are included between 70,2 db(A) and 83,5 dB(A). Noise pressure levels are higher for pneumatic type harvesters (B1 - B3) compare to electric type harvesters (A1 – A5).

Noise levels measured for the three pneumatic shakers under test were very similar, ranging from 82,2 dB(A) for B1 and 83,5 dB(A) for B3. Sound pressure levels measured for the electrical shakers were very different. Harvesters A3 and A4 showed the lowest emission levels but are also characterized by lower harvesting capacity than the others. Harvesters A1, A2, A5 comparable with regard to the harvesting capacity with pneumatic harvesters showed emission levels between 72,9 dB(A) (Harvester A2) and 81,5 dB(A) (Harvester A1). Harvester A2, which showed the lower sound pressure level, is equipped with a power unit with an automatic sensor. The sensor slows the rakes down when they are out of the branches and restores their harvesting speed when they touch the foliage. This solution seem to be useful to limit noise emissions during the harvesting task.

The highest C-weighted peak sound pressure level ($L_{p,Cpeak}$) measured is equal to 109,8 dB (C) (Harvester A1), widely below the limits value.
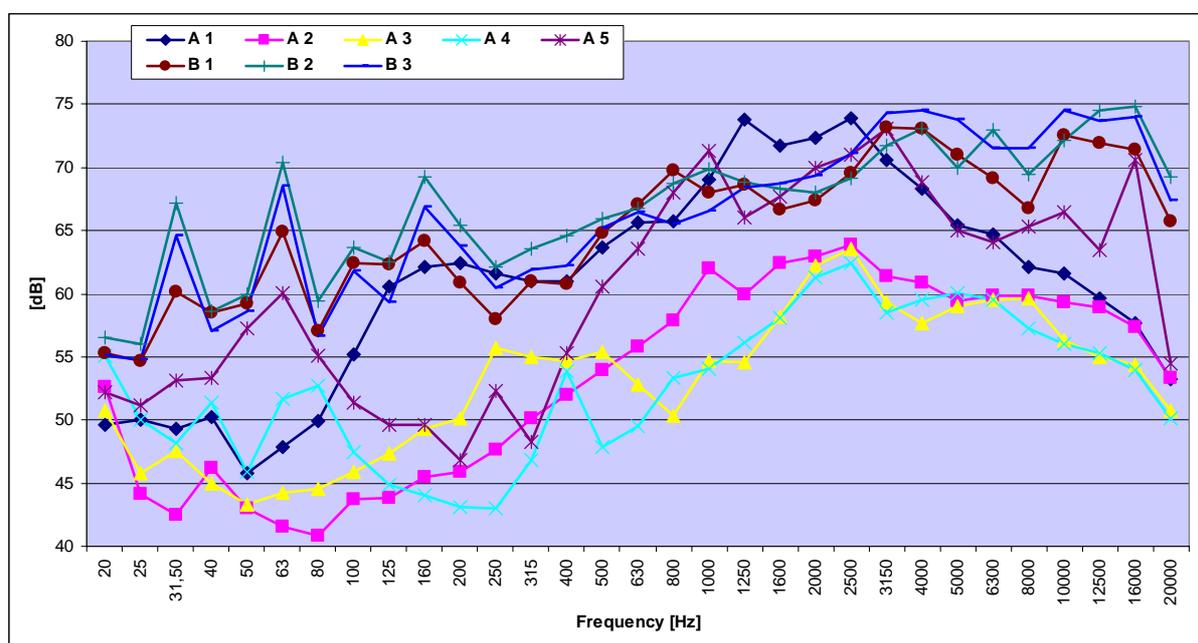

Figure 2 One-third octave bands sound pressure level RMS spectrum measured

The frequency spectrum curves of the noise showed similar trends for the three pneumatic harvesters (B1 – B3). The spectra showed some tonal components at low frequency the first of which at 31 Hz. This tonal component correspond to the beat rate of the rakes of 1600-1800 movements per minute. The frequency spectrum curves also showed appreciable sound pressure level for all the frequencies but especially on medium-high frequencies (2000-16000 Hz). Human auditory system is most sensitive between 2000 Hz and 5000 Hz (ISO 226:2003) where pneumatic harvesters under test showed higher sound pressure level than the electric harvesters.

The five electric harvesters under test (A1 – A5) showed different sound pressure level spectrums but with lower sound pressure levels than the pneumatic shakers especially at low and high frequencies. Harvester A5 showed higher emission levels between 1000 Hz and 2000 Hz than sound pressure levels measured for the pneumatic shakers under test.

The daily noise exposure level, $L_{EX,8h}$ for workers involved in olive harvesting in Azienda Agraria Didattico-Sperimentale of Università Politecnica delle Marche was

determined for the Harvester A1, the electric harvester owned by the Farm. The work analysis provided information to defined the workers nominal day. The nominal day of each worker consist of sequence of four different tasks: harvesting task with handheld olive harvester (3 h), displacement of the collection nets (3 h), collecting of the olive from the networks (1,5 h) and work planning/break (0,5 h). All workers perform the same work and therefore can be regarded as one homogenous noise exposure group.

Noise contribution from the olive collecting from the net and from work planning/break is negligible to the noise exposure level. These tasks are accomplished in the absence of noise sources. The noise measurements done in this working period showed an A-weighted equivalent continuous sound pressure level ($L_{p,A,eqT}$) minor than 60 dB(A). The noise level during the displacement of the collection nets was determined with three measurement of 5 min. This task is performed in the area affected by the noise generated by the harvester in use. Tasks, time spend for each task and measurement results are shown in Table 2.

Table 2 Worker's nominal day and noise levels measured

Task	Duration h	Noise level $L_{p,A,eqT}$ dB(A)		
		Meas. 1	Meas. 2	Meas. 3
harvesting task	3	80,6	82,2	81,8
displacement of the net	3	72,1	74,2	71,6
collecting of the olive from the net, breaks	2	60	60	60

The expanded uncertainty was determined in accordance with ISO 9612. The standard uncertainty due to sampling noise levels is calculated; the standard uncertainty due to instrumentation was fixed to 0,7 dB, the standard uncertainty due to the microphone position was fixed to 1 dB; the uncertainty in duration was excluded.

During the olive harvest, the workers are subjected to a daily A-weighted noise exposure level (1) of 77,9 dB with an associated expanded uncertainty for a one side coverage of 95% (K=1,65) of 2,1 dB.

Conclusion

The present study has focused on the evaluation of noise exposure for workers during the olive harvest in Azienda Agraria Didattico-Sperimentale of Università Politecnica delle Marche. Eight different commercial models were tested with the aim of compare the noise levels of electric and pneumatic olive harvesters Eight different commercial models were tested. The results showed that A-weighted sound pressure levels ($L_{p,A,eq,T}$) measured for all the harvesters under test are included between 69 db(A) and 83,5 dB(A). The highest C-weighted peak sound pressure level ($L_{p,Cpeak}$) measured is equal to 109,8 dB (C), widely below the limits value.

Noise pressure level are higher for pneumatic type harvesters compare to electric type harvesters. Noise levels measured for the three pneumatic shakers under test ranged from 82,2 dB(A) and 83,5 dB(A). Pneumatic machines showed similar trends of the frequency spectrum curves with some tonal components at low frequency, corresponding to the beat rate of the rakes, with appreciable sound pressure level for all the frequencies but especially on medium-high frequencies (2000-16000 Hz). Noise levels measured for the electrical shakers were very different, ranging from 70,2 dB(A) and 81,5 dB(A) but with four of the five machines were

under 80 dB(A). One of the electrical machines is equipped with a power unit with an automatic sensor which slows the rakes down when they are out of the branches and restores their harvesting speed when they touch the foliage. This solution seem to be useful to limit noise emissions during the harvesting task.

The daily noise exposure level, $L_{EX,8h}$ for workers involved in olive harvesting in Azienda Agraria Didattico-Sperimentale of Università Politecnica delle Marche, determined for the electric harvester owned by the Farm, showed respect to the limitations in D.Lgs.81/2008 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise).

In the future new measurement sessions will be conducted with the aim of further validate the data collected and identify the influence of each of the technical characteristic of the harvesters on the sound pressure levels emitted. The aim of the research will be to study the reduction of the noise levels on an olive harvester type and define possible interventions with low technical and economic impacts to be made to the harvester model examined for the reduction of the noise.

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Risk assessment due to transmission of vibrations from olive electrical and pneumatic harvesters to the Hand-Arm System (HAV): definition and evaluation of levels and exposure time

Nardini G.[(1) *], Lori V.[(1)], Paroncini M.[(1)], Candido D.[(2)], Della Pasqua M.[(2)]

[(1)] *DIISM, Dipartimento di Ingegneria Industriale e Scienze Matematiche, Via Brecce Bianche -60100 Ancona, ITALY*

[(2)] *INAIL Direzione Regionale Marche, Via Piave, 25 -60100 Ancona, ITALY*

corresponding author: Tel 0039 071 2204876, Fax 0039 071 2204770, g.nardini@univpm.it

Abstract

The paper is focused on exposure to vibration during the olive harvest for farmers of Azienda Agraria of Università Politecnica of Marche to highlight the importance of the exposure to vibrations transmitted to the hand-arm system in agriculture and its consequences on human health. To assess the exposure to mechanical vibration transmitted to operators during the olive harvest, measurements were done using a vibration measuring equipment during the regular working activity. The vibration samplings were carried out on electric and pneumatic harvesters. The measured data were compared with the prevention values for the safety requirements fixed by the normative. The analysis of the results shows that the electric harvesters transmit vibrations equivalent and in some cases higher than ones provided by the pneumatic harvesters. The paper, evaluating the risk to the hand-arm system due to vibrations, give an overview of the exposure of workers to the risks arising from vibrations to which operators are exposed when using olive harvesters.

Keywords: vibrations exposure, agriculture, health and safety

Introduction

Every day farmers are exposed to health and safety risks, due to work environment and the machineries they use. Some of these risks, like vibrations, are underestimated by workers as well since they do not represent an immediate damage for the health. Indeed, disease symptoms can appear several years afterwards. In fact the frequent use of vibrating hand-held tools can result in various chronic diseases. Technical literature presents so many studies and researches on transmission of vibrations to the hand-arm system (HAV). Nataletti *et al.* 2008 presented the Italian vibration database for risk assessment. Chetter *et al.* 1998 investigated the effects of hand arm vibrations sindrome. Dewangan and Tewari 2008 studied the characteristics of vibrations transmission in the hand–arm system and subjective response during field operation of a hand tractor.

Aldien *et al.* 2006 investigated the influence of hand forces and handle size on power absorption of the human hand–arm exposed to z_h-axis vibration, Bustrom 1997 investigated the influence of biodynamic factors on the mechanical impedance of the hand and arm. Pascuzzi *et al.* 2009 studied workers' exposures to vibrations produced by portable shakers. Monarca *et al.* 2008 studied the transmissions of vibrations from portable agricultural machinery to the Hand-Arm System (HAV), Cerruto *et al.* 2010 investigated the vibrations produced by electric shakers for olive harvesting.

The aim of this research is to give a contribution to vibrations risk assessment in particular for the hand-arm system at which operators are exposed during the working phases deriving from the utilization of electric and pneumatic harvesters. For this reason the hand-

arm vibrations due to the electric and pneumatic harvesters were investigated in the Azienda Agraria of the Università Politecnica of Marche during the regular working activity. The assessment was done through direct measurements, using the adequate equipment to record the vibration metric levels of each analyzed harvesters. The electric model of the harvester utilized in the Azienda Agraria and other electric and pneumatic models were measured to give an overview of the vibrations exposure of workers to which operators are exposed during the olive harvest.

The procedure was carried out following all legal provisions and the most recent ISO standards (UNI EN ISO 5349-1:2004, UNI EN ISO 5349-2:2004). The measured data were compared with the prevention values for the safety requirements fixed by the normative (Decreto Legislativo 81 del 2008.).

Methods and Materials

The experimental tests were carried out in an Azienda Agraria's olives trees field of Università Politecnica of Marche. The Azienda Agraria was created on 1993 to conduct research and development field projects on behalf of the Università Politecnica of Marche.

Landscape management and maintenance of the entire University campuses was also included in the activities. The Azienda Agraria leases 75 ha in Agugliano, ruled as integrated production, and 73 ha in Gallignano, managed as organic production, botanical garden and forest. In the Azienda Agraria only an electric model of the harvester was utilized by two operators in turn so other electric and pneumatic models were measured in same tests to give an overview of the vibrations exposure of workers to which operators are exposed during the olive harvest. To smooth the influence of external factors the harvesters were used by the same operator, expert in the use of this typology of tools due to his job activity during the olives harvesting campaigns. The tests were carried out during some days of the olive harvest in the year 2010 and in the year 2011. Table 1 shows the technical characteristics provided by manufacturers of the electric model utilized by Azienda Agraria (A1) and of other tested models.

Table 1. Technical characteristics of the tested olive harvesters

Model	Engine	Description
A1	Electric	It has the carbon fiber comb with a frequency of vibration of 800 strokes/minutes. The engine is placed on bottom of the bar near the handgrip. The head is inclinable in two positions and it has an harvest system at lateral oscillations. It is powered by a battery backpack. It has a weigh of 3 kg.
A2	Electric	Harvesting system with double motion: while the combs oscillate, with a movement from right to left, at the same time the individual prongs move in the opposite rotary direction, creating an ellipse of 8x7 cm. The two combs move performing 1150 cycles for minute. It weighs 1,22 kg. It has a velocity of 1080-1150 rpm
A3	Electric	It reaches dense areas of any tree, with a productivity up to 120 kg/hour. It is powered by 12 Volt normal battery (of a car or of a tractor). It has a special frequency rectifier that, autonomously and in an automatic manner, controls and sets the speed and the power according the efforts done by the machine. The electrical motor is inside the handle of the machine. It has a weigh of 2,2 Kg.

