Topic 3
"Safety in field and in greenhouses"

Oral Presentation

A New European Standard for cab Filters Performance Evaluation: Content and Criticism

Balsari P.[1], Ghigo D.[1]
[1]*University of Torino. DEIAFA, Mechanics Section*
Via Leonardo da Vinci, 44 – 10095 Grugliasco (TO), ITALY.
Tel 0039 011-6708587 paolo.balsari@unito.it

Abstract
When driving tractors and self-propelled machines the operator could be exposed to hazardous substances such as dust, aerosols or vapours (for example during the application of plant protection products or fertilisers).
Cabs of agricultural tractors and self-propelled machines provided with filters could reduce operator exposure by air-borne contaminants generated during farming operations if the air filtering is appropriate and correctly functioning. To give indication to cabs and filter manufacturers on these latter aspects a European Standard was developed (EN15695).
This European Standard will be applicable to filters and cabs of agricultural and forestry tractors and self-propelled sprayers.
Its purpose is to limit the exposure of the driver to hazardous substances like PPP and liquid fertilisers. It also specifies the information to be provided by the tractor or self-propelled sprayer manufacturer.
The proposed classification includes 4 categories of cabs and 3 categories of filters.
Critical points.
Currently few cabins are equipped with internal pressurization and practically no one has a pressure gauge as required by the Standard.
The main critical points in achieving a greater level of safety for the operator are:
- **the standard failure in defining the useful life of filters which depend also on the PPP used;**
- **the small size of the filters which also limits their duration and effectiveness;**
- **the impossibility to install in the actual cabs both dust filters and activated carbon filters.**

Keywords: European Standard, cab filters, operator safety,

Introduction

During the application of plant protection products and fertilizers the operator that is on board of tractors or self-propelled machines can be exposed to hazardous substances such as dusts, aerosols or vapour.
Analyzing all the operations related to the preparation of the pesticide mixture and its distribution, the most hazardous ones or with the higher possibility of a direct contact between the operator and pesticides are:

- filling and emptying the main sprayer tank;
- distribution of the pesticide mixture on the crops;
- washing the tank and the empty PPP can;
- sprayer and component (nozzle, filters) maintenance.

The operator's exposure to plant protection products is documented by several studies (Hamey, 1999; Vercruysse et al., 1999; Mazzi et al., 1999) and especially occurs when, during the pesticide distribution, tractors without protection cab are used.

Among the measures that farmers must adopt to ensure their safety (e.g. personal protective equipment – PPE) it's important to use security cab accompanied by appropriate filters to isolate the operator from the outside. Tractors and self propelled machines cabins equipped with filters can reduce operator exposure to air pollutants only if the filtering system is appropriate and properly functioning.

Use of cabins and filters

In the last years the use of tractors equipped with cab protection has gradually increased as well as a greater spread of the use of filters suitable for operator protection. In 2002 one third of the tractors used for pesticide application in orchards in the countryside of Saluzzo (province of Cuneo, Piemonte Region, North west of Italy) was still without cabin or with cabin devoid of any type of filter (Figure 1). This means that the operator in all these cases should use appropriate PPE to ensure his own safety. In reality only 70% of them declared to use gloves, mask and suit, whereas the 10% to use not any protective clothing (Figure 2) (Balsari, Oggero, 2002).

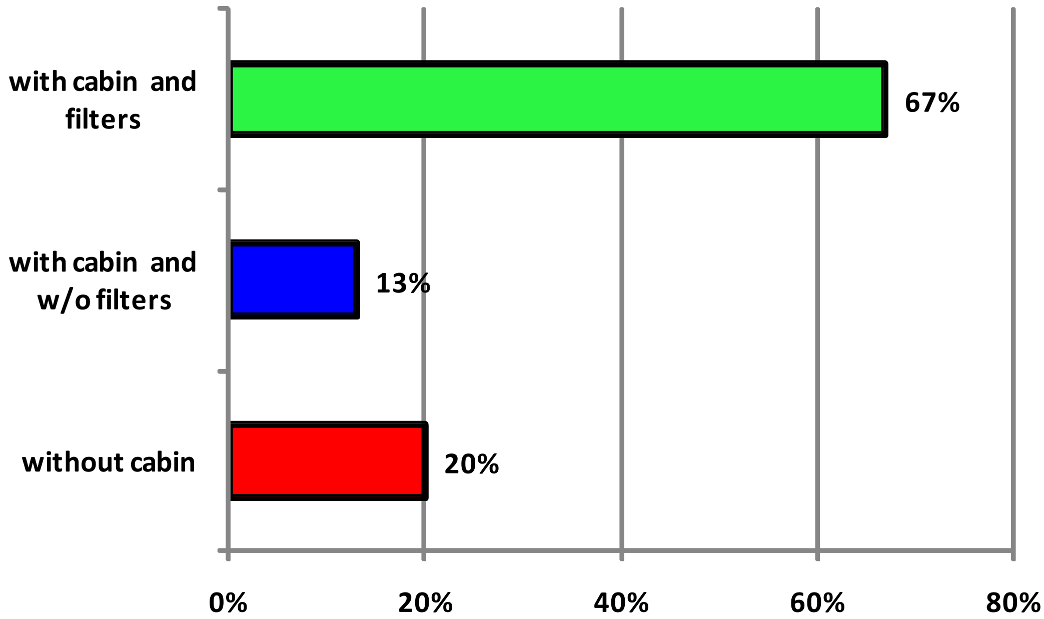
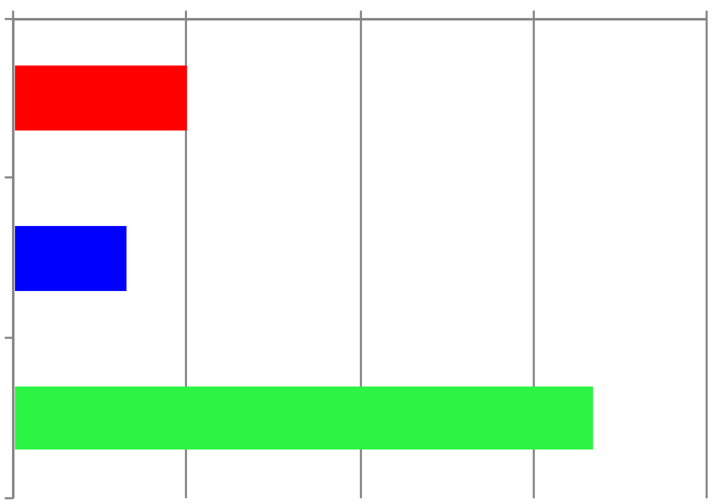