A4	Electric	It has a harvesting capacity 80-120 Kg/h, the weight of the harvester is 0,75 Kg, while the weight of the telescopic bar is 0,90 Kg. Its current consumption is 3-5 Ah, the supply voltage is 12 Volt, the charging time of the battery backpack is 4 hours and the charging time of the battery-holder bag is 2 hours
A5	Electric	It has a frequency of vibration of 1150 strokes/minutes, the supply voltage is 12 Volt, a current consumption of 6 Ah, it has a weigh of 2,7 Kg
B1	Pneumatic	It has a system "short stroke" with a frequency of vibration of 1800 strokes/minutes. The combs have the prongs with the tested profile "tuning fork". The weight of the harvester is 1,00 Kg, while the weight of the telescopic bar is 1,74 Kg.
B2	Pneumatic	The combs move sideways, the one opposite to another, crossing and thus increasing the radius of action. The frequency of vibration of 1600 strokes/minutes. The weight of the harvester is 0,98 Kg, while the weight of the telescopic bar is 1,74 Kg
B3	Pneumatic	It has the prongs more tapered than other pneumatic models. The frequency of vibration of 1600 strokes/minutes. The weight of the harvester is 1,00 Kg, while the weight of the telescopic bar is 1,74 Kg

The A1 model was equipped with a carbon bar, the A3 with a plastic bar and all other models with the alluminum bars. For the tests all bars had the same length of 2 m.
The measurements were carried out respecting the indications contained in the provisions UNI EN ISO 5349-2.
The instruments used were a 4 channel vibration meter (Maestro), a vibration transducer (triaxial accelerometer) Brand PCB Piezotronics Model 356B21 and a calibrator AT01.

Table 2. Technical characteristics of the vibration meter utilized for the tests

Specifications	
Precision	Class 1, ISO 8041 standard
Triaxial accelerometer	
Sensitivity	10mV/g
Frequency response at 10%	0,5 to 6000 Hz
Maximum value	500g
Weight	10,5g (15,9g with the hand-arm piece)
Monoaxial accelerometer	
Sensitivity	10mV/g
Low cut-off frequency at 10%	0,1 Hz
Maximum value	500g
Weight	18g
Measurements ranges	
3 meas.ranges for an 10mV/g accelerometer	0-5000m/s^2, 0-1000m/s^2, 0-100 m/s^2
Linearity domain for peak acceleration	From 2 to 5000m/s^2
Linearity domain for effective acceleration	From 0,2 to 600m/s^2
Possibility to connect accelerometers of different	100mV/g (range 0-500m/s^2, 0-100m/s^2, 0-10 m/s^2

sensivities	
Measurement stabilisation time	35s
Reference range	0–5000m/s^2

Hand arm vibration (calculation and display of the following values):	
Peak and effective accelerations on 3 axes band pass filtered (4 axis if using Aux)	6,3-1250Hz
Weighted effective accelerations on 3 axes ((4 axis if using Aux)	According to wh hand arm filters of the standard ISO 8041/A1:1998
Calculation and display of the following values: multiaxial equivalent acceleration on the weighted channel according to the formula:	$A_{wtot} = (a_{wx}^2 + a_{wy}^2 + a_{wz}^2)^{1/2}$

Basic vibration meter	
Peak and effective accelerations	Band pass filtered 0,4-1000Hz or 10-1000Hz

The measures were performed by fixing the accelerometer in two points of the bars of electric and pneumatic harvesters in ordinary working conditions, in particular in the first tests the accelerometer was fixed in the bottom of the bar near the hand of operator (control hand) and in the second tests in the middle of the bar near the other hand of the operator (auxiliary hand). The utilized accelerometer was firmly fixed on the handle of the harvester, close to the hand of the operator, but not affecting the normal course of action. To fix the accelerometers on the harvester, specific adaptor with a plastic band was utilized; while the accelerometer cables, in order to avoid distortions in the measured signal or eventual damages, was fixed near the transducer with adhesive tape. These measurements were carried out for every harvester model during the regular working activity.

Particular attention was used during the fixing process of the accelerometers on the auxiliary and command handles, in order to have each axis oriented in the directions imposed by the provisions UNI EN ISO 5349-1 (basicentric coordinate system).

The equivalent accelerations weighed up in frequency on the single axis (aw_x, aw_y, aw_z) and total (A_{wtot},), acquired simultaneously, were measured during working load that is the real dynamic behavior of the harvesters. The measurement time was 300 s. The tests for every harvester models were repeated three times. To make the measurements repeatable, it was necessary to equalize the maintenance conditions of the instruments under test. Before each test series and at the end of the series a calibration of the measurements instruments was carried out. Comparisons among different harvesters were carried out in standard conditions, keeping constant all external factors (operator's influence, operating modes, load parameters).

To assess the vibrations exposure level transmitted to the hand-arm system the value of daily exposure standardised to an eight hour reference period A(8) (m/s^2) for each olive harvesters was determined, estimated on the base of the root of the sum of the squares (A_{wtot}) of the root mean square value of the frequency-weighted accelerations, calculated on the three orthogonal axes x, y, z, in agreement with the ISO 5349 – 1. The A(8) values were calculated through the following formula:

$$A(8) = A_{wtot} (T/8)^{1/2} \qquad\qquad (1)$$

$$A_{wtot} = (a_{wx}^2 + a_{wy}^2 + a_{wz}^2)^{1/2} \qquad\qquad (2)$$

where:

T is the total daily vibration exposure (hours);
a_{wx} aw_y aw_z are the values of frequency-weighted acceleration (m/s^2) on the *x*, *y*, *z* axes.

However, since it was noticed that in the Azienda Agraria only two operators worked using the olive harvester in total for three hours for day during the olive harvest in their regular working day, it was considered a total vibrations exposure time of three hours (T = 3 hours) for each worker. Thus, in order to test a more realistic level of exposure for the operators, the respective A(8) values referred to 3 hours of exposure were calculated.

The A(8) values were compared with the *Daily Exposure Action Value* of 2,5 m/s^2 and the *Daily Exposure Limit Value* of 5,0 m/s^2 established by the EU 2002/44/EC directive, implemented in Italy with the government decree 187/2005.

All acceleration data were compare to analyse the differences related to different olive harvesters under test and they were compared with the prevention values for the safety requirements fixed by the normative to make the employers able to organize adequate work schemes, respecting the health of the workers.

Results

The vibration samplings were carried out on electric and pneumatic harvesters.

The values a_{wx}, a_{wy} and a_{wz} were measured, according to the previsions contained in UNI EN ISO 53491, during the three repetitions made for each harvesters at working load; the total equivalent accelerations were calculated. Table 2 show the accelerations related to the hand-arm. For each column are respectively indicated the A(8) values referred to a three hours exposure period and A_{wtot} values. For the harvesters under test the values related to each limb are indicated. In any case, the calculation of the daily exposure level was done considering the higher value.

Table 3. A_{weq} and A(8) values for each harvester under test

Model	Operative conditions	A_{weq} (m/s^2) Control hand	A_{weq} (m/s^2) Auxiliary hand	A(8) (m/s^2)
A1	working load	21,0	12,5	12 ,86
A2	working load	14,7	9,1	9,00
A3	working load	27,3	19	16,71
A4	working load	8,5	14	8,57
A5	working load	5,8	8,2	5,02
B1	working load	7,2	11	6,74
B2	working load	11,8	16,6	10,17
B3	working load	10,7	11,6	7,10

The analysis of the results shows that the electric harvesters transmit vibrations analogous and in some cases higher than ones provided by the pneumatic harvesters. The pneumatic and electric harvesters having the engine at the top of the bar show higher vibrations levels near the auxiliary hand, instead the electric harvesters having the engine located at the bottom of the bar show higher vibrations levels near the control hand. However, the vibrations given off by the harvesters correspond to A(8) values greater than the daily exposure limit value established by the European directive 2002/44/CE. All times are clearly incompatible with the length of a standard work-day in agriculture. Thus, being a high risk situation the employer must take immediate measures to lower the exposure, individuating the

causes of the overcoming and taking the protection and prevention measures to avoid a new overcoming.

Conclusion

The present research, evaluating the risk to the hand-arm system due to vibrations, give an overview of the exposure of workers to the risks arising from vibrations to which operators are exposed when using olive harvesters. The results of the carried outs tests, point out the high values of acceleration transmitted to the hand-arm system produced by the electric and pneumatic harvesters. The Italian laws, with the object to evaluate of human exposure to hand-transmitted vibration, prohibit the overcoming the short period exposure limit value of 20 m/s^2 and impose a daily eight hours exposure limit value of 5 m/s^2. For all examined harvesters, the values are greatly higher than the limit ones laid down in the law in force.

The research on agro-forestry machineries may encourage operators and constructors to adopt ergonomic instruments to guarantee high work performances, as well as workers health and safety. In design phase, in fact, the in-depth study of some technical aspects is very important to have an effective reduction of the effects of the exposure to damaging vibrations.

These considerations are susceptible to be integrated by further investigations.

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Improving vibration comfort on modern crawler tractors

Pessina D., Facchinetti D.
Dept. of Agricultural and Environmental Sciences - University of Milan
Via Celoria, 2 - 20133 Milan, Italy
phone +39 02 503 16876; fax +39 02 503 16845
e-mail corresponding author: domenico.pessina@unimi.it

Abstract

Many means have been recently introduced on modern agricultural tractors to improve the vibration comfort; apart the driver's seat suspension, cab/floor and front axle pneumatic or hydraulic suspensions systems were fitted. Nevertheless, these device have been applied only on new high-power wheeled tractor models. Unfortunately, the situation on agricultural crawler tractors is not so good: no cab or front axle suspension are provided, and sometimes (also on new tractor models) no or a poor seat suspension is fitted; as a consequence, the vibration levels measured on board of crawler tractors often widely exceed the limit provided by the Standards. The crawler tractor manufacturers try to reduce the vibration transmission by isolating the driver's place with silent-blocks and improving the seat suspension quality. The vibration levels at the driver's place of a group of medium power crawler tractors have been recorded, differing the models examined for the track support rollers number, the seat suspension type and stiffness and the coupling of a hitched implement. The seat suspension type and its correct adjustment (in relation to the driver's mass) influence remarkably the vibration level. Similarly, the increase of the track roller support number (from 5 to 6) improved the situation, probably due to a better stability of the machine, especially when travelling at high speed on hard surface. On the contrary, an implement coupled at the rear 3-point linkage does not change remarkably the vibration comfort during transport, because the mass distribution of the crawler tractor does not result significantly affected.

Keywords: vibration, crawler tractor, seat suspension

Introduction

In the agricultural sector, working conditions are frequently poor and drivers of agricultural self-propelled machinery are still at risk of high levels of vibration exposure (*Scarlett et al., 2007*). The European Union Directive No. 2002/44/CE (European Commission, 2002) defines the criteria for measuring and then calculating the level of vibration. National guidelines have been formulated to reduce the risk and are reported in the Italian Decree No. 81/2008. In order to define minimum health and safety requirements in the work place, the Decree also specifies the most suitable national standard to be adopted. The working conditions and the manufacturing characteristics of the machinery can have a big impact on vibration levels such as the travelling speed and the soil surface profile (*Servadio et al., 2007*). These include the travelling speed and the soil surface profile. In fact, very high acceleration values are normally recorded when carrying out agricultural operations at high speed along hard and irregular surfaces (*Solecki, 2007*).

On modern agricultural tractors, many devices have recently been fitted to improve vibration comfort. Apart from the driver's seat, equipped with a passive or sometimes with an active electronically controlled pneumatic suspension, pneumatic or hydraulic suspensions on the cab floor and the front axle have recently been fitted. A more elastic tyre wall combined with a low inflation pressure can improve operator comfort, especially on hard surfaces at high speed (*Pessina, 1993*). The type of seat suspension, and above all its correct adjustment

(related to the driver's mass), also have a big impact on the level of vibration (*Nuccitelli et al., 1993*). Furthermore, the ride comfort is also very sensitive to the stiffness of the rear suspension of the cab (*Uys et al., 2007*): the hydropneumatic suspension can significantly improve the situation (*Hammes and Meyer, 2010*). In particular, the active or semi-active cab suspension is able to reduce the level of vibration with respect to traditional types (*Deprez et al., 2005*). Nevertheless, all these have only been applied on the latest wheeled tractors, especially on high-powered models. Unfortunately, conditions of agricultural crawler tractors are still very poor: at the moment, no cab or front axle suspension systems are provided, even on recent models. As a consequence, the vibration levels measured often widely exceed the limits provided by the official national standards. The manufacturers of crawler tractors are currently working on trying to improve the level of operator comfort, and are attempting to reduce both the production and the transmission of the vibration. Attention is being paid to both the low and high frequency parts of the spectrum. In the first case, the vibration is produced by the tractor travelling on hard or compacted surfaces and the seat suspension is designed to reduce its transmission. In the second, the vibration is generated by the running engine and gearbox; silent blocks fitted between the tractor body and the floor reduce their propagation. Also, some tractor parameters can influence the vibration level in the driving seat: the wheelbase and the distribution of mass in the cab, among others, play an important role.

Materials and methods

The Whole Body Vibration (WBV) in the driving seat of a group of crawler tractors produced by some leading Italian manufacturers with different technical characteristics were measured, recorded and compared. Three medium powered crawler tractors equipped with steel tracks were considered (A, B and C), each produced by a different Italian manufacturer. Their main technical characteristics are summarized in **Table 1**; all tractors were equipped with a seat with a mechanical suspension.

Table 1. Main technical characteristics and settings of the 3 tested crawler tractors produced by different Italian manufacturers.

Tested tractor	Seat suspension type	Seat suspension stiffness	Engine max power, kW	Mass, kg	Wheelbase, mm	Track width, mm
A			75.3	5470	1650	1350
B	mechanical	max stiff, correct, max soft	74.5	4900	1656	1300
C			72.5	4690	1650	1300

Given that very high vibration levels were recorded in the driving seat, a 4th tractor model (D, very similar to A) was tested in two versions arranged on different machines. In order to evaluate the level of vibration of a theoretically more stable and comfortable crawler machine, the traditional D(1) arrangement was compared with the D(2) version that was equipped with a seat with a pneumatic suspension and, above all, a 6-roller track instead of the conventional 5-roller version (**Figure 1**). The addition of one roller in the track system leads to an increase of 200 mm of the wheelbase: from 1650 to 1850 mm. Furthermore, to evaluate the influence of a correct (or incorrect) seat suspension setting, all the tests (carried out in 3 runs for each testing condition) were repeated, adjusting the suspension to the most stiff (equivalent to an operator mass of 130 kg), the correct (90 kg) and the most soft (50 kg) settings (**Table 2**).

Figure 1. Tractor D in version D1 (left) equipped with a 5-roller track support and seat with mechanical suspension, and in version D2 (right) with a 6-roller track support and seat with pneumatic suspension.

Table 2. Settings of the tested tractor D, in version D(1) with 5-roller track support and mechanical seat suspension, and version D(2) with 6-roller track support and pneumatic suspension.

Tested tractor	Track support rollers, no.	Seat suspension type	Seat suspension setting	Mass, kg	Wheelbase, mm	Track width, mm
D1	5	mechanical	max stiff, correct,	5470	1650	1350
D2	6	pneumatic	max soft	5620	1850	1350

Two paths, each approximately 200 m long, were selected on a sloping farm track of compacted clay soil. These were run separately (the first uphill and the second downhill) at approximately 1 min each at a speed of 7 km/h.

The 3 tractors A, B and C, were tested uncoupled. In order to simulate daily working conditions, the two tractors D1 and D2 were coupled with a ripper (working width 1.80 m, typical working depth 0.60 m, mass 480 kg) hitched to the three-point linkage. WBV values were measured on the driver's seat, using a triaxial accelerometer Dytran 5313M2 (mass 11 g, sensitivity 99.3 mV/g) operated by a 4-channel human vibration meter (Quest Technologies HAVPro) complying with ISO 8041:1990 standards. Data elaboration took into consideration the provisions of the European Union Directive No. 2002/44/EC (European Commission, 2002) concerning:

$$a_{wmax} = \max (1.4\, a_{wx};\; 1.4\, a_{wy};\; a_{wz})$$

As an alternative, the ISO 2631-1:1997 standard was considered, as follows:

- single axes values: a_{wx}; a_{wy}; a_{wz}

- overall root mean square (RMS) value:
$$a_{wsum} = [(1.4\, a_{wx})^2 + (1.4\, a_{wy})^2 + a_{wz}^2)]^{1/2}$$

The Italian Decree No. 81/2008 currently in force concerning evaluation of vibration (referred to in the previous Italian Decree No. 187/2005 and subsequent European Community Directive No. 2002/44/CE), provides for the comparison of the limits with the a_{wmax} values obtained. However, the present study considered the single axes (in terms of 1.4 a_{wx}; 1.4 a_{wy}; a_{wz}) and the a_{wsum} values because they seem to better represent the real disturbance to the driver caused by vibrations.

Results and discussion

Results recorded on the 3 comparable traditional tractors are shown in **Figure 2**. For clarity, only the z (vertical) axis values have been reported, as this is the direction that offers the most effective damping action of the seat suspension device. Furthermore, the vibration in the vertical direction is the most dangerous for the drivers because it affects the vertebral column and, in particular, the intervertebral elasticity of the discs. In general, levels are quite high, exceeding 0.5 m/s² in 94% and 1.0 m/s² in 66% of the cases examined. This confirms the seriousness of the situation considering that the real a_{wsum} levels are even higher due to the contribution of the vibration in the two other horizontal axes, x (longitudinal) and y (transversal). Tractors A and B showed similar levels, but vehicle C was the least comfortable showing remarkable differences in comparison with the others in all the test conditions.

The seat suspension setting dramatically influenced the levels: both the most soft and stiff settings revealed quite a high vibration increase in tractors A and B. As expected, the worst results were recorded with the highest stiffness, but surprisingly also the softest showed a poor comfort level. In this last case, the vibration increase was probably due to the frequent peaks recorded when the suspension spring reaches its maximum displacement in compression and, therefore, its damping action is completely interrupted.

The fact that there was reduced comfort with an incorrect seat setting is quite remarkable, reaching an increase that ranges from approximately 90% and 270%. This confirms the importance of a correct adjustment in order to assure the best suspension performance.

Tractor C highlighted a poor general comfort level and small differences among the different suspension adjustments; the highest values were measured at the most soft setting. However, the increase in suspension stiffness did not cause any significant worsening of the damping quality, also when compared with the correct setting.

No great difference was observed between the two paths considered for the tests (uphill and downhill on a sloped farm track of compacted clay soil). In spite of the constant travelling speed, the uphill path was less smooth than the downhill because the levels measured were always higher.

This first set of results were alarming and suggested the need for a new series of measurements to be taken in order to identify the improvements that could be made. The first modification was to change the driver's seat. A model equipped with a pneumatic rather than a mechanical suspension was so fitted. In fact, it is widely recognized that the pneumatic spring provides superior damping. Second, the fitting of a 6-roller track, instead of the traditional type with 5 rollers, introduced two potential benefits: a) an increase in the wheelbase (+12%) and, consequently, an improvement in the longitudinal stability of the tractor; b) an increase in the total track area in contact with the ground which is better able to absorb the unevenness of the soil when travelling. **Figures 3 and 4** show the weighted vibration levels recorded according to the two paths: uphill (rougher) and downhill smoother). The correct adjustment of the stiffness of the suspension provided better results in the z (vertical) axis, especially travelling uphill; the two other horizontal directions of vibration

performed better, considering the downhill path, for the mechanical seat. This was probably due to the involuntary compensatory movements of the driver's body, trying to maintain the best equilibrium when encountering an uneven surface.
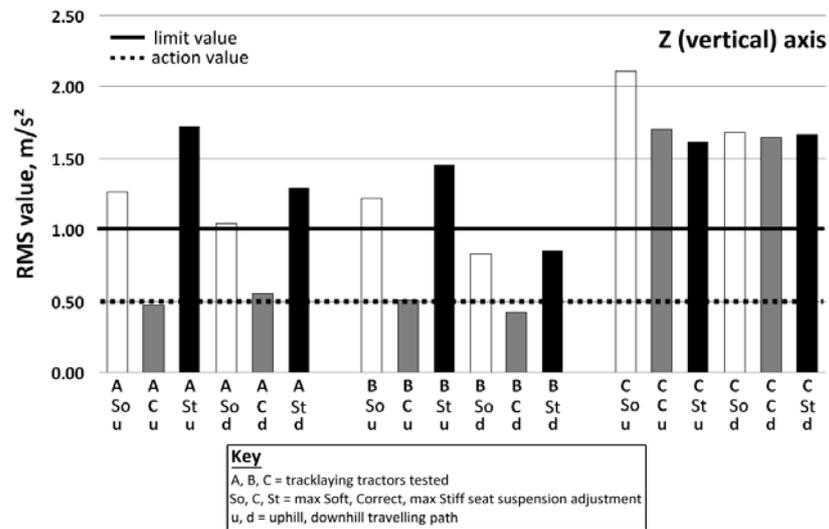

Figure 2. Weighted vibration levels measured on z axis (a_{wz}) on conventional tractors A, B and C, tested with different seat suspension adjustments, travelling uphill and downhill. A theoretical comparison with values stipulated by the Italian Decree No. 81/2008 is shown. Exposure action value, 0.5 m/s²; exposure limit value, 1.0 m/s². RMS, root mean square.
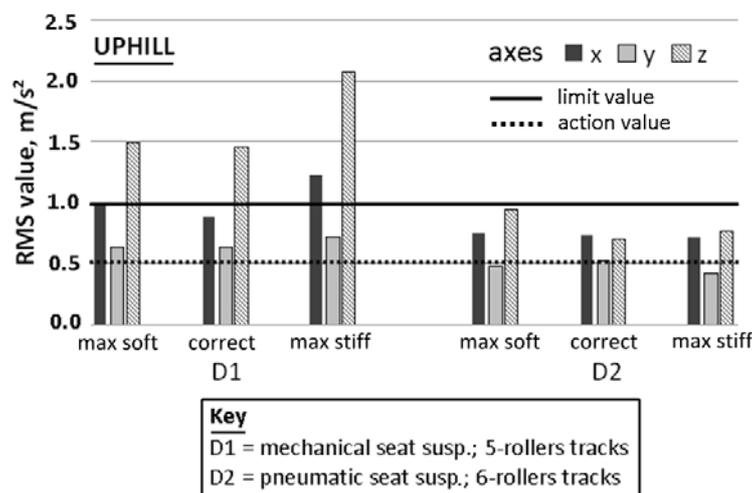

Figure 3. Weighted vibration levels measured on tractors D1 and D2, travelling uphill. A theoretical comparison with values stipulated by the Italian Decree No. 81/2008 is shown. Exposure action value, 0.5 m/s²; exposure limit value, 1.0 m/s². RMS, root mean square.

No great difference was seen between the levels recorded in the 3 axes of the seat with pneumatic suspension (combined with the 6-roller track fitting). Values were always lower (in some cases remarkably lower) than those recorded on the mechanical seat and 5-roller track combination, both travelling uphill and downhill. This is quite a good result, considering also that, on adopting the most favourable arrangement, none of the single axes vibration levels measured exceeded 1.0 m/s².

Furthermore, the y (transversal) axis showed lower values when compared to the x axis (longitudinal); this is probably due to the coupling of the ripper hitched at the 3-point linkage, acting as a sort of spring able to stress the pitch movement of the tractor body. **Figure 5** shows one of the several possible comparisons between the uphill and downhill time history.
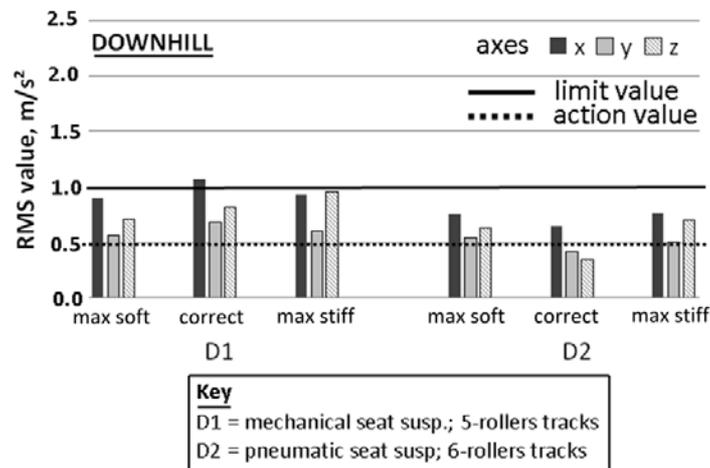

Figure 4. Weighted vibration levels measured on tractors D(1) and D(2), travelling downhill. A theoretical comparison with values stipulated by the Italian Decree No. 81/2008 is shown. Exposure action, 0.5 m/s²; exposure limit, 1.0 m/s². RMS, root mean square.
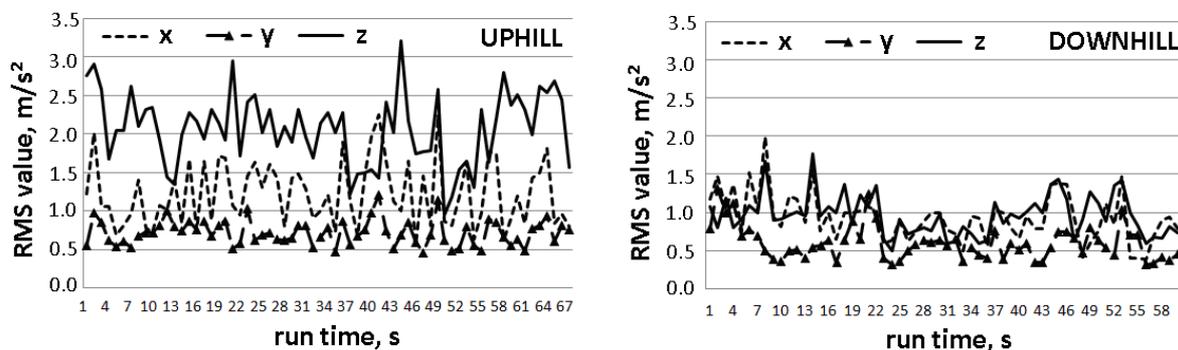

Figure 5. Time history of the vibration measurements on tractor D(1), equipped with 5-roller track support, travelling uphill and downhill, with the maximum *stiff* setting of the mechanical suspension of the seat. RMS, root mean square.

The z (vertical) axis highlighted the highest values moving uphill, while downhill the levels were generally lower, due to the smoother surface. Furthermore, the level peaks were clearly higher in the uphill path, confirming the unevenness of the ground. Conventional tractors A, B and C (**Table 3**) showed very high overall RMS (a_{wsum}) levels both travelling uphill and downhill. In a theoretical comparison with values stipulated in the Italian Decree No. 81/2008, all values except one exceeded the exposure limit, even with the correct seat suspension adjustment. However, the values recorded on the correctly adjusted seats of tractors A and B were slightly higher than 1.0 m/s², while the increase in the maximum stiff and soft settings ranged from 60-100% travelling uphill and from 10-70% travelling downhill.

Performance on tractor C was always poor, and there was no significant difference even when the setting was changed. The results obtained on the two versions of tractor D are particularly interesting (**Table 4**). The combination of the 6-roller tracks and the pneumatic suspension of D(2) always performed better than D(1) equipped with the 5-roller tracks and mechanical seat suspension. The reduction in vibration is quite remarkable, ranging from 30-55%. Again, with the best combination, both the uphill and downhill absolute values are very close to the exposure limit, and the difference among correct and incorrect seat suspension adjustments is markedly reduced. This represents a sort of added value, because a possible oversight when adjusting the setting does not necessarily translate into less comfortable driving conditions.

Table 3. Overall root mean square (a_{wsum}, m/s²) values measured on conventional crawler tractors A, B and C. In a theoretical comparison with value stipulated in the Italian Decree No. 81/2008, all values exceeded the exposure limit except values in italics which exceeded the exposure action but not the exposure limit.

Seat susp.	uphill			downhill		
adjustment	A	B	C	A	B	C
max stiff	**2.00**	**1.90**	**1.83**	**1.69**	**1.12**	**1.85**
correct	**1.20**	**1.07**	**1.92**	**1.06**	*0.88*	**1.83**
max soft	**1.68**	**1.60**	**2.29**	**1.40**	**1.28**	**1.89**

Table 4. Overall root mean square (a_{wsum}, m/s²) values measured on D(1) and D(2) tractors with different track support rollers and type of seat suspension. In a theoretical comparison with values stipulated in the Italian Decree No. 81/2008, all values exceeded exposure limit except values in italics which exceeded the exposure action but not the exposure limit.

Seat susp.	uphill		downhill	
adjustment	5 rollers and mech. susp.	6 rollers and pneum. susp.	5 rollers and mech. susp.	6 rollers and pneum. susp.
max stiff	**2.51**	**1.13**	**1.47**	**1.03**
correct	**1.81**	**1.14**	**1.50**	*0.85*
max soft	**1.89**	**1.29**	**1.28**	**1.12**

Conclusions
Drivers of agricultural crawler tractors run quite a high risk of discomfort from vibration. The average speed on a typical farm track is about 7 km/h and, at this speed, vibration levels always exceed 0.5 m/s², and very frequently even 1.0 m/s². Predictably, the situation will worsen at a higher travelling speed, up to 15 km/h, the maximum speed for crawler tractors. Operative factors related to the field itself could also lead to poor conditions of comfort, for example, due to the unevenness of the surface to be worked and the fact that the attached machinery will also contribute to the overall vibration level.
The type of seat suspension dramatically influences the level of comfort. Quite a good result was obtained with a seat equipped with a pneumatic rather than a mechanical suspension. The tests were repeated on two similar tractors each with a different track roller support and type of seat suspension. The 6-roller version performed better than the 5-roller. This was probably due to the higher stability provided by a longer wheelbase and the increased surface of contact with the ground that were better able to absorb the unevenness of the soil. Unfortunately, it

was not possible to evaluate separately the individual contribution of the number of rollers and the type of seat suspension.