Figure 1– Diffusion of farm tractors with isolated cabin in north west Italy orchard areas in year 2002 (results of an inquiry made by DEIAFA – University of Torino



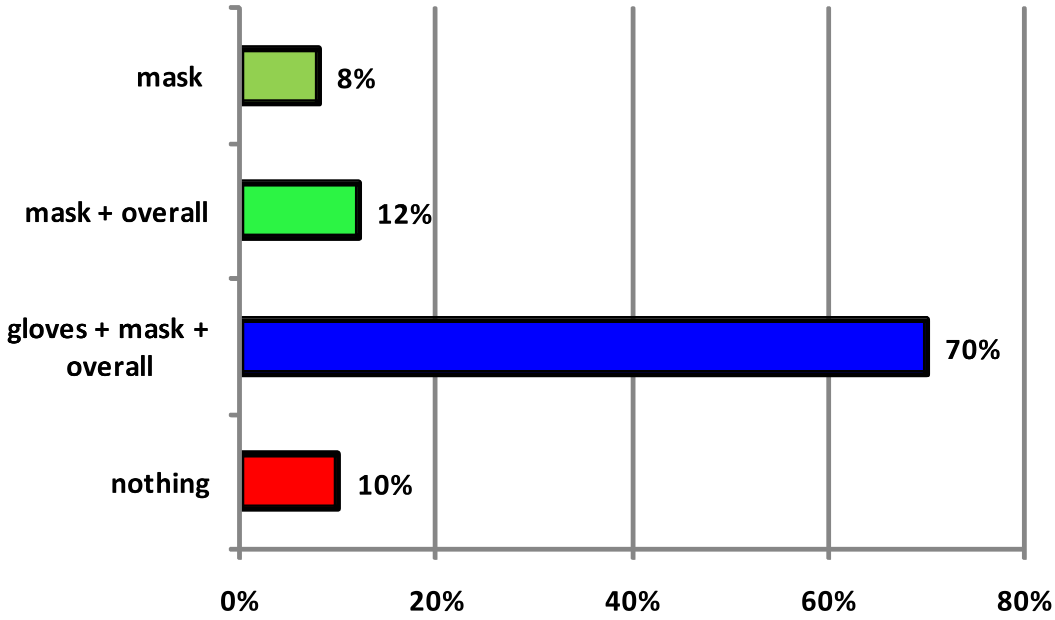


Figure 2 - PPE used by farmers who use tractors without cab or with a cabin without filters (results of an inquiry made by DEIAFA – University of Torino)

According to the results of that investigation, it can therefore be said that the majority of farmers are exposed to risks associated with PPP when using tractors equipped with cabin without proper protective filters. This occurs because the cab presence provides the operator a false sense of safety leading to underestimate the risk of contamination.
It is also necessary to consider that most of the tractor models are still sold without an appropriate protective cabin set. Currently there is a wide choice for farmers. All tractors and self propelled machines manufacturers can essentially provide three levels of technology to protect the drivers: tractor without a cab, tractor with cab but without activated carbon filters or pressurized cabs accompanied by appropriate activated carbon filters for protection against the main types of pollutants.
The last version is the only one that, when properly installed and used, can provide an adequate protection for the operator. The use of activated carbon filters ensure clean air inlet. Moreover, the pressurized system prevents the entry of contaminants through points with a non-perfect coupling between the cab and the tractor.
The best performance can be achieved if the tractor is designed and already put on the market with a protective cabin, whereas the latter is often installed at a later time and it is made by a different manufacturer.
The tractor driver level of protection is the result of combining the protection provided by the filter, the cabin design and their combination.
In order to provide common methodologies for the operator safety evaluation of these two components a European Standard (EN15695:2009) has recently been developed.

The European Standard

The EN15695 standard is composed of two parts:

- EN15695-1 describing the cabin classification requirement and test procedure;

- EN15695-2 describing the test procedure to assess filters performances and their functional requirements.

The standard applies to filters and cabins for agricultural and forestry tractors and self propelled machines. Its purpose is to limit the exposure of the driver to dangerous substances such as pesticides and liquid fertilizers.
The standard also indicates information that the manufacturer must provide within the instruction handbook.
The application of this standard filters and/or cabins manufacturers, can now asses unequivocally the benefits of their products in terms of operator safety.
The classification proposed by the standard provides four categories of cabins:

1. cab not providing a specified level of protection against hazardous substances;
2. cab providing protection against dust(s);
3. cab providing protection against dust(s) and aerosols;
4. cab providing protection against dust(s), aerosols and vapours;

and 3 categories of filters:

1. dust filters;
2. aerosol filters;
3. vapour filters.

a) <u>EN15695-1</u>

Cabins performance evaluation

The tests to which cabins must be submitted are:

- performance of the ventilation system: fresh air flow and presence and intensity of internal pressurization;
- tightness of the air delivery and filtration system (relative leakage);
- isolation effectiveness of air delivery and of the filtration system installed in the cab.

The ***intensity of the cab internal pressurization*** is defined by the difference between the static pressures inside and outside the cab; it shall be measured for each air delivery and filtration system rating tested and it shall be at least 50 Pa or 20 Pa, if a pressure indicator is provided.

The ***new air flow rate*** is measured by channeling the air to the diffusers and measuring the air discharge velocity by anemometry.

The ***relative leakage*** (L_r) is determined by the following relationship:

$$L_R = \frac{Q_2}{Q_1}$$

where:
Q_1 is the air velocity measured with the anemometer at the inlet side of the test hood;
Q_2 is the air velocity at the inlet side of the test hood.

The relative leakage shall be: LR < 2 %.

The *isolation effectiveness* is measured by placing the cab under test in a large closed room in which an aerosol is generated. The isolation effectiveness is determined from the aerosol concentrations measured by an optical counter inside and outside the cab.
The test aerosol is obtained by spraying NaCl or KCl salt solution at 1 % in distilled water. A helical fan generating a flow rate of 4 000 m3·h^{-1} to 5 000 m3·h^{-1} ensures a homogeneous aerosol concentration in the volume.
The aerosol concentration will be between 7 x 104 particles per litre ($d_p \geq$ 0,5 µm) and the maximum concentration corresponding to the saturation limit of the optical counter used. This data, which is generally defined for a coincidence rate of 10 %, is supplied by the manufacturer.
The generator shall be capable of producing droplets having a median diameter by volume between 10 µm and 15 µm inclusive.
The isolation effectiveness of air delivery and filtration system installed in the cab shall be at least by 98%.

In the Standard it is also mentioned that in the instruction and maintenance handbook intervals for replacement of filters and proper methods of use must be specified.

b) EN15695-2

Characterisation of Filters Performance

The filters performances requirement are the following:

- ability to retain small dust particles (Figure 3) in the air flow;
- capacity to retain aerosols inside the air flow in a timeframe of 20' and with maximum concentration downstream the filter of 0.05%;
- penetration of a gas (cyclohexane) inside the air flow in a time of 70' and with a concentration upstream the filter of 500 µg/g and 10 µg/g downstream.

The tests above described should be carried out after submitting the filter to a procedure of preconditioning. At this stage, the sample should be subjected to vibration and shock in order to simulate the conditions of transport, storage and use of the filter.

The effectiveness against *dust* shall be checked by placing the filter in the orientation of that in the cab. The airflow shall be the same of that measured in the cab, at the air delivery and filtration system inlet, in the highest flow rate operating condition. The temperature shall be (23 ± 2) °C. The relative humidity shall be (80 ± 3) %.
The filter media shall be tested for fractional efficiency in accordance with ISO 14269-4 (Figure 3) over 30 min with a fine dust concentration of 1 g/m3.
The air delivery system filter shall have a performance of ≥ 99 % gravimetric efficiency.

Size µm	Fine grade % (V/V) max.	Coarse grade % (V/V) max.
≤5.5	38±3	13±3
≤11	54±3	24±3
≤22	71±3	37±3
≤44	89±3	56±3
≤88	97±3	84±3
≤125	100	100

Figure 3_Particle size distribution by volume described in ISP 14269-4

The effectiveness against *aerosols* of filters shall be checked during a period of 20 min at the maximum flow rate when tested with paraffin oil or DEHS or DOP.
The maximum aerosol penetration shall be ≤ 0,05 %.

The effectiveness against *vapours* of filters shall be checked with cyclohexane (C6H12), for 70 min, with a test gas concentration of 500 µg/g upstream the air delivery and filtration system.
Downstream the filter, the test vapour concentration shall not exceed the threshold of 10 µg/g throughout the entire test.

Main criticisms

The EN 15695 standard, as indicated in paragraph 1, does not cover:

- the exposure linked to fumigants;
- the category of cab and performance level to be used for any particular application;
- the actual cab performance in field applications;
- the field endurance of filters.

The most critical issues, identified by the analysis of EN 15695 concerning:

- no indication of the useful life of filters depending on their operating conditions and/or methodologies relevant to its determination;
- the complexity of the tests and their cost.

From a practical point of view should be also underlined that:

- the size of the filters, often related to the construction requirements of the cabins, affect its useful life (Figure 4);
- for the same reason, it is often not possible to mount an anti-dust filter to protect the activated carbon filter;
- no devices are available on the market indicating the exhaustion of the filtering capacity of activated carbon filters.
- there is often a reduced or none availability of spare activated carbon filters.

Currently the tractor instructions handbooks do not provide the user with any information concerning the filtration systems and the intervals for filters replacement .
The filters tend to clog the dust as they approach their exhaustion and thus indirectly protect the operator from exposure to external chemical agents. On the other hand, an activated carbon filter, with the unwinding of its filtering capacity does not limit its permeability. Thus, in the latter case the operator does not knows if the filtration system is working properly.
In agricultural practice is often advisable to install the activated carbon filters only before pesticide application in order to protect filters from dust and preserve their functionality for a

long time. Nevertheless, it is necessary to consider that under certain operating conditions, the presence of dust from soil, itself inert and not dangerous for the operator, it is common and extremely detrimental to the effectiveness of the filters themselves. Having to exchange the type of cab filters many times during the year it may happen that the operator does not know with absolute certainty which type of filter it is installed on his tractor. To solve this problem it could be useful to have a system for filters recognition. Moreover, in order to prolong the useful life of activated carbon filters and maximize the operator protection, to use a filtering cascade.

Cabins manufacturers have the tendency to increase the maneuverability of tractors for orchards and vineyards, to reduce as much as possible their sizes. However, that requirement has many effects on shape and size of filters and on their functionality due to the reduced availability of space.

This drawback could be overcomed by redesign the cabin, putting as priority the welfare and health of the operator.

It should be also underlined that working with the best filtration system does not ensure the reduction and removal of hazards for the driver. It is common, even during pesticide treatments, the use of tractor with portions of the cabin open for example, to facilitate the entry of commands used to control trailed sprayers or to reach them in case of mounted sprayers (Figure 5) or to cool the interior of the cabin down if the tractor has no air-conditioning system.

In order to ensure the maximum operator safety, besides on technical equipment of machines, it should be important to invest, on raising their awareness and training on safety aspects.

Figure 4_ Particular of cabin filter housing

Figure 5_ Rear window open to allow passage of piping

Conclusion

The tests described in EN 15695 are characterized by both a certain complexity and high performing costs. This may be an obstacle for the research and the development of new types of cabs or for the use of new filtering materials. Due to the high cost linked to the wide number of cab models and filters, it will be difficult to get the certification of all materials available on the distribution network.
Moreover, this Standards should be extended by including tests focused at the determination of the filters useful life.
In order to increase the operator safety it might be useful to provide the farmer with a quick and easy method to verify the functionality of carbon filters.

References

EN 15695-1:2009 Agricultural tractors and self-propelled sprayers - Protection of the operator (driver) against hazardous substances - Part 1: Cab classification, requirements and test procedures

EN 15695-1:2009 Agricultural tractors and self-propelled sprayers - Protection of the operator (driver) against hazardous substances - Part 2: Filters, requirements and test procedures

BALSARI P., OGGERO G. (2002) La sicurezza dell'operatore durante la preparazione e la distribuzione della miscela fitoiatrica alle colture frutticole

HAMEY P.Y. (1999) - Assessing risks to operators, bystanders, and workers from the use of plant protection products. In: Human and environmental exposure to xenobiotics (AA.VV.), La Goliardica Pavese, Pavia, pag. 619-631.

MAZZI F., CAPRI E., TREVISAN M., GLASS C.R., WILD S.A. (1999). Potential operator, bystander and environmental exposure in sloped vineyards. In: Human and environmental exposure to xenobiotics (AA.VV.), La Goliardica Pavese, Pavia, pag. 731-736.

VERCRUYSSE F., STEURBAUT W., DEJONCKHEERE W. (1999). Exposure to pesticides in apple and pear orchards. In: Human and environmental exposure to xenobiotics (AA.VV.), La Goliardica Pavese, Pavia, pag. 639-647.