As expected, the attachment of implements at the 3-point linkage increases the level of vibration, especially on the x (longitudinal) axis, probably because the pitch movement of the tractor is stressed. A theoretical comparison was made with values stipulated by the Italian Decree No. 81/20008. In general, the overall RMS vibration (a_{wsum}) levels recorded were always higher than the exposure action value (0.5 m/s²), and also frequently exceeded the exposure limit (1.0 m/s²). In order to assure a suitable reduction in drivers' risk, these results would require a reduction to be made in the total hours worked with respect to the traditional 8 h/day, sometimes with quite a radical cut of up to 2 h/day or even more. This is hardly realistic and, therefore, further measures to reduce vibration levels on crawler tractors are urgently required. Possible solutions could include the universal adoption of rubber tracks and/or the fitting of silent blocks on the cab floor and suspension devices on one or both axles.

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Safety at the workplace in the grafted cuttings production: first results of a study in Friuli Venetia Giulia (North East of Italy)

Vello M.[b,c], Cividino S.R.S.[b], Gubiani R.[b], Colantoni A.[a] , Lessi A [b].

[a]*DAFNE, Department of Agriculture, Forestry, Nature and Energy, University of Tuscia, Via San Camillo De Lellis, 01100 Viterbo, ITALY*

[b] *DiSA, Department of Agriculture and Environmental Sciences, University of Udine, Via delle Scienze, 208 , 33100 Udine, ITALY , +39 0432 558656, fax +39 0432 558603*

[c]*CIRMONT, International Research Centre for the Mountain, via Linussio 1, 33020 Amaro (Ud) Italy, tel and fax: +39 0433 467124*
Email corresponding Author: rino.gubiani@uniud.it

Abstract
The grafted cuttings production in Friuli-Venezia Giulia (North East of Italy) represents a compartment of strong importance in the agricultural scenery. The production is in fact exported in 32 countries of the whole world. Despite the great attention on safety at the workplace, very little information is available concerning safety levels in this particular sector. The present work wants to evaluate the situation of safety at the workplace in a sample of 15 firms, analyzing the fulfilment of formalities required by Italian law and the safety management, in order to have a starting point for further and contemplated studies related to this theme and to study practical solutions for a better management of safety.
The research was carried out during 2011 and was divided into three steps. The first step consisted of the selection of the sample; the second step led up to the creation of a check list. During the third step we carried out the survey on the sampling and we elaborated the collected data. First results show some critical point concerning the requirement established by law, while good levels of safety management are recorded in the most part of firms. Starting from these results, this search wants finally propose some practical tool for a better management of safety levels, with particular attention to the interference risk (present in agriculture, but little studied) and to the training of workers.

Keywords: risk analysis, grafts, safety management

Introduction

The grafted cuttings production in Friuli-Venezia Giulia (North East of Italy) represents a compartment of strong importance in the agricultural scenery. The production is in fact exported in 32 countries of the whole world. Besides the significant induced, these companies represent a virtuous model of agriculture, where the quality efficiency and the process innovation are the keys of the strategic mission and vision.

The economic structure of production is characterized by small and medium family run farms, with workflow concentrated in certain periods of the year. The following describes the main operational steps and working conditions.

The activity is very similar between farms of the sector. The phases can be so summarize:
1. selection of the material, cleaning and cutting of the cane (December - February);
2. selection of gems grafts, cut from the vine, disinfection and settle into refrigerators (January-February);

3. grafting of rooted cuttings, performed no longer manually, but automatically (March);

4. definitive establishment (May);
5. rooted cuttings harvesting from the nursery (November).
     All these operations are performed in a synergistic and cooperative way between companies belonging to the sector. Although it's a real added value, this generates different scenarios of interference risk in terms of safety at the workplace.
     The study, starting from the agriculture sector in the grape nursery and wine production, wants to define procedures for the safety management, in order to arrive to organizational and procedural solution for the management of the promiscuous activities and equipments related to a cooperative, in respect of the health and safety of all workers.

Materials and Methods
     The research was carried out during 2011 in a sample of 15 firms belonging to a cooperative
and was divided into three steps. The first step consisted of the selection of the sample; the second step led up to the creation of a check list. During the third step we carried out the survey on the sampling and we elaborated the collected data. For each farm three surveys were conducted. The selected companies are representative of the sector of the region Friuli Venetia Giulia and are homogeneous for the following criteria:

• activities;

• machinery and equipment;

• workforce (from5 to 10 workers for farm);

• business structures (meant to spaces and work areas)

     The methodology consists of three distinct types of analysis, as defined by law in force:
• analysis of the formal aspects related to the documentation;
• machineries and equipments, workplaces, photometric evaluations;
• interference risk assessment.
     Each work area was evaluated by using a specific checklist (Gubiani and Cividino, 2006) divided into 3 sections. Each section were analyzed for 35 parameters of technical nature and related to management, organization, behavior.
     All evaluations are referred to binding legislation and expressed according to the typical risk assessment (Fig. 1)
R = F * M, in which: F = frequency   M = magnitude
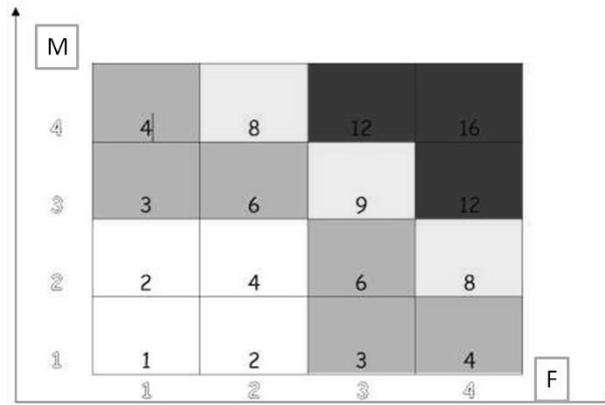
Figure 1. Risk matrix

The noise risk assessment has been evaluated according to the standardized method and using the *Larson Davis* Sound Level Meter class I LTX

Results

The results analyze the three main areas of investigation. As revealed in Figure 1, the formal aspects have been omitted. Only the 25% of the sample, in fact, has a documentation formally correct, though not updated to the Italian law in force (Legislative Decree 81/08).

The 90% of the sample wants to update and rectify the situation within a year. In all farms, the figure of the representative of the workers for the safety (established by Legislative Decree 81/08), while the emergency management is correctly dealt by 95% of the analyzed sample. The formal part related to the management of risk of pesticides and machinery is almost absent and only the 10% of companies maintain at its place all documents required by law.

This last element is due to the promiscuity of use of machineries, products and workplaces that can be seen also in the section on training, where only 25% of the sample correctly handle the training itself. The rolling stock (especially concerning tractors) is in keeping with the Law in force and new: there are no machineries built before 2000, with a recorded low risk (Fig. 2). Conversely, concerning rooted cuttings harvesting machineries, the following negative elements, that have defined a high risk level, were observed:

- self-built machineries;
- modified machineries;
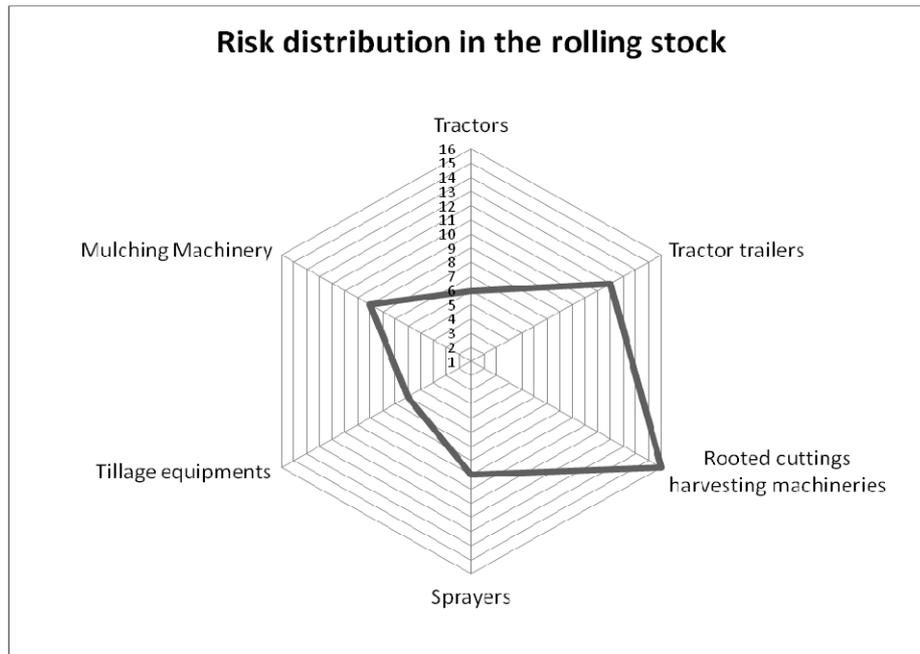- exchanged machineries without any documentation.

Figure 2. Risk analysis in the rolling stock

Figure 3. Risk analysis at the workplaces

Besides, from the analysis of the Figure 3, a low risk level at the workplaces can be observed. In fact, all places are very simple; there are no technological places (excluded the refrigerators); the greatest part of the used machineries are not complex. Nevertheless, a series of critical points, related to the workmanships performed of the operators, are reported below (Fig. 4):

- modified machineries, with a remarkable risk of cut and shearing;
- dusts' presence in the workmanships in closed places;
- non ergonomic and often badly illuminated workplaces.

Other specific risks, even very high, such as repetitive movements, incongruous

postures, noise, clearly emerge from the search. However, business activities are exhausted in a short period, although they should be considered more particularly in a optic of health monitoring and prevention of occupational diseases
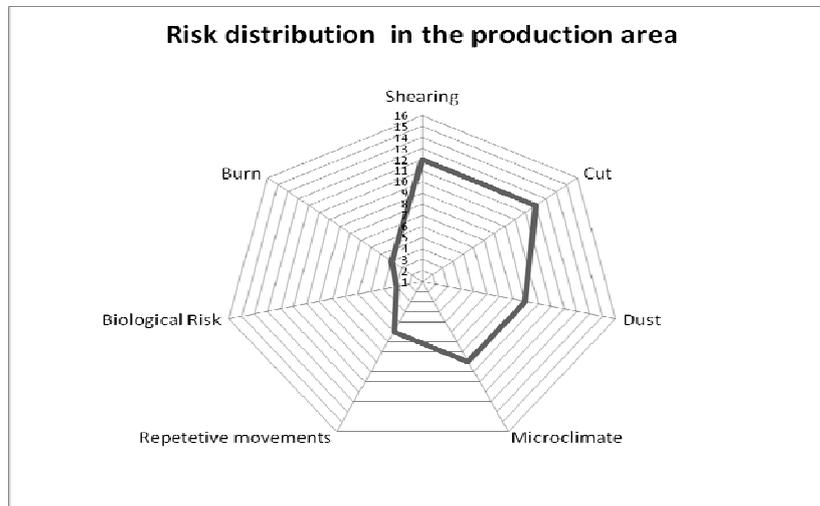

Figure 4. Risk analysis in the production area

The last area of study has analyzed the interference risk between the different farms (Cividino and Gubiani, 2010). The survey led to the definition of a protocol (Fig. 5), for the risk management; this model has been tested and validated at the sample firms.
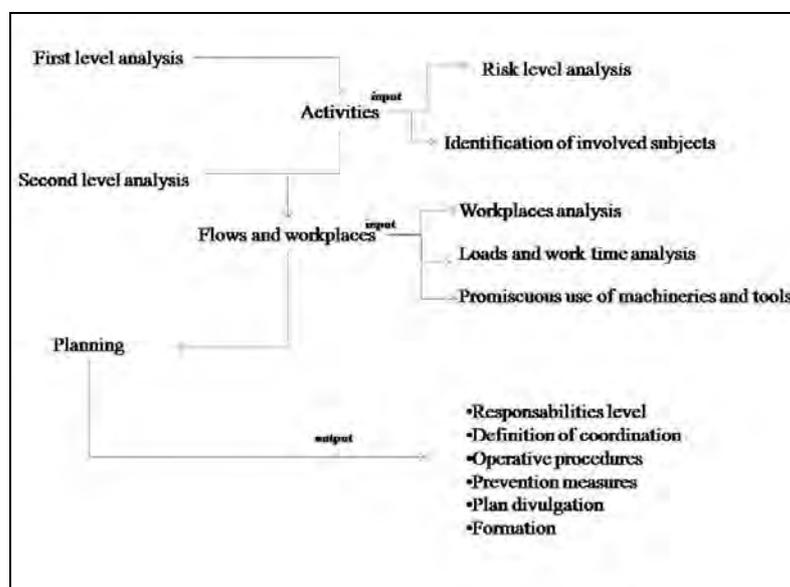

Figure 5. Protocol for safety management

Conclusions

First results show some critical point concerning the requirement established by law, while good levels of safety management are recorded in the most part of firms. Starting from these results, this search wants finally propose some practical tool for a better management of

safety levels, with particular attention to the interference risk (present in agriculture, but little studied) and to the training of workers.

The work emphasizes the need to design an internal area, within the sector, for the safety management, in order to increase coordination between farmers, have a center of training and ensure an internal audit the sector, reducing costs. The search is a starting point.

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Topic 6

"Noise, Vibration, Dust, Endotoxin, Microorganism"

Poster Presentation

Analysis of the influence of different typologies of tires on the whole body vibration exposure of an industrial truck operator

Cutini M., Romano E.
Agriculture Research Council – Agricultural Engineering Research Unit (CRA-ING); Laboratory of Treviglio, via Milano 43, 24047 Treviglio BG, ITALY.
Tel 0039 0957147518, Fax 0039 0957147600
Email corresponding Author: maurizio.cutini@entecra.it

Abstract

Purpose of the tests, of experimental kind, was to measure the exposure to whole body vibration of an operator of an industrial truck fitted with different tires.

In the use of these vehicles only the displacement has significance values of whole body vibrations.

Following this aim and in agree with the manufacturer (Trelleborg Wheel System) and the adopted standard this employment has been tested.

The adopted standard for the tests was the EN 13059:2002+A1:2008 (E).

An industrial truck fitted with different tires has been tested in two conditions of load and in three conditions of forward speed. The accelerations have been measured at the three axis at the cushion of the seat and at the vertical axis at the frame of the vehicle at the base of the seat. Two artificial bumps were superposed on the surface of a concrete track as specified in the standard.