The Effect of Task Frequency on Risk of Biomechanical Overloading of the Upper Limbs in Manual Pruning in Vineyards

Bonsignore R.[1], Camillieri D.[1], Rapisarda V.[2-3], Schillaci G.[1]
[1]*University of Catania. DIA, Mechanics Section*
Via Santa Sofia, 100 – 95123 Catania, ITALY.
Tel. +39 095 7147512, Fax +39 095 7147600, giampaolo.schillaci@unict.it
[2]*Occupational Medicine, Policlinico Universitario "G. Rodolico", via S. Sofia 78, 95100 Catania ITALY. Tel. +39 095 7021 412 e-mail: nandorapisarda@libero.it*
[3]*Occupational Medicine, Azienda Foreste Demaniali, Enna, ITALY.*

Abstract

Among the factors affecting the risk of biomechanical overloading of the upper limbs, repetitiveness is certainly the most important. In manual pruning of vineyards repetitiveness is closely linked with the frequency of cuts and technical actions in unit time. The aim of the research was to assess the interaction between independent variables (tool used for pruning, vine cultivars pruned, work times) and the variable dependent (cut frequency). The data collected made it possible to extract the representative frequency for time periods and calculate the Ocra Index for each period, to compare the results obtained with the index calculated on the basis of the average daily frequency and, finally, to trace the progress of the work productivity curve during the day. The action frequency was evaluated with analytical counting of the technical actions by re-examining video films of the work in slow motion. Statistical analyses were carried out with the publicly available software R. Statistical analysis of cut frequency was carried out using data collected from 18 pruning operators. Two tools (traditional shears and long handled hacksaws), three cvv (Nero d'Avola, Merlot, Nerello mascalese) and three different time periods were considered. Eight repetitions were carried out for each pruning operator. The influence of the above factors was extrapolated by means of variance analysis (ANOVA). Subsequently, given the highly significant results for the first and second order interactions, in two pruning sites (traditional shears and long handled hacksaw) the respective daily work productivity curves of the workers were found, further sub-dividing the work day into thirty minute periods. The analyses confirm the great significance of the interaction of the independent variable, even if it cannot be seen which of the variables is the most significant. The workers' work productivity curves depends not only on the characteristics of the site (species and growing method, tool used for pruning, etc) but above all on the tiredness of the operator, which varies during the day, following a sinusoidal curve similar to that found in other work sites (CNR, 1981).

Keywords: OCRA, WMSDs, vine cultivation, productivity

Introduction

Among the factors affecting the risk of upper limb biomechanical overloading, which can, in time, provoke damage to the muscular-skeletal system (*WMSDs*, *Work related Muscolo Skeletal Disorders*), repetitiveness is the most important (*Colombini et al.*, 2005).
From recent studies (*Regione del Veneto*, 2008) it would seem that there is evidence of an association between repetitiveness of gestures and upper limb pathologies, above all those affecting the neck, shoulder and hand wrist system. There is no certain evidence that the elbow is affected.

Traditional literature defines as repetitive work characterised by cycles lasting less than 30 seconds (2 cycles/minute) or when 50% of the work time, irrespective of duration, is spent carrying out the same gesture or sequence of gestures (*Silverstein et al.*, 1986, 1987).
Repetitiveness is, therefore, closely connected to action frequency, that is to say the number of technical actions in unit time (actions/minute). By technical action what is meant is an action involving mechanical activity that can be identified with a set of movements (of one or more segments of the upper limbs) that permits the carrying out of an operation aiming at a pre-determined operation, and not a single gesture or single biomechanical movement (*Colombini et al.*, 2005).
In manual vineyard pruning, which is characterised by exposure to risk, the repetitiveness is closely linked to the frequency of cuts and the associated technical actions (*Montomoli et. al.*, 2008; *Schillaci et al.*, 2009, 2010).
The aim of the research was to assess the effect of the factor frequency on the calculation of upper limb skeletal-muscular risk. Once the variability of frequency (hourly productivity) had been calculated for different periods of the day, the Ocra Index was calculated with the weighted mean frequency and this was compared with the value calculated with the mean daily frequency.

Materials and methods

The manual pruning was broken down into basic components (C.I.O.S.T.A. - A.I.G.R. methodology), this also revealing times and methods of operation executions.
The technical actions and the frequency of gestures were assessed both in the field and by re-examining the video films of the work in slow motion. The statistical analysis was carried out by means of the publicly available software Assistat ed R.
The data was collected from a sample of 18 professional pruners, with 8 repetitions for each of them. The factors taken into consideration were: the two tools used (traditional secateurs and long handled saw, the three cultivars (Nero d'Avola, Merlot, Nerello mascalese) and the three different time slots (7÷9 - 9÷11 - 12÷15). The influence of the factors was extrapolated with variance analysis (ANOVA).
Once the normal distribution of the frequencies found in the field had been evaluated and the factors influencing them highlighted, the Ocra indices were calculated and the daily productivity curves traced.
The Ocra indices were calculated for two pruning sites – one using traditional secateurs and one using a long-handled saw. For each site the indices were calculated with the mean daily frequencies and the mean frequency for time slots, dividing the working day (7 p.m. ÷ 3 p.m.) into hourly periods. The strain value was obtained from the opinions expressed by the pruners and a recovery time suitable for every hour of work was considered. The calculation only took into consideration the dominant limb, which is the one most exposed to tiring.
The daily productivity curves were found for both sites, further sub-dividing the working day (7÷15 p .m.) into thirty-minute periods.

Results

Frequency analysis

1) Normality finding.

Tab. 1 – Normality analysis

NORMALITY (a = 5%)				
Test	Value	Vkrit	p-value	Normal
Kolmogorov-Smirnov (D)	0.07699	0.10437	p > .15	Yes
Cramér-von Mises (W2)	0.05546	0.12513	p > .15	Yes
Anderson-Darling (A2)	0.36470	0.74900	p > .15	Yes
Kuiper (V)	0.12350	0.17250	p > .15	Yes
Watson (U2)	0.04911	0.11520	p > .15	Yes
Lilliefors (D)	0.06310	0.10442	p > .15	Yes
Shapiro-Wilk (W)	0.98099	0.34772		Yes

The analyses carried out with the tests indicated in table 1 gave the normal distribution of the data collected and this enabled adaptation to a linear model for the ANOVA test.
The distribution of the data for the mean cut frequency (*Fig. 1*) was 23.40 cuts/min (σ = 4.76).

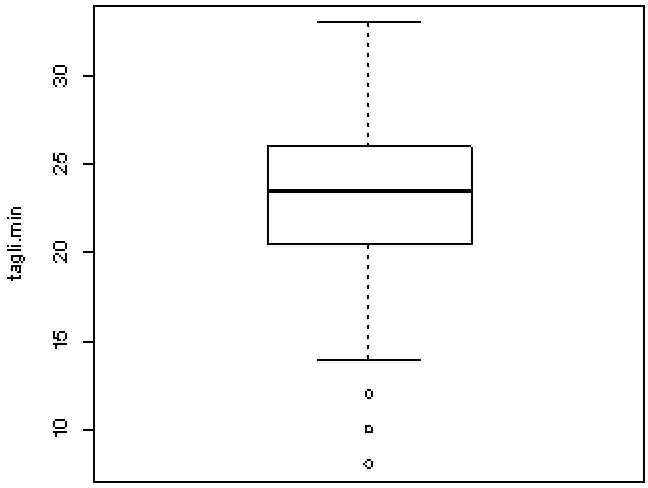


Fig. 1 – Distribution of mean frequency data

2) ANOVA analyses.
The aim of the analyses was to establish the significance of the independent variables (tool used for pruning, cultivar pruned, time of work) on the cut frequency effect (dependent variable).
From the analyses it emerges that all the factors considered have great statistical significance. The repetition (*Fig. 2*) does not have significance and hence the experiment shows great repeatability.
The mean frequencies found for the instruments (*Fig. 3*) were 22.57 cuts/min (σ = 4.88) for the secateurs and 25.88 cuts/min (σ = 3.43) for the shears.
The mean frequencies found for the cultivars were 24.58 cuts/min (*Fig. 4*) (σ = 4.88) for Nero d'Avola, 20.00 cuts/min (σ = 6.20) per Merlot and 24.50 cuts/min (σ = 3.47) for Nerello mascalese.

The mean frequencies found for time periods (*Fig. 5*) were 24.06 cuts/min (σ = 5.51) for time period 7÷9, 21.53 cuts/min (σ = 4.02) for time period 9÷11 and 25.87 cuts/min (σ = 3.58) for time period 12÷15.

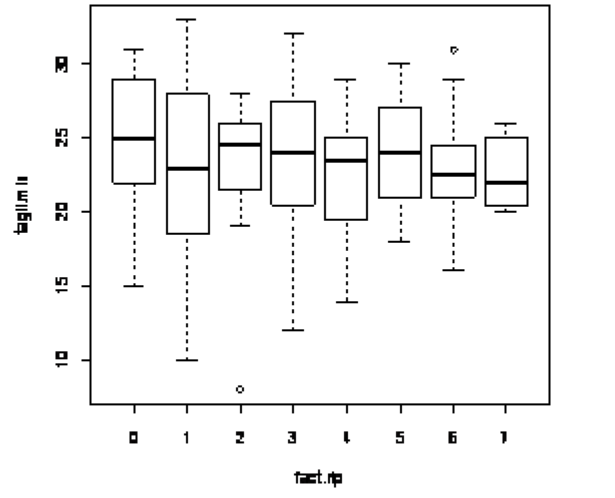


Fig. 2 – Mean frequencies for repetitions

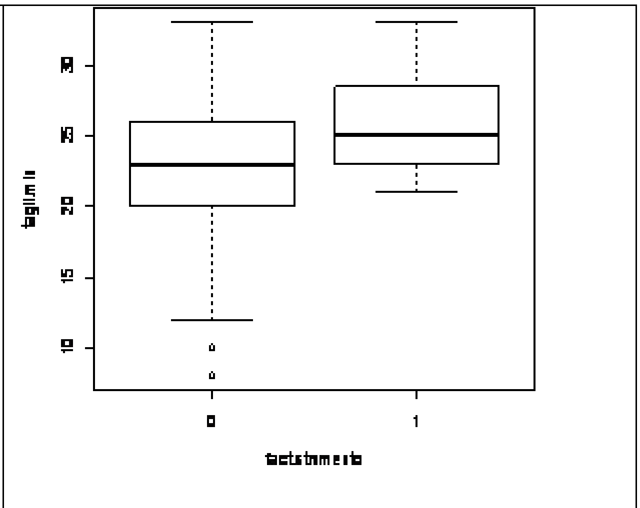


Fig. 3 – Mean frequencies for tools

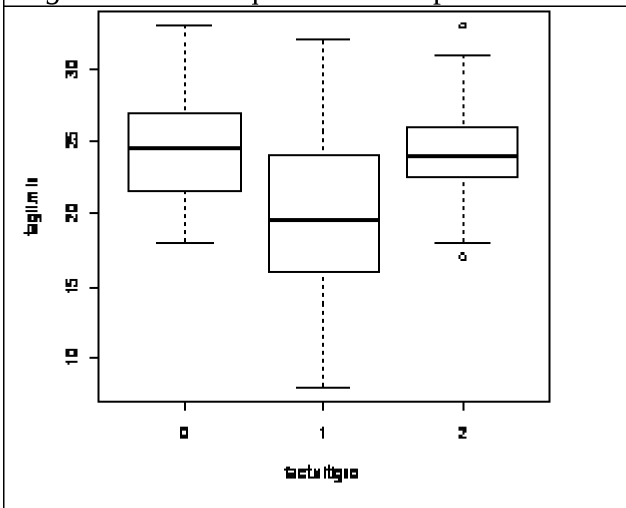


Fig. 4 – Mean frequencies for cultivars

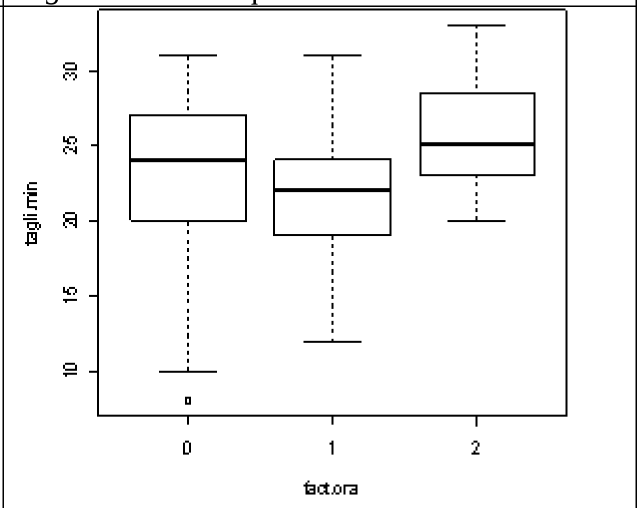
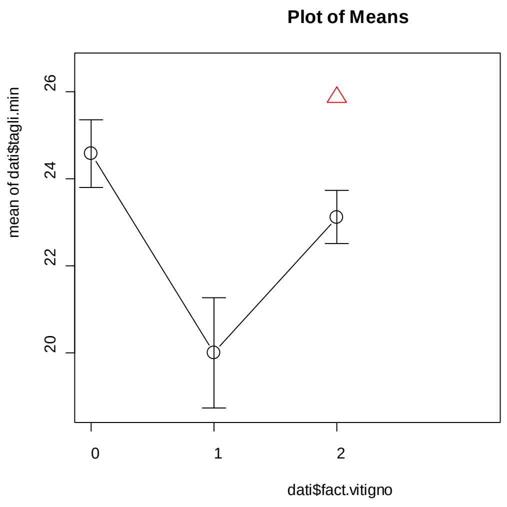