The values of the accelerations resulted from 0.6 m·s^{-2} to 2.3 m·s^{-2} covering all the range between comfortable and uncomfortable depending from test setting.

The level of solicitation increases with the increasing of the speed also if not in a linear fashion.

The adoption of the ballast levels the values of exposure in all the tested conditions.

The exposure's value at the frame resulted, generally higher than at the seat.

The variable tire resulted not significant in the values at the frame. It resulted, instead, influencing the values at the seat.

Keywords: safety, comfort, solicitation

Introduction

Professional drivers could be exposed to risk of whole body vibrations (Okunribido, 2006; Seidel, 1986) that requires a specific investigation reported in the European Parliament Directive 2002/44/EEC, which also defines the minimum safety requirements. Moreover, in 2008, Italy adopted a specific national regulation (Decree n. 81, 2008) concerning worker safety, with a specific chapter on the limits regarding exposure to whole body vibration.

In the use of an industrial truck vehicle there are three main sources of vibration for the operator: the operation of displacement, of power lifting and the engine.

Only the displacement has significance values of whole body vibrations.

Purpose of this work was to measure the exposure to whole body vibration of an operator of an industrial truck vehicle fitted with different tires. In agree with the manufacturer (Trelleborg Wheel System) and the adopted standard (EN 13059:2002), only the displacement employment has been tested.

Beside, during working an operator is subjected to all the described operations and with different requirements of time, consequently the results won't be representative of the daily exposure to vibration of an operator, that will result lower, but will allow to evaluate and

compare the usual component of an industrial truck. The reference standard is adapt for evaluating different trucks, different seats or different tires.

Different settings of the vehicle (i.e. mass weight and distribution on the axles) and operating condition (i.e. speed) have influence on operator's comfort (Cutini, 2010) so tests have been repeated with three different set of tires, with the same nominal characteristics, taking into account also the variables mass and forward speed. The industrial truck has been furnished from the Customer that has supplied also the tires, the rims and their assembling.

Material and methods

The measurements carried out during tests have regarded the exposure to whole body vibration of an operator of an industrial truck.

The normative, reported in tab. 1, have been taken into account only as reference for methods and adapted for the purpose of the work.

Table 1. – List of the normative used

Purpose	Normative	Title
Operator's comfort	ISO 2631-1:1997	Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration – Part 1: General requirement
Mechanical vibration	UNI EN 1032/2009	Testing of mobile machinery in order to determine the vibration emission value
Safety of industrial trucks	UNI EN 13059/2008	Test methods for measuring vibration

Where not indicated in table 1 or it wouldn't be possible to follow the standard schemes or would have been adopted integrations, specially designed testing procedures have been used in agreement with the Customer and reported in this report.

The measurement of the masses has been carried out by a weighing machine of 20 t.

A triaxial pad accelerometer on the seat and a monoaxial on the frame of the vehicle at the base of the seat have been adopted for the measurement of the acceleration. Time histories have been acquired by a signal conditioner and a PC both on board. The forward speed has been measured by a Peiseler wheel. The list of instruments is reported in table 2.

Table 2. List of the adopted instruments

Instrumentation/material	Mark/model	Measurement typology
Weighing machine	20 t	Mass
Pad triaxial accelerometer	PCB Piezotronics 356 B 40	Acceleration, vibration
Monoaxial accelerometer	PCB Piezotronics 352	Acceleration, vibration
Data logger	Rogadaq 16	Signal conditioner
Speed wheel	Peiseler	Forward speed

Three different typology, called "Variant", of tires, then called "TR", of industrial truck have been adopted.

The main geometrical data of the tires and the codes adopted for the present work are reported in tab. 3.

Table 3. List and main characteristics of the tested tires

Variant	Measures		Mean diameter (mm)	
	Front	Rear	Front	Rear
TR 1	23x10-12	18x7-8	458	587
TR 2	23x10-12	18x7-8	458	587
TR 3	23x10-12	18x7-8	458	587

The tires for the test have fit out an electrical industrial truck Jungheinrich, type EFG-V25, The tested vehicle had the following masses for the test (with operator of 83 kg):
- Without load on the forks (SZ): 5075 kg
- With load (CZ): 6555 kg.

The load has been calculated following the standard's requirements at the 60% of the rated load capacity of the truck.

Comfort test have been carried out on a stretch of the 1050 m test track of concrete of the CRA-ING of Treviglio. Two artificial bumps were superposed on the surface as specified in the UNI13059 standard. Test track specifications were:
- lateral slope: 2%;
- length of the stretch of the test: 25 m
- dimensions of the obstacles:
  - 8 mm heigh
  - 150 mm length
  - width enough to involve completely the widthtrack of the vehicle.
- obstacles' distance: 10 m

Fig. 1 shows a global view of the test stretch layout on the track.

Figure 1. The layout of the test stretch

A global view of the test track of the CRA-ING of Treviglio and the location of the adopted stretch for the test are reported in fig. 2.
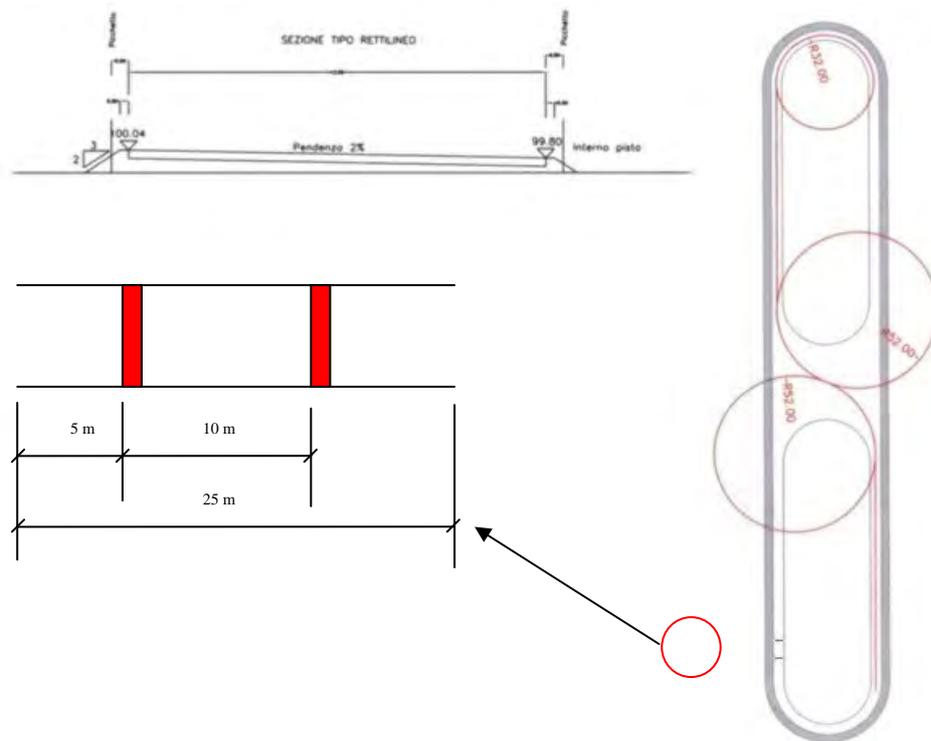

Fig. 2: The test track of 1050 m of the Laboratory di Treviglio and the adopted stretch

The value of exposure to vibration is obtained from indexes evaluated from the acceleration at the whole body of the operator on the three axes: x (longitudinal), y (lateral), z (vertical); beside the value at the z axis, as expected as the test typology, resulted always higher than those obtained at the x and y axis. Following this reason and as required from the standard the analysis will be referred only to this axis.

The exposure value has been calculated following the specifications of the standard ISO 2631. The relevant filters and the weights indicated in the standard have been adopted.

The result is the weighted root mean square of the time history of the acceleration at the z axis, the unit of measurement is always an acceleration and is expressed in m/s^2.

As the seat of the driver didn't allow regulations, it has been adopted an accelerometer also at the base of the seat.

Tires have been tested in two conditions of load and in three conditions of forward speed.

The environmental condition saw an overcast sky and the average temperature during the days of the tests between 18,5 and 20,8 °C.

The test condition are reported in detail with the relevant codes adopted and indicating the variables and the variants:

- the accelerations have been measured in the following positions:
  - Z axis at the cushion of the seat: z sed.
  - Z axis at the frame of the vehicle at the base of the seat: z macc.

- the adopted forward speed were:
    - 5 km/h (in addition at that required from the standard): 5
    - 10 km/h (required in the standard):10
    - 14 km/h (maximum forward speed of the vehicle): 14.
- the test has been carried out both with ballast on the forks, both without. The height of the base of the forks from the ground during the test was of 40 cm. This value was chosen for safety reason in the passage on the bump in the ballasted condition.
    - with ballast: CZ
    - without ballast: SZ
- 3 set of tires have been tested and their specifications are reported in tab.3.
- 3 repetitions for each condition have been carried out.

The data recording was always made in continuous mode. The measurement tolerance respected was the same reported in the adopted standards.

Results
The values resulted different between the seat and the frame.
The results are reported in tab. 4 and tab. 5 and represent the value of the exposure at the whole body vibration at the z axis of the operator.
The reported value is the average of the three measurements.

Tab.4: The level of exposure to vibration at the operator's seat

Variant	z sed (m/s^2)					
	5		10		14	
	SZ	CZ	SZ	CZ	SZ	CZ
TR1	0,68	0,61	1,35	1,23	1,69	1,4
TR2	0,78	0,67	1,57	1,24	1,79	1,46
TR3	0,78	0,68	1,54	1,22	1,81	1,48

Tab.5: The level of exposure to vibration at the vehicle's frame

Variant	z macc (m/s^2)					
	5		10		14	
	SZ	CZ	SZ	CZ	SZ	CZ
TR1	0,78	0,58	1,84	1,44	2,13	1,45
TR2	0,88	0,69	2,21	1,32	2,32	1,48
TR3	0,9	0,67	2,17	1,26	2,1	1,42

A first analysis shows that the level of solicitation increases with the increasing of the speed also if not in a linear fashion.
The adoption of the ballast levels the values of exposure in all the tested conditions.
The exposure's value at the frame resulted, generally higher than at the seat.
As the values are very close, above all those interesting the variable TR, a statistic analysis of the results has been carried out.
The analysis of variance shows that the repetition ("Rep") factor was not significant confirming the repeatability of the test.

The variable TR resulted not significant in the values at the frame (z macc). It resulted, instead, influencing the values at the seat.

The ballast ("Z") and speed ("V") variables resulted significant.

Results are showed in tab. 6:

Tab.6: Significance analysis of the main variables of the test

Variable	z sed	z macch
TR	**	
V	***	***
Z	***	***
Rep		

This first result seems indicating that the difference of influence of the different tires on the operator's comfort, at least in the tested typology, are referred more to an effect in combination with the seat characteristics than to the effects on the vehicle.

The analysis of the interactions at the first and second order confirms that previously declared (tab. 7).

Tab.7: Analysis of the interaction of the first and second order of the main variables of the test

Variabile	z sed	z macch
TRxV	**	
TRxZ	***	
VxZ	***	***
TRxVxZ		

The Duncan test analysis has been carried out for individuating a class division

The results of the Duncan test confirm the influence of the "Z" and "V" variables, beside it's possible to note as at the frame there isn't a significant difference between 10 and 14 km/h.

The results of the Duncan test are reported in tab. 8.

Tab.8: Duncan test results

Variable	Variant	z sed		z macch	
		Class	Average	Class	Average
TR	TR1	b	1,1605	b	1,3705
	TR2	a	1,2511	a	1,4833
	TR3	ab	1,2511	ab	1,4183
V	5	c	0,7097	b	0,7716
	10	b	1,3711	a	1,705
	14	a	1,5741	a	1,8086
Z	SZ	a	1,3235	a	1,7105
	CZ	b	1,1131	b	1,1462

Conclusions

The analysis of the "TR" variable confirms that the values of the different variants are very close and that is possible to focus a class separation only between the variants TR1 and TR2 both at the frame, both at the seat beside, as underlined, with the analysis of variance it didn't was meaningful at the frame.

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Transmissibility of agricultural tractors seats

Deboli R.[1], Calvo A.[2], Preti C.[1]
(1) IMAMOTER-CNR, Strada delle Cacce 73, 10135 Torino, Italy
(2) University of Turin. DEIAFA, Mechanics Section, V. Leonardo da Vinci 44, 10095
Grugliasco (Torino). Italy
* Email corresponding Author: r.deboli@imamoter.cnr.it.

Abstract
Other than the technological development of the tractor components, in the last decennia the interest for the driver comfort increased. Noise and vibration control priority increased too. Especially for the vibration, driver's seat plays a great role.
Modern tractors are often equipped without any type of suspension and the task of the tires is to reduce vibration caused by the uneven ground where these machines travel.
When the tractor moves, it is solicited by a vibrational excitation that, through the vehicle, reaches the driver causing to him a stressing and tiring situation.
Tractor drivers' seats must reduce the solicitations levels transmitted to the driver. For this reason, the European Directive 78/764 requires the validation of the seats. The validation must be done in a laboratory: the Directive requires only tests concerning the damping capacity along the vertical direction, whereas nothing is required for the other two directions, longitudinal and transversal.
To verify the vibrational comfort values given by seat with pneumatic suspension, tests have been carried out using a 93 kW tractor. The tests have been executed with tractor speed of 13 km/h running on different surfaces: an artificial test track (ISO 5008), an asphalt road, an un-metalled farm road, a grass field and an harrowed clay field.
The acceleration values have always been revealed over the seat and over the cabin platform.
During tests, along X and Y axes, the seat transmissibility were always greater of one.

Keywords: CEE 78/674, ISO 5008, WBV

Introduction

Agricultural workers are besides the most exposed operators to the risk of backbone pathology (Kelsey and Hardy, 1975; Pope et al., 1990).

One of the main responsible of damages to the backbone is the transmission of mechanical vibration in the workplace (Brinkmann et al., 1988; Hulshof and Van Zanten, 1987).

Tractor's drivers are really exposed to high whole body vibration (WBV) levels, also of impulsive type. A standard was published (ISO 2631-1: 1997) to permit the measure of WBV, because of the increase of certain type of pathologies connected to the backbone. This standard locates a frequency interval between 0.5 and 80 Hz and a weighting filter which considers the different human body sensibility to the vibrating stimulus frequencies.

Many authors during the time studied the frequency intervals more dangerous for the whole body. These values were first observed by Coermann (Coermann, 1962) and were evaluated considering both the different subject postures during the mechanical vibration exposure and the vibration direction (Miwa, 1975; Fairley and Griffin, 1989). Other than the main movement value around 5 Hz, axial movements along the backbone at highest frequencies were observed (Matsumoto and Griffin,1998).

The vibration transmission along the backbone chiefly occurs through the driver seat: in 1978 a Directive which defines the characteristics of forestry machines and agricultural tractors seats was enacted (Council Directive 78/764/EEC, 1978). This Directive defines the transmissibility values of the seat in function of the machine where the seat will be mounted.

In order to reduce the health risks and the discomfort to the driver and to enable the driver to work at a faster pace, it is important to isolate the driver from the machine vibration as much as possible (Lines et al., 1995).

This is done positioning elastic deformable elements between the tractor and the driver's body. These elastic elements are the seat suspension systems. Usually these systems are made of metallic springs, or air springs with one hydraulic shock absorber.

The seats have an important job: for this reason their damping capacities are verified using the EU Directive 78/764. Tractor seats are laboratory tested, using special vibrating benches (Morgia et al., 2009).

Aim of this work has been to notice the acceleration values (vertical, longitudinal and transversal) using a driver seat mounted on an agricultural tractor, used to travel over different surfaces and with different implement configurations (Scarlett et al., 2007; Stayner, 2001).

Materials and methods

To verify the vibrational comfort values given by the seat, tests have been carried out using a 4WD tractor (table 1) defined as tractor of Category A, class II by 78/764 EEC.

Table 1. Main features of tractor

Item	Measure unit	Value
Tractor power	kW	93
Cylinders	n	6
Displacement	cm^3	6720
Wheel base,	mm	2661
Trackwith front	mm	1407
Trackwith rear	mm	1426
Mass front	kg	2044
Mass rear	kg	3066
Cab suspension		silent-blocks
Axles suspension		Any
Front tires		320/70 R 24
Rear tires		480/70 R 30

Seat characteristic

In table 2 are reported the main characteristics of the seat under investigation. The seat had pneumatic suspension and hydraulic dumper.

Table 2. Seat characteristics

Features	
Suspension type	Pneumatic
Dumper type	Hydraulic
Category (764/78 EEC standard)	II and III
Fore-aft isolator	No
APS positioning system (60 mm)	Manual

Surfaces characteristic

Tests have been carried out on different surfaces:

- A smooth ISO, 100 m track (from standard ISO 5008: 2001), which represents an un-metalled farm roadway, designed to test the fitness for validity of tractor seats. This track provides an acceleration input which, at the cab floor, is dominated by the vertical component.
- Asphalt: tractor vibration were tested on a conglomerate bituminous rectilinear plane tract of 400 m length. These type of tests gave us information about the seat behaviour during transfer on the road.
- Grassland field.
- Harrowed clay (Figure 1).
- Un-metalled farm road, with its typical potholes.

The use of ISO 5008 ride vibration track tests provides a reasonable basis for comparison seats under tests for the high repeatability and reproducibility of vibration data.

Figure 1 Tractor with implement running on harrowed clay

Operative conditions

In order to maintain the test programme within reasonable limits we have carried out the test only at one speed: 13 km/h (this choice is connected to the fact that it is possible cross all the surfaced tested, from grass to harrowed clay and so on, at this velocity). Tractor forward speed was monitored by radar (derived from a Doppler radar sensor). Tire pressure was maintained constant at 1.6 bar.

Three test replicates were performed each time, considering tractor running on each surface type and with or without implements or ballast.

Tests were carried out with tractor in different settings (table 3): unladen (without any ballast), with ballast and with ballast plus one implement (harrow tines of 600 kg mass)

During all the tests, the same operator (70 kg mass and 180 cm tall) and the same drive behaviour was maintained.

Test instruments

During each passage across the tracks, vibration levels were measured in three mutually perpendicular directions (X, longitudinal; Y transverse; Z, vertical), both upon the surface of the operator's seat and upon the vehicle cab floor, close to the seat mounting.

Tri-axial vibration on the driver's seat was measured by placing a semi-rigid mounting disc, incorporating three mutually-perpendicular piezoelectric accelerometers (ICP®, Integrate Current Preamplifier, from PCB, type SEN020 with sensitivity of 100mV/g), on the seat cushion, approximately between the driver's ischial tuberosities (vertically below the seat Index Point).

Two Larson Davis Human Vibration Meter type HVM100 (serial N. 219 and 292) were used to condition the seat and cab floor accelerometers.

Table 3- Mass distribution of the tractor under investigation

	front	%	rear	%	Total
	kg		kg		kg
Unladen	1530	40	2220	60	3770
Laden	2160	47	2440	53	4560
Laden plus implement	1660	32	3510	68	5160

The acceleration records were frequency-weighted, using the weighting factors *wd* and *wk* specified in ISO 2631-1 for the horizontal and vertical axes respectively, before calculating the root mean- square (r.m.s.) acceleration values. The horizontal (X and Y-axis) components were multiplied by a factor of 1.4, as also specified in ISO 2631-1. Combined (vector-sum) three-axis acceleration values were obtained for the seat and cab floor by calculating the root-sum-of-squares (RSS) of the combined orthogonal axes components.

To better understand the possible influence of track type, ballast/unballast, with/without implement over the measure vibration, data have been grouped in different ways (by track type, etc.). All data were elaborated using the SPSS software to verify differences among tracks and tractor settings, using the ANOVA procedure.

Results

Concerning tests on field, the results are given using the ratio (*T*, transmissibility) between the acceleration on the seat and the acceleration on the cab floor of the tractor, in the frequency range 0.5-80 Hz.

$$T = \frac{a_{wS}}{a_{wB}}$$

were a_{wS} is the weighted acceleration upon the surface of the operator's seat and a_{wB} is the weighted acceleration upon the vehicle cab floor, close to the seat mounting.

The ratio between the acceleration levels (seat/platform) is a good indicator of the damping properties of seats. In theory, this value should always be less than the unit.

The figure 2 shows these ratios obtained in the different work conditions (crossed surfaces) and tractor settings at the constant velocity of 13 km/h.
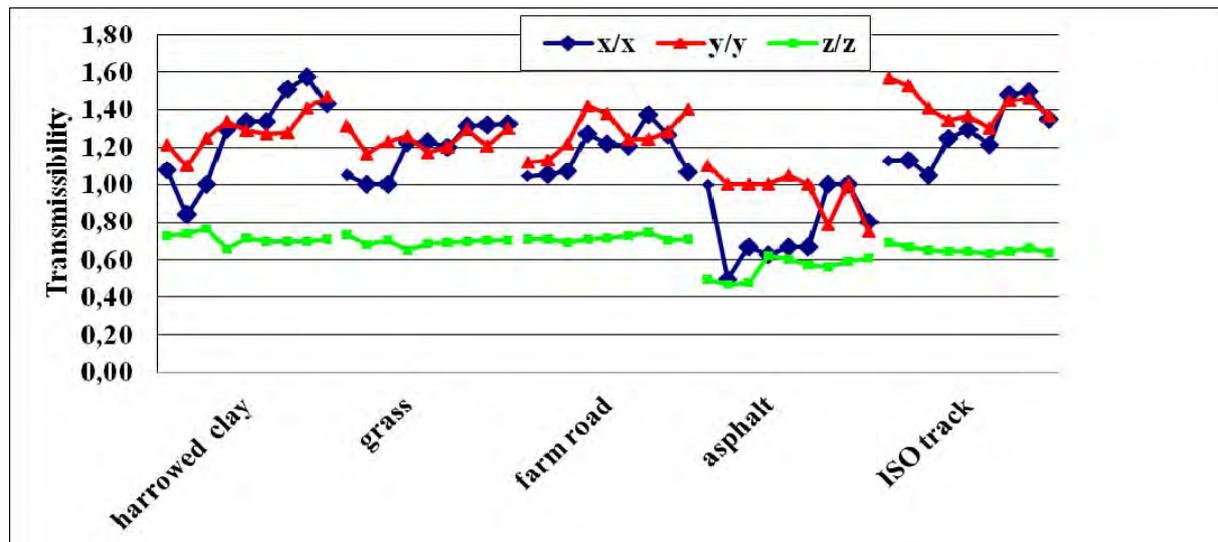
Figure 2 – Seat transmissibility along the three directions

The graph of figure 2 reveals that along the vertical Z direction, the acceleration ratio is constantly under the 1 value (between 0.6 and 0.8) over all the surfaces, whit a slight decrease (around 0.5) when the tractor crosses the asphalt road.

Along the Y direction the ratio is around 1.2 over the grass, 1.3 over the harrowed clay (but with an higher variability), around 1 over the asphalt and higher over the ISO track (> 1.4).

Along the longitudinal direction X, the ratio is more variable than the others, independently from the crossed surfaces.

Comparing the ratios along the X and Y directions, it is possible to notice that the ratio along the Y axis is more constant along all the crossed surfaces.

To verify the differences among tracks and tractor setting, the ANOVA procedure was used.

The first comparison was between ballast and implement: the ratio along the X axis in this case is influenced by the lack of both ballast and implement. The presence of ballast and the lack of implement seems to have less influence on the ratio along this axis.

Along the Y axis, the acceleration ratio it is not influenced by the presence/absence of the ballast or the implement.

Along the Z axis the same behavior of the X axis is observed.

The second comparison was between surfaces.

Along the X axis, the ratio is influenced by the presence of the asphalt, which makes the values significantly different.

Along the Y and Z axis, the ratios are statistically equal over the grass, the clay and the un-metalled farm road. For the asphalt and the ISO track, ratios are statistically different from the previous surfaces.

Conclusions

The results of the tests underlined that an amplification problem does exist, concerning the acceleration transmissibility along the driver seat of an agricultural tractor, especially along the longitudinal and transversal directions.

These behaviors are underlined from an initial observation of the results of the test (see Figure 2). From this figure would appear to question about seat effectiveness upon the test tractor in these conditions, given that longitudinal (X) and transverse (Y) axis 'seat' acceleration levels appear to increase relative to those recorded upon the cab floor at identical forward speeds (seat and floor WBV was measured simultaneously).

However, these characteristics are not as surprising. The operator's seat surface is further (higher) from the tractor's lateral (roll) and longitudinal (pitch) centers than the cab floor: consequently, acceleration levels measured in those axes at that point will be greater than those recorded on the cab floor. Allied to this is the difficulty of incorporating effective horizontal (X or Yaxis) suspension systems into agricultural vehicle seats.

Suspension seat development has, to date, concentrated upon vertical (Z) axis performance.

Modern suspension seats undoubtedly do serve to improve operator ride comfort, but are most likely to attenuate Z-axis vibrations. Even then their effectiveness is limited to circumstances when the input acceleration (cab floor) frequency is greater than the natural frequency of the seat suspension system.

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Inhalable dust emission in hazelnuts mechanical harvesting (*Corylus avellana* L.): test of a low impact suction-type pneumatic collector

M. Fedrizzi[1], M. Pagano[1], C. Perrino[2], M. Cecchini[3], M. Guerrieri[3],
P. Gallo[1], M. Biocca[1]

[1] *Agricultural Research Council, Agricultural Engineering Research Unit (CRA-ING) Monterotondo (Rome), Italy*

[2] *Institute of Atmospheric Pollution Research of the Italian National Research Council (CNR-IIA) – Monterotondo St. (Rome, Italy)*

[3] *University of Tuscia, DAFNE Department (Viterbo, Italy)*

Corresponding Author Email: marco.fedrizzi@entecra.it
Tel 0039 0690675230

Abstract
The paper will point out the possibility of reducing easily the quantity of inhalable dust emitted into the atmosphere during hazelnuts mechanical harvesting by the use of an innovative device, installed on a self-propelled suction-type pneumatic collector. The paper reports the results of preliminary tests carried out in Italy.

The tests of hazelnuts mechanical harvesting were prepared using two self-propelled suction-type pneumatic harvesting having the same technical characteristics; only one of these was equipped with a new electro-hydraulic device, designed in order to facilitate the reducing of inhalable dust emitted into the atmosphere.

The effectiveness was measured both in ambient air and close to the machine driver. The dust samples were analyzed for the mass concentration and chemical composition of inorganic species (elements analyzed by X-rays fluorescence and ions analyzed by ion chromatography).

The results showed that the dust concentration significantly decreases when the new device has been used; the reduction of dust emission has exceeded 70% in environmental sampling and 60% in personal sampling, in comparison with the other machine without the device. The chemical analysis of the sampled particulates revealed the presence of soil components and small amounts of ionic species.

The remaining fraction is to be attributed to organic species.

Since a satisfactory general dust reduction has been obtained, it is expected that further research will be conducted including the determination of the level of free crystalline silica (SLC) in the areosol, which can be a high risk factor both for the operators and for the bystanders.

Keywords: dust, PM_{10}, hazelnut, harvesting

Introduction

"The health risk depends on the chemical nature of particles and on their dimensions".

Particulate atmospheric is a mixture liquid or solid, individually suspended in the atmosphere, different in size, chemical nature, emissive source and health effects; may interact with each other and with the atmosphere and the change over time.

The smallest particles, with aerodynamic diameter around 10 µm (PM10), can penetrate in breathing apparatus and reach lungs (PM2.5), alveolus and finally the blood (particles with diameter less than 0.1 µm). The particles dimension determines also their persistence in atmosphere. The particles in the diameter range from 0.1 to 1 µm show the higher lifetime in

air and they can be transported for long distance. They can create severe risk, especially if they contain fibers like silica crystalline, a frequent cause of serious diseases including fibrosis and cancer (Cecchini et al. 2005).

The accepted concentration of particles is regulated by European and national legislations. For the particulate material the upper limits is 40 µg m-3 for annual average and 50 µg m-3 for the day average, that during a year cannot occurs more than 35 times.

The legislation also establishes annual average concentration limit of PM 2.5 of 28 µg m-3 (for the year 2011, that will be reduced gradually to reach 25 µg m-3 in 2015).

These limits are applicable outdoor and are aimed at preventing health risks for the population; however the issue is not appropriate to those activities carried out outside, like the agricultural practices, due to no reference of specific emissions limits. The dust generated from the soil during the hazelnut harvesting constitutes a risk for the workers and for the population living nearby (Cavariani & Bedini, 2011) especially in specialized area of hazelnut cultivation. To find a possible solution to this issue, the use of an innovative electric-hydraulic device on self-propelled harvesting machine has been assessed in order to reduce dust concentration in the atmosphere during the harvesting.

The paper will point out the possibility of reducing easily the quantity of inhalable dust emitted into the atmosphere during hazelnuts mechanical harvesting by the use of an innovative device, installed on a self-propelled suction-type pneumatic harvesting. The paper reports the results of preliminary tests carried out in central Italy.