Fig. 5 – Mean frequencies for time periods

3) Execution of multiple comparison tests to show differences between the means. From the Tukey test on data from the cut carried out with shears performed with an experimental design is a factor analysis, it can be seen that the cultivars Nero d'Avola and Nerello mascalese cause a similar effect, while the frequency for the cultivar Merlot seems to be much lower (*Fig. 6*). As regards work periods, the times 7÷9 - 9÷11 have a similar effect while the third time period, after the lunch break, has a different effect (*Fig. 7*).

4) Execution of Tukey test on data sample from completely random experiment. From the Tukey test carried out on data samples from the two instruments to be compared, conducted with an experimental design and completely random experiment, it was found that the cases analysed (12 in total) gave similar values, but that three results are noticeably lower than the others. These all regard the use of secateurs in the second time period (9÷11) for all three cultivars.


Plot of Means
mean of dati$tagli.min
20
22
24
26
0
1
2
dati$fact.vitigno

On the "secateur" site, the daily exposure index is 4.1. On the "saw" site the daily index is 4.5. In both cases the index can be considered to belong to the 'slightly red' belt, ie to a slight exposure risk.

Productivity indices

The productivity indices were calculated for both sites (Tabs. 4 and 5). These were derived from the relationship between the hourly productivity and the mean daily productivity (CBR, AA.VV.,1981)

Tab. 4 – Pruning work productivity in "secateur" site

		Productivity	**Mean productivity**	**Producvity index**	**Difference**	**Ocra Index**
Time period		cuts/(h*op.)	cuts/(h*op.)	%	%	
7	7.30	1185	1342	88.27	-11.73	3.6
7.30-	8	1440		107.26	7.26	4.4
8	8.30	1635		121.79	21.79	5.0
8.30	9	1605		119.55	19.55	4.9
9	9.30	1485		110.61	10.61	4.5
9.30	10	1410		105.03	5.03	4.3
10	10.30	1200		89.39	-10.61	3.7
10.30	11	735		54.75	-45.25	2.2
11-12		Break				
12	12.30	1020	1342	75.98	-24.02	3.1
12.30	13	1365		101.68	1.68	4.2
13	13.30	1560		116.20	16.20	4.8
13.30	14	1500		111.73	11.73	4.6
14	14.30	1350		100.56	0.56	4.1
14.30	15	1305		97.21	-2.79	4.0

Tab. 5 – Pruning work productivity in "saw" site

		Productivity	Mean productivity	Productivity index	Difference	Ocra Index
Time period		cuts/(h*op.)	cuts/(h*op.)	%	%	
7	7.30	1290	1461	88.27	-11.73	3.9
7.30-	8	1350		92.38	-7.62	4.1
8	8.30	1560		106.74	6.74	4.8
8.30	9	1530		104.69	4.69	4.7
9	9.30	1620		110.85	10.85	4.9
9.30	10	1440		98.53	-1.47	4.4
10	10.30	1470		100.59	0.59	4.5
10.30	11	1410		96.48	-3.52	4.3
11-12		Break				
12	12.30	Break				
12.30	13	1110	1461	75.95	-24.05	3.4
13	13.30	1380		94.43	-5.57	4.2
13.30	14	1710		117.01	17.01	5.2
14	14.30	1440		98.53	-1.47	4.4
14.30	15	1560		106.74	6.74	4.8
		1590		108.80	8.80	4.8

From the values obtained the curves representing the work productivity in both sites were drawn up (*Figs. 8 and 9*).

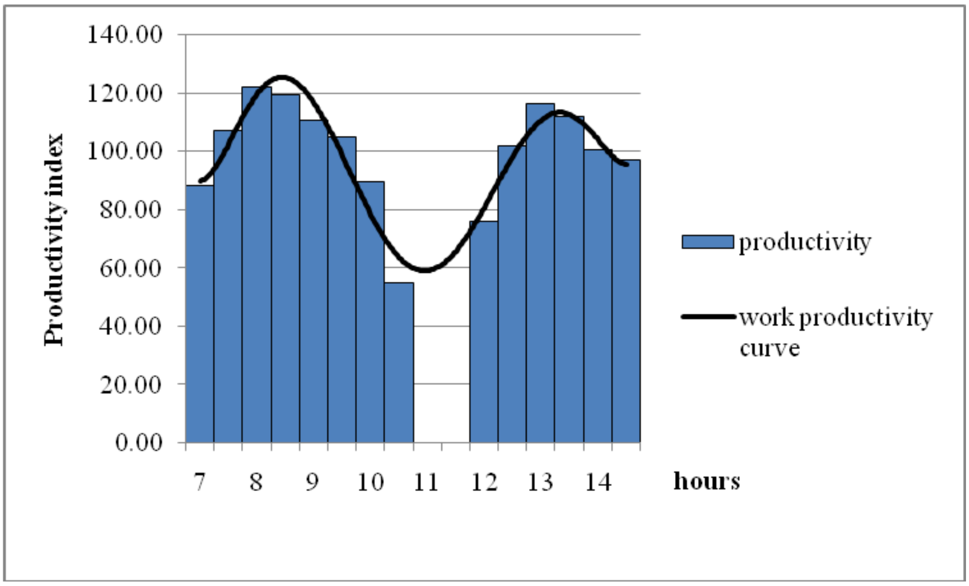


Fig. 8 – "Secateur" site – Work productivity curve

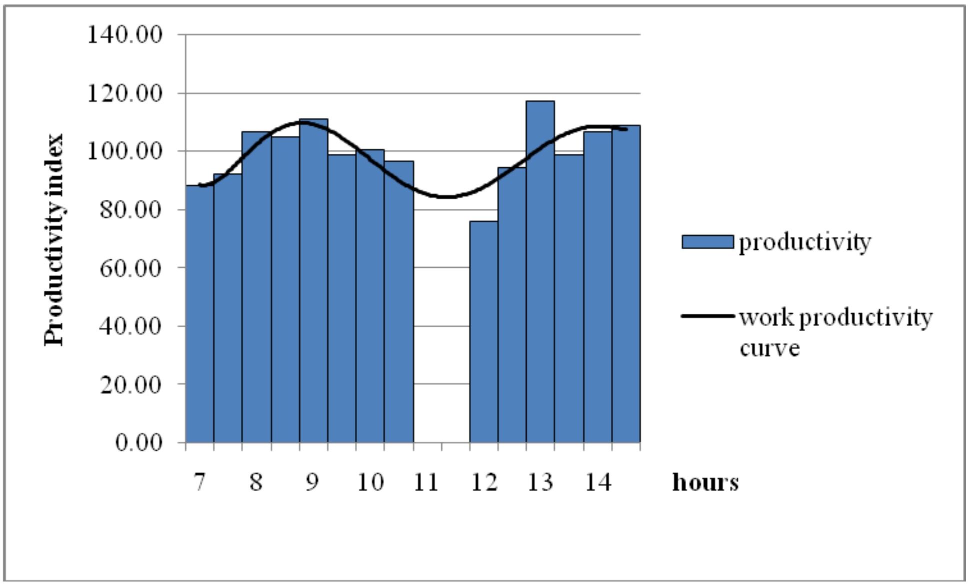


Fig. 9 – "Saw" site – Work productivity curve

Looking at both the pruning sites, it can be seen that the mean productivity is higher for the "saw" site, with , on average, 119 cuts more per hour (about 2 per minute).
On the "secateur" site greatest productivity is reached between 8-9 and the curve shows two peaks corresponding the 8-9 and 13-14 time periods. There is least productivity between 10-11 after three hours of work and just before the lunch break. In fact between 10.30 and 11 there is a 45.25% reduction in productivity.
On the "saw" site the greatest productivity was found in the 13-14 time period and the curve shows two peaks corresponding to the 9-10 and 14-15 time periods. There is least

productivity between 12-13, just after the lunch break. In fact between 12 and 12.30 there is a 24.05% drop in productivity.
The following graphs show a comparison of the Ocra indices using the mean frequencies for the time periods with respect to those calculated using the daily mean frequencies (figs. 10-11).

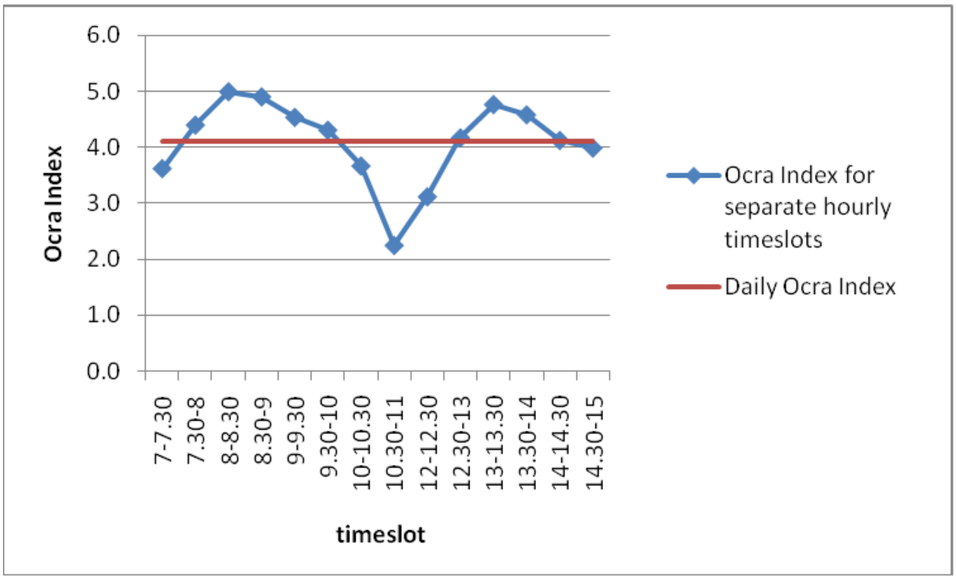


Fig. 10 – "Secateur" site – Trend and comparison of indices

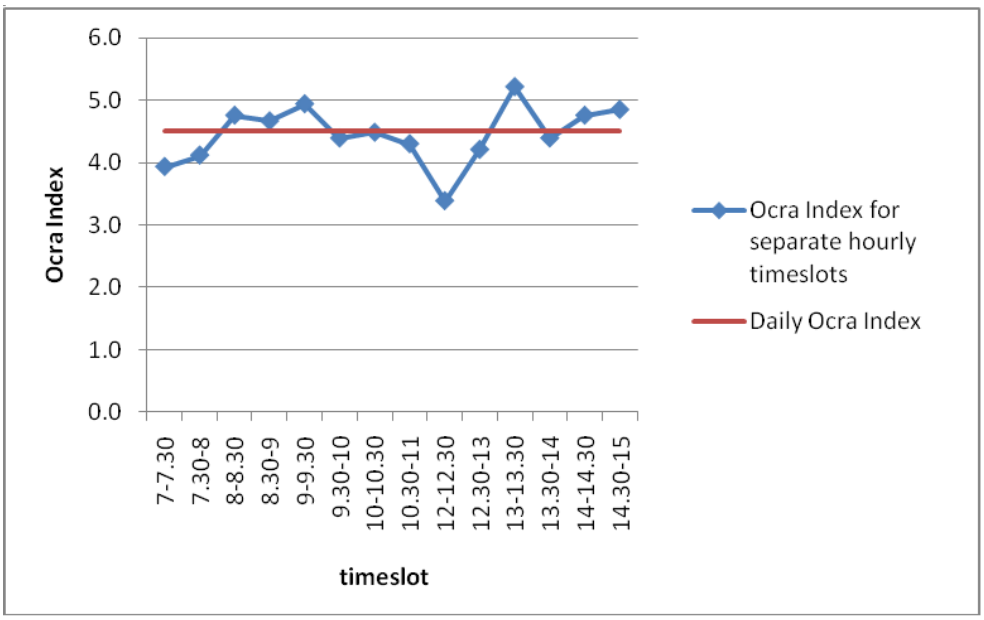


Fig. 11 – "Saw" site – Trend and comparison of indices

On the "secateur" site the half hour time period frequency findings show that for 57% of the daily working time the respective Ocra Index is higher than the Ocra Index calculated looking at the mean daily frequency (4.1). Moreover, it should not be overlooked that for a time period of little less than 30% of the working day, the index is in the upper risk bracket

(average risk, from 4.6 to 5.0), while for about 15% of the work time – around the lunch time – the risk fell to borderline – 2.2-3.7.
On the "saw" site, for 43% of the daily working day, the Ocra Index calculated for time periods is higher than the mean daily Ocra Index (4.5). For all of this period the higher risk bracket is reached as the daily mean is at the limit between minimum and average exposure. For about 7% of the work time – in the half hour after the lunch break – the Index drops to a lower risk bracket (borderline).