Methods

The test were carried out in central Italy, in a hazelnuts yard (*Corylus avellana* var. "Tonda di Giffoni") in September 2011

To improve the reduction of particles (dust) emitted in the air during the action of mechanical harvesting (Fig. 2) on this harvester, was installed a new system device conceived to transfer a quantity of sprayed water on the harvesting head and into the tube located downstream of the vacuum chamber (Fig. 1).

For the test was employed a self-propelled harvesting machine made by FACMA model "Cimina 300 S" (Fig. 3).

The water contained in a tank of 300 l is conveyed to the nozzles (sprayers) with an electro-hydraulic pump (12 V) with a flow of 12.5 l min^{-1} at 2.4 bar.

The aerosol produced by the nozzles is mixed with dust and mud reaching the ground, without the raising of dust during harvesting.

During the tests, in order to reduce interference in the sampling and to minimize the dust re-suspension, the tube located downstream of the vacuum chamber, which leads the outgoing air to the outside, has been arranged to direct the flow forced air upwards.

Usually however this flow of air is directed towards the ground to take advantage of its ability to move in adjacent inter-row the hazelnuts present near the base of the plants and not achievable by the harvesting head.

To evaluate the performance of the abatement device, we carried out sampling of atmospheric particulate matter (PM10) during mechanical harvesting performed with and without the experimental device. Samplings were carried out in the centre of the field (two sampling units), at the border of the field (one sampling unit) and on the harvesting machine, close to the operator (one sampling unit).

During the two sampling periods (with and without the device), the machine covered the same distance and the same path.

We used Tecora Skypost samplers operating at the flow rate of 38 l min^{-1} on 47 mm Ø filters for the sampling units in the field and SKC Leland Legacy samplers operating at the flow rate of 10 l min-1 on 37 mm Ø filters for the sampling unit on the harvesting machine. Sampling on two different filter membranes is necessary to carry out the complete chemical characterization of the collected dust (inorganic and organic species).

Sampling duration of each experiment was 30 minutes. Each sampling unit was composed of two PM samplers, one for collection of PM on Teflon filters, the other one for collection of PM on quartz fiber filters.

Were also measured PM number concentration by using an optical counter operating in the size range 0.3 – 10 µm (Grimm-Tecora mod. 1.108). The counter was set so as to obtain particle number concentration in the following size ranges: 0.3-0.5 µm, 0.5-1.0 µm, 1.0-1.5 µm, 1.5 – 3.0 µm, 3.0-5.0 µm, 5.0-10 µm. After the sampling, PM mass concentration was determined on Teflon filters by the gravimetric procedure, after 48 h conditioning at $20 \pm 1°C$ and $50 \pm 5\%$ relative humidity. Then, the elemental content of the collected dust (Al, Ca, Cl, Cu, Cr, Fe, Mn, Na, Ni, Pb, S, Si, Ti, V, Zn) was analyzed by X-ray fluorescence, a non-destructive technique (X-LAB 2000, Spectro, Germany).

Finally, Teflon filters were water-extracted and analyzed by ion chromatography for anions and cations (ICS 90, Dionex Co., CA, USA). Quartz filters were analysed by thermo-optical analysis for their elemental and organic carbon content (Sunset Laboratory, OR, USA).

The overall method allows the determination of all PM macro-components and the evaluation of the strength of the main PM sources (Perrino et al., 2009).

Results

During the conduct of the 2 tests with the use of the machine without the device (test 1 and 2), PM10 concentration was very high, and ranged from 0.77 to 1.20 mg m^{-3} at the field edge and from 0.90 to 2.10 mg m^{-3} at the two positions in the centre of the field.

Close to the machine operator, the concentration was even higher, and ranged from 7.7 to 8.8 mg m^{-3}.

The continuous measurements carried out by means of the optical particle counter showed that in the fixed positions the concentration was very variable and dependent on the machine position during its work. PM 10 min^{-1} average concentration was below 0.1 mg m^{-3} when the machine was at its maximum distance from the measurement point, and reached concentration as high as 10-20 mg m^{-3} when he machine was close to the fixed sampling point.

The sampling point on the machine (operator) was, instead, always very close to the dust cloud produced by the harvesting, and this caused a higher concentration value.

When the abatement device was used, a significant reduction of PM_{10} concentration was observed, both in the field and on the operator. Average reduction was 83% in the centre of the field, 68% at the border, 70% on the operator.

The results obtained by the optical particle counter show that the produced dust was mainly in the coarse fraction. About 60% of the mass was in the range 5 to 10 µm, and 20% in the range 3 to 5 µm.

Chemical analyses of the samples collected when using the unmodified harvesting machine show that soil dust was the prevailing PM source, accounting, on average, for 55% of the PM10 mass.

Main constituents were silicon (13% of the total mass), aluminum (4.0%), iron (3.5%), potassium (1.3%), sodium (1.0%). Other constituents of soil (e.g.: Mn, Ti) were in the range between 0.1 and 1% of the total mass, while elements deriving from anthropogenic sources (e.g.: Cr, Ni, Pb, V) were widely below 0.1%.

The remaining fraction was mostly constituted by organics (12%), while sea-salt, anthropogenic compounds and species produced by secondary reactions in the atmosphere were negligible.

The sum of the chemical analyses accounted for about 70% of the collected mass determined by the gravimetric procedure, indicates the presence of a remarkable amount of water adsorbed or bound to PM particles.

When using the abatement device, the concentration of soil components markedly decreased: in the centre of the field the reduction was, on average more than 90%, passing from 835 to 73 $\mu g\ m^{-3}$.

A reduction was observed also for organics (from 175 to 60 $\mu g\ m^{-3}$, about 65%), while the other components were almost unaffected. When using the device, soil components constituted, on average, 28% of the collected mass.

Again, to obtain the mass closure we have to consider the presence of water. Atmospheric particulate matter collected during hazelnut harvesting was, as expected, mainly composed by soil components, organic species and water. Mechanized harvesting generates remarkably high concentrations of dust, both in the field and close to the operator.

The use of the abatement device allowed a relevant reduction of the dust concentration, which exceeded 80% in the centre of the field.

The reduction mainly concerned soil components.

A such result is a positive result if considering that the device is still being tested; it encourages to think that the dust transported for long distances can be significantly reduced with positive effects on population that live near by the hazelnuts cultivation.

Main results of the experiments are summarized in Table 1.

Table 1. PM10 concentration during harvesting without with the abatement device

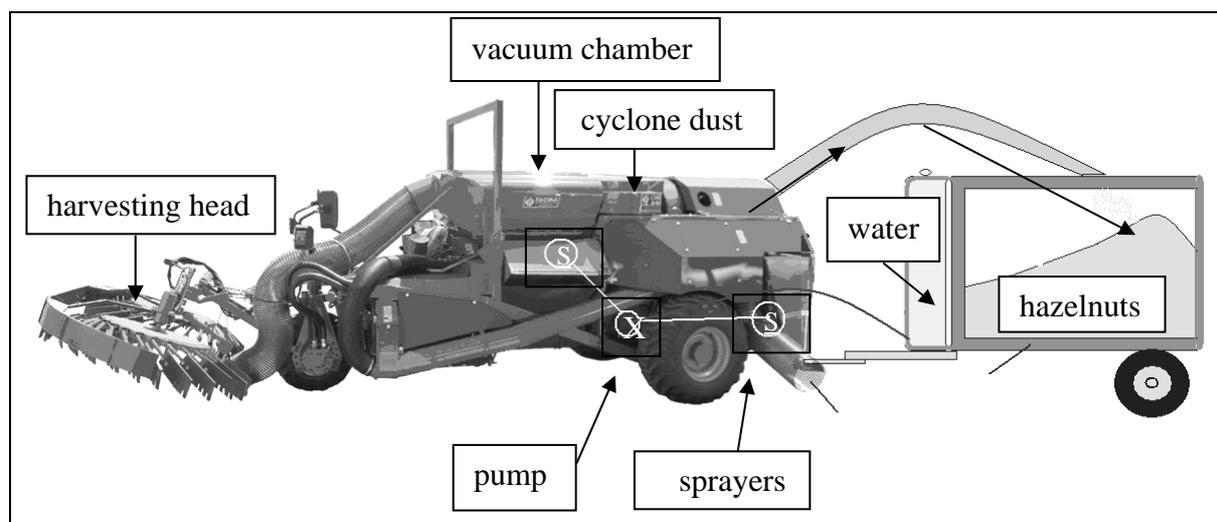|	ABATEMENT DEVICE	CENTER PM_{10} (mg m^{-3})	CENTER PM_{10} (mg m^{-3})	BORDER PM_{10} (mg m^{-3})	OPERATOR PM_{10} (mg m^{-3})
TEST 1	NO	1.20	0.90	0.77	8.8
TEST 2	NO	2.10	1.60	1.20	7.7
TEST 3	YES	0.30	0.34	0.28	2.8
TEST 4	YES	0.14	0.22	0.33	2.1

Figure 1 – sketch of the dust abatement device on self-propelled harvesting machine

Figure 2 - dust production during the operations of mechanical hazelnuts harvesting.

Figure 3 - self-propelled harvesting machine - model "Cimina 300 S" .

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Vibration transmitted to operator's hands by a new type of rotary pick-up for the harvest of table olives

Gambella F.[(1)], Deboli R [(2)], Preti C. [(2)] Calvo A.[(3)]
(1) University of Sassari, Department of Agricultural Engineering, Viale Italia 39, 07100 Sassari.
(2) IMAMOTER-CNR, Strada delle Cacce 73, 10135 Torino, Italy
(3) University of Turin, DEIAFA, Mechanics Section, V. Leonardo da Vinci 44, 10095 Grugliasco (Torino)

*Corresponding author: gambella@uniss.it

Abstract
Fruit removal is the main aim of vibratory fruit-harvesting machines used on fruit-bearing trees. The harvesting methods vary and depend on different factors such as fruit species, characteristics, tree size and the grower's economic situation. New types of rotary table olive hand harvesters have been studied. This work has two aims. The first objective is to determine and evaluate vibration transmitted to operator's hand. The second one is to evaluate the combination, in terms of the best performance, of the machines used for mechanized harvesting of table olives. Several factors have been examined: undulating teeth variation thickness, different rotational speed and different coating material used to reduce the impact damage on olives.

Keywords: labor saving-machine, vibration, materials.

Introduction

One of the items with the highest impact on costs of production of table olives is the harvest of drupes, which is still mainly conducted by hand. For over fifteen years, are present on the market electric labor saving hand-guided machines, able to roughly triple the productivity of workers compared to manual harvesting (Cerruto et al., 2009; Nasini et al., 2007, Paschino et al., 2010). The saving labor machines have always been marked by a lack of information from the ergonomic point of view e.i. noise, vibrations transmitted to the hand-arm system and fatigue due to the weight (Biocca et al., 1008; Blandini et al., 1997; Ceruto et al., 2009; Deboli et al., 2008). All these aspects are often underestimated by users, concerned above all to productivity. For years many manufacturers, just to try to meet the needs of ergonomics dictated by the latest regulations (D. Lgs 187/2005, D. Lgs. 81/2008), introduced on the market, alongside traditional pneumatic models and those mechanically operated by two-stroke engines, also models driven by electric motors, which are characterized especially by lower noise level, greater lightness, ease of handling (the batteries, high capacity, can also be inserted into special pockets on the operator) and, therefore, from a level of comfort generally higher. The development of these new machines has prompted many changes that have affected the operating principle, the shape of the working and building materials, which are expected to also affect the hand-arm vibration transmitted to operators during the work.

The aim of this study was to measure the level of vibration transmitted to the operator's hand while using a experimental electric labor saving machine (with rotary combs) used in the harvest of table olives. We have investigated the level of vibration generated by three different types of plastic coating material, such as natural rubber, silicon and vulcanized rubber, used as coating of the teeth in order to minimize the damage to the drupes.

Materials and methods

The electric machine for the mechanical harvesting of table olives, used in experimental tests, was an electric combing model Olivella 105C Midi product by Coima Italy Srl (Pescara) (Fig. 1). The work organ was a electric comb-type device consisting of five tungsten teeth coated with different plastic materials. In order to reduce the likelihood of damage from impact to the olives, with consequent oxidation of the fruit and depreciation of the quality of the harvested product, were made for three different protection coatings with a thickness of 7 mm (S1), 14 mm (S2) and 19 mm (S3). Moreover, in correspondence of each thickness were used three different kinds of plastic material: Vulcanized rubber (N) Natural Rubber (R), and Silicon (B)

Figure 1. The modified labor saving machine Coima mod 105.

(Fig. 2). Finally, the teeth coated were tested at three different rotation speed V1 (2000 rev/min), V2 (3000 rev/min) and V3 (4000 rev/min). The speed of rotation of the teeth was controlled through the use of a mechanical revolution counter (DEUMO 2) with a measuring range of the number of revolution between 400 and 50,000 rev/min. It should be emphasized that the various coatings used were experimental and density/distribution along the rake was not optimal.

Figure 2. Comparison between different plastic material used for coated the teeth: from the left vulcanized rubber (G); natural rubber (C) and silicon (S).

Test equipment

The chain measurement was made up of an acquisition system of vibrations specific for the human body and a triaxial accelerometer. The acquisition system of vibrations (Larson Davis, model HVM1009) was used to conduct measurements relative to the hand-arm exposure using vibrating tools. A triaxial accelerometer, which allows to measure the vibrations along the three axes (x, y and z) simultaneously, was used. The accelerometer model was SEN020 PCB (ICP Company) with a sensitivity of 1 mV/g and a mass of 10 g. The position of the accelerometer was on the top of the grip, as this is the position in which it is possible to measure the vibration entering inside the hand. The accelerometer was positioned on the handle by means of a metal support tightened with a metal clamp, keeping the resilient material which envelops the handle grip.

Cultivars, number of plants subject to harvest

The olive harvesting test has been conducted on a farm specializing in the production of table olives situated in the plain of Ozieri (Northern Sardinia, Italy). The cultivar used is the "Manna" (*Olea europea L.*) collected in the first week of January to the green maturation. The olives were harvested from plants of the same age of 5 years, which presented multibranched vase-shaped (2.5 meters height) with the main branches about 70 cm from the ground to allow the placement of the catched nets under-tree. Each test was performed in duplicate,
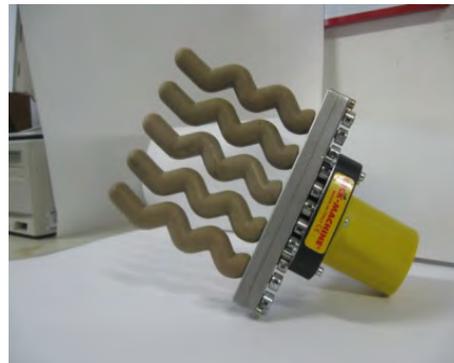
considering 27 trees under production (2 kg/tree average) and 27 trees with high production (4kg/tree average) disposed in neighbouring rows.

Statistical Analysis

The data of all tests were statistically analyzed with the software Minitab 16, by the simple analysis of variance (ANOVA) comparing the result of vibrations transmitted to the hand-arm used in different operating conditions (respectively 2000, 3000 and 4000 rev/min), of different materials used (natural rubber, silicon and vulcanized rubber) and the different thicknesses of protection products (7 mm 14 mm and 19 mm). The means were separated with the Kruskal-Wallis.

Results and discussion

1. Acceleration values on machines tested unloaded. Thickness: 7mm, 14mm and 19mm for teeth Red, Black and White (B, R and N.) and tested at three different number of revolution/min Rotation speed: 2000; 3000 and 4000 rev/min.

In all tests, with the teeth of a thickness of 7 mm and with a rotation equal to 2000, 3000, and 4000 rev/min, the values of acceleration equivalent are resulted to be different as evidenced by statistical analysis ($p \geq 0.05$).

The separation of the mean highlighted how the electric rake coated with materials more elastic (B and R) have provided acceleration values which would lead to the overcoming of the daily value of action permissible exposure (2.5 m/s^2) in all three rotation speed used. Only in the case of the use of rubber (R) and 2000 rev/min, the value of global acceleration is found to be lower (1.99 m/sec^2). With the use of a more rigid material (N), the acceleration value has been consistently lower and ranged between 0.42 m/s^2 at 2000 rev/min and 1.23 m/s^2 at 4000 rev/min. The acceleration values measured were significantly different to the three rotation speed also used for the thicknesses of 14 mm. These values are varied respectively from 3.19 to 0.69 m/s^2, for the three materials tested at 2000 rev/min, up to a maximum of 12.14 m/s^2 of the material B to 4000 rev/min. Furthermore, with the three operating conditions tested, the teeth coated with vulcanized rubber (N) had acceleration values respectively varying from 0.65 m/s^2 at 2000 rev/min up to the value of 1.16 m/s^2 at 4000 rev/min (Table 1).

The acceleration values collected for all the teeth R, B and N, with a thickness of 19 mm and at a speed of 2000 rev/min, were respectively 10.50 m/s^2, 5.35 m/s^2 and 3.88 m/s^2. For thickness 19 mm and with a rotation of 3000 rev/min, the maximum acceleration was equal to 11.96 m/s^2, 9.88 m/s^2 and 5.70 m/s^2. At the rotation of 4000 rev/min were generated acceleration values of 12.75 m/s^2 for the material B, 13.53 m/s^2 for the material R and 11.26 m/s^2 for the material N. The analysis of variance of the values of global acceleration, detected in the different types of plastic material, showed significant differences between the materials.

The evidence of unloaded tests could draw the following conclusions:

- the vulcanized rubber (N) reduces the amount of vibration transmitted to the hand than the other two materials at a speed of 2000 and 3000 rev/min;

- the action values of acceleration would be less than the daily limit allowed. The silicone (B) is stiffer than the rubber acquiring a behavior similar to vulcanized rubber in all tests. At the same diameter (19 mm, R) and rotation speeds ranging between 3000 rev/min. and 4000 rev/min, the silicone rubber and natural rubber seem to play a positive role in increasing vibration than rubber vulcanized (13.53 and 12.75 m/s^2 m/s^2 5.70 m/s^2 and 11 against, 26 m/s^2);

- the values of the measured acceleration with the first three heads are rather high (of the order of 13 m/s^2) and the thickness and type of the coating material of teeth positively affects on acceleration values obtained.

2. Acceleration values measured using the machines on olive trees. Thickness: 7mm, 14mm and 19mm for teeth Red, Black and White (B, R and N.) Rotation speed: 2000; 3000 and 4000 rev/min

The normal action of this machine is to cause the separation of the olives from the branch by impact of the teeth on the olives. To characterize the machine and the coatings of the experimental rake, were carried out simulations during the olive harvesting on some olive trees with the three thicknesses of protection at a speed of rotation of the comb equal to 4000 rev/min.

Table 2 shows the values of acceleration weighted with the machines used on olive trees only at the rotation speed of 4000 rev/min, but considering all the sizes of teeth coated (7 mm, 14 mm and 19 mm) and all the kind of material used (natural rubber, silicon, and vulcanized rubber). Analyzing the data, are possible the following considerations.

Rotation speed at 4000 rev/min and teeth coated with B, R and N. In this case, the B and N rake tested in working condition have produced dynamic acceleration levels increasing in function of the thickness. Different outcome had the rake type R. In fact, it, with a thickness of 14mm and a speed of 4000 rev/min, produced an acceleration value of 5.73 m/s^2, lower than the thickness of 7 mm (6.31 m/s^2) and that of 19 mm (9.59 m/s^2) (always at a rotation speed of 4000 rev/min). The value of maximum acceleration equal to 11.38 m/s^2 was produced by rake B (silicone) with a thickness of 19 mm and at a speed of 4000 rev/min, while the N rake had values of 7.19 m/s^2. Also during the dynamical combing, the teeth mounted in the harvesting head produced an abnormal kinematic behavior, due to the excessive thickness of the material used for the teeth coating.. For the 14 mm thickness the N had a value of acceleration equal to 3.92 m/s^2 (almost three times less than the teeth coated with material B, 11.37 m/s^2), while the R reported 5.73 m/s^2. For the thickness of 7 mm and 19 mm, using a rotation speed of 4000 rev/min, the lower acceleration values are 2.92 m/s^2 and 7.19 m/s^2 for teeth coated with the material N. For the thickness of 7 mm, the highest acceleration value is 6.48 m/s^2, produced by teeth B. For rake type R, the maximum acceleration was 9.59 m/s^2 for the thickness of 19 mm, while for the thickness of 7mm was 6.31 m/s^2 at the same rotation speed. The statistical analysis with rotation speeds of 4000 rev/min shows a significant difference in working conditions considered The significant statistical differences assigned to all the three materials three different behaviors, even if the minimum values of acceleration were recorded for all the tests conducted with the protective material with greater rigidity as that of N-type (Table 2).

From tree tests, it can be deduced that in tests on olive tree materials B and R appear to have a positive role in increasing vibration (from 6.48 m/s^2 for B to 6.31 m/ s^2 for R and 2.92 m/s^2 for N), with respect to the material N.

Conclusions

From the experiments conducted the following considerations can be drawn.

• The hand-arm vibration from the different rake models tested depend mainly from kinematics of the rake used, varying in the different trials from a minimum of 6.3 m/s^2 to a maximum of 22.4 m/s^2. Probably this aspect is the main element to be taken into account by the ergonomic point of view.

• With the same diameter (19 mm), silicon and natural rubber in all tests, compared to vulcanized rubber, produced higher levels of acceleration (17.89 m/s^2 silicone, 13.77 m/s^2 natural rubber and 11m/s2 vulcanized rubber).

• Also for the thicknesses of smaller diameter (14 mm), the silicon and natural rubber in all tests, with respect to the vulcanized rubber, produced higher levels of acceleration (14,51 m/s^2 silicone, 10.77 m/s^2 natural rubber and 4.24 m/s^2 vulcanized rubber).

Finally, even for the thickness of 7 mm was found the same results with the silicon and rubber with acceleration levels higher than the vulcanized rubber (12.28 m/s^2 silicon, 9.02 m/s^2 natural rubber and 5.93 m/s^2 vulcanized rubber).

• The statistical analysis showed similar behavior at speeds of 3000 and 4000 rev/min for the two materials of the elastic type, different from the more rigid material (vulcanized rubber).

• The action of the foliage certainly affects the level of acceleration transmitted to the hands of workers, because of olive trees have been recorded different global acceleration values.

• Finally, taking into account the measurements made during collection, can derive specific guidelines on the use of personal protective equipment.

Table 1. Global weighted acceleration measured on the three different types of onduline (silicone, vulcanized rubber and natural rubber) unloaded Thickness: 7 mm, 14 mm, 19 mm. Rotation speed: 2000 rev/min, 3000 rev/min, 4000 rev/min

Teeth	Thikcness	Operative condiction	Work	Global acceleration
Materials B = Silicon R = Natural rubber N = Vulcanized rubber	mm	numbers rev/min.	type of position	RMS (m/s^2)
B	7	2000	Unloaded	3,00 a
R	7	2000	Unloaded	1,99 b
N	7	2000	Unloaded	0,42 c
B	7	3000	Unloaded	7,39 a
R	7	3000	Unloaded	4,31 b
N	7	3000	Unloaded	0,69 c
B	7	4000	Unloaded	12,28 a
R	7	4000	Unloaded	6,65 b
N	7	4000	Unloaded	1,23 c
B	14	2000	Unloaded	3,19 a
R	14	2000	Unloaded	2,49 a
N	14	2000	Unloaded	0,65 b
B	14	3000	Unloaded	7,54 a
R	14	3000	Unloaded	4,02 b
N	14	3000	Unloaded	1,28 c
B	14	4000	Unloaded	12,14 a
R	14	4000	Unloaded	10,77 a
N	14	4000	Unloaded	1,16 b

B	19	2000	Unloaded	10,50 a
R	19	2000	Unloaded	5,35 b
N	19	2000	Unloaded	3,88 b
B	19	3000	Unloaded	11,96 a
R	19	3000	Unloaded	9,88 ab
N	19	3000	Unloaded	5,70 b
B	19	4000	Unloaded	12,75 a
R	19	4000	Unloaded	13,53 a
N	19	4000	Unloaded	11,26 b

Averages where do not appear the letter a are statistically different for p ≥ 0,05

Table 2. RMS acceleration measured on the olive tree tests with the three differnt types of onduline (silicone, vulcanized rubber and natural rubber). Thickness: 7 mm, 14 mm, 19 mm. Rotation speed: 2000 rev/min, 3000 rev/min, 4000 rev/min

Teeth	Thikcness	Operative condiction	Work	Global acceleration (RMS)
Material B = Silicone N = Vulcanized rubber R = Natural rubber	mm	rev/min	Olive tree	(m/s^2)
B	7	4000	combing	6,48 a
R	7	4000	combing	6,31 a
N	7	4000	combing	2,92 b
B	14	4000	combing	11,37 a
R	14	4000	combing	5,73 b
N	14	4000	combing	3,92 c
B	19	4000	combing	11,38 a
R	19	4000	combing	9,59 b
N	19	4000	combing	7,19 c

Averages where do not appear the letter a are statistically different for p ≥ 0,05

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Comparison of noise level of tractors with cab and without

Mehrzad Payandeh[1], Mansoor Behroozi Lar[2]
[1]M.Sc. Student in Agricultural Mechanization, Islamic Azad University, Shoushtar branch,Shoushtar, IRAN.
[2] Department of Agricultural Mechanization, Shoushtar Branch, Islamic Azad University, Shoushtar, IRAN.
Tel 00989371090172
Email corresponding Author: Payandeh.mehrzad@hotmail.com

Keywords: noise, tractors, cabin

Objectives
"Noise" or "unwanted sound" is one of the major sources of discomfort to the workers which affects human both psychologically and physically. Tractor operator comfort is affected by how much noise of tractor produces during continuous operation. Noise at work in agriculture or horticulture can cause hearing loss.

Methods
A tractor without cabin and one with cabin (closed window and open window) loaded with mounted moldboard plow and disk harrow were tested for noise level in different gears at the driver's ear and bystander ear. The permissible exposure time for safe hearing effect was calculated. The sound level trend versus gears was also shown.

Expected Results
Results showed that the Sound Pressure Level (SPL) at the driver ear for the tractor without cab in all gears ranging from a low of 91 dB(A) to a high of 93 dB(A) were more than NIOSH allowable 85 dB(A) criteria for eight hour of operation. All domestically manufactured in Iran are without cabin. The SPL of the tractor with open windows cab with a range of 86 to 88 dB(A) was also higher than the standards but lower than that for the tractor without cab. Loading with moldboard and disk did show significant effect at Hi 1 gear for no cabin and open window cabin. The SPL for closed cabin in all cases stayed below 82 dB(A). It was concluded that the driver should either stay on driving for less than 2 hours with tractors without cabin and open window cabin or the only best way, the tractors should be equipped with factory made cabins.

First surveys on chainsaw operators' hard wood dust and exhaust gases exposure: a Tuscan project

Volpi D.[1], Sciarra G.[2], Nannicini C.[1], Fabiano F.[3], Marchi E.[3], Neri F.[3], Piegai F.[3], Poggi L.[3]

(1)Tuscany Region – Prevention and Work Protection Department - Via Taddeo Alderotti, 26– 50139 Florence - ITALY Tel + 39 0554383215 Fax +390554383058 daniela.volpi@regione.toscana.it, cecilia.nannicini@regione.toscana.it
(2)Local Health Unit n. 7 Siena – ITALY, g.sciarra@usl7.toscana.it
(3)DEISTAF -University of Florence Via S. Bonaventura, 13 – 50145 Florence - ITALY Tel + 39 05530231271 Fax +39055319179 fabio.fabiano@unifi.it, emarchi@unifi.it, francesco.neri@unifi.it, piegai@unifi.it, lorepoggino@hotmail.it
Email corresponding Author: cecilia.nannicini@regione.toscana.it

Keywords: wood dust, chainsawer safety, exhaust gases

Objectives

In 2010 the Tuscany Region promoted a research project on the evaluation of the forest operators' hard wood dust and exhausts gases exposure in chainsaw cutting operation and in chipping operation, using a standardized survey methodology.

The primary aim of this project is to correlate the chainsaw working time with the dust polluting amounts measured in different forest sites and working operations (coppice clear cut, softwood thinnings or sanitary cut) and to highlight the operational aspects and the operator behaviours that may maximize the exposure to the polluting agents.

Methods

The mass concentration of respirable particles and total dust at the workplace was determined by the method of personal collectors (Button Sampler, Iom plus Xad, Radiello) connected to different air pumps. The surveys were focused on the collection of: the hard wood dusts, the polycyclic aromatic hydrocarbons (PAHs) and the values of benzene, toluene, etilbenzene and xilene present in the exhaust gases.

Results

One of the most important result is the reduction of the polluting agents concentration measured by personal collectors using the special fuels (alkylate petrol) for chainsaws in comparison to the normal fuels usually adopted.

Conclusion and Perspectives

Concerning the hard wood dusts concentration analysis in processing fuelwood and in softwood thinnings different results were observed. In coppice clearcut or in softwood pruning concentrations were quite similar to the limit values of 5 mg/m³, allowed by the European Union. At the same time an high influence of the survey season (winter or summer), the operators' working methods and the tree species was also highlighted.