Conclusions e prospects

This preliminary analysis has shown that the frequency data come from a normal population. The ANOVA analysis has shown the great significance of the variable independents (tools used for pruning, cultivar pruned, work times) on the cut frequency. As regards the cultivar, the cut frequency seems to change most for Merlot, particularly when Guyot pruned. In the case of pruning with secateurs, regardless of which cultivar is considered there was a drop in work frequency in the second time period (9-11).
Starting with frequency, productivity was calculated and a curve with an undulatory trend was found – similar to that found by other authors working on citrus fruit harvesting. The curve can be used to better identify breaks for diminishing tiredness and reducing the Ocra Index. Studies carried out about citrus pruning or flowers harvesting have shown good effects of a break at almost 2.5 – 3 hours from the beginning of the work and a second one at 2 – 2.5 hours from the first one; future work will examine if similar effects can be obtained also in wine winter pruning.
Our studies show that starting at 7 o'clock in the morning, the lower exposition to biomechanical overload runs from 10 and 13 o'clock. That circumstance is more evident if operators use secateurs.
As concerns wine winter pruning, calculating Ocra index per each hour or per short time slots enhanced a potentially dangerous underestimate that could occurs when we used the daily average value. When we carry out studies about agricultural activities, in which frequency can varies consistently throughout the day, that circumstance must be take in account to preserve health and safety of workers.

Bibliography

Camillieri D., Rapisarda V., Balloni S., Schillaci G. 2010. *The effect of task frequency on the risk of biomechanical overloading of the upper limb during tomato binding.* Proc. Int. Conf. "Work safety and risk prevention in agro-food and forest systems", Sept 16-18, Ragusa, Italy.
Colombini D., Occhipinti E., Fanti M. 2005. Il metodo OCRA per l'analisi e la prevenzione del rischio da movimenti ripetuti. *Collana Salute e lavoro, Franco Angeli Editore*.

Consiglio Nazionale delle Ricerche. 1981. *Meccanizzazione della potatura e della raccolta degli agrumi.* Accademia nazionale di Agricoltura. Bologna

Montomoli L., Colombini D., Fanti M., Ruschioni A., Ardissone S., Sarrini D., Coppola G., Sartorelli P. 2008. *Risultati degli studi e dell'analisi del rischio clinico da sovraccarico biomeccanico degli arti superiori in viticoltura e olivicoltura.* Seminario EPM, giugno 2008.

Occhipinti E , Colombini D. 2007. *Updating reference values and predictive models of the OCRA method in the risk assessment of work-related muskoloskeletal disorders of the upper limbs*. Ergonomics.; 50: 1727-39

Regione del Veneto, Azienda AlSS17. 2008. *Metodi per la valutazione del rischio da sovraccarico biomeccanico degli arti superiori.* Documento a cura del gruppo di lavoro del C.R.R.E.O.

Schillaci G., Balloni S., Rapisarda V., Romano E., Bonsignore R., Camillieri D. 2009. *Valutazione del rischio da esposizione a movimenti ripetitivi degli arti superiori nella potatura manuale del vigneto*. Atti del IX Convegno Nazionale dell'Associazione Italiana di Ingegneria Agraria, Ischia Porto, 12-16 settembre.

Schillaci G., Balloni S., Bonsignore R., Camillieri D., Romano E. 2010. *Hand forces during manual vine branches cutting.* CD-Rom Proc. del Third International Congress on Mountain Viticulture, Castiglione di Sicilia (Italy), may 12/14.

Schillaci G., Balloni S., Caruso L., Camillieri D. 2010. *Risk due to repetitive movements in manual vineyard pruning*. CD-Rom Proc. Third International Congress on Mountain Viticulture, Castiglione di Sicilia (Italy), may 12/14.

Silverstein B, Fine L, Armstrong T. *Hand wrist cumulative trauma disorders in industry*. Brit J Indus Med 43:779-784, 1986.

Silverstein T, Fine L, Armstrong T. *Occupational factors and carpal tunnel syndrome*. Am J Ind Med 11:343-358, 1987.

Evaluation of Testing Procedures for ROPS Fitted on Self-propelled Agricultural Machinery

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

Abstract

Fatalities and serious injuries resulting from rollover accidents involving tractors and self-propelled agricultural machinery often occur in the field. Since 1974 tractors have been fitted with Roll-Over Protective Structure (ROPS) according to the requirements of the EC directive 74/150 EEC. On the contrary rollover protection of the driver was not required for self-propelled agricultural machinery until recently. The recognized potential risk of rollover for these machines, currently considered by the EC Directive 2006/42/EC, has led to manufactures implementing ROPS on new or existing self-propelled agricultural machinery, such as grape harvesters and sprayers. Consequently there is a need to develop standard strength tests for these applications. Nowadays ROPS tests involving agricultural machinery are carried out according to the ROPS testing procedure studied for tractors and/or earth-moving machinery.
An evaluation of the applicability of the tractor OECD ROPS Codes 4 and 8 to rollover protective structures retrofitted on in-use grape harvester was performed and the strength test results are presented and discussed.
The results showed that the Code 8 procedure was more suitable for evaluating the strength performance of the ROPS retrofitted on the tested grape harvesters. However the results demonstrated also some points where the testing procedures need to be modified in order to match the specific characteristics of the machinery considered.

Keywords: rollover, safety, OECD ROPS codes, energy, force

Introduction

The safety and health of the workers are considered in many official documents of the European Community (EC).

The Directive 2006/42/EC, often identified as "Machinery Directive", foresees requirements for the manufactures in order to reduce the potential risks for the machinery users. In particular for the case of self-propelled machinery with a ride-on driver, if the potential risk of rollover in the normal operation of the vehicle is recognised, the manufacturer has to minimise the risk by fitting a roll-over protective structure (ROPS) which has to provide and guarantee a survival volume for the operator in case of the machine overturning.

The first agricultural vehicle considered at risk of rollover was the tractor. Indeed tractor rollover has been a major issue since 1930, as stated by many international researches (Devis e Rehkuger, 1974; Myers, 2000), and at the end of the fifties it reached a strategic role for the high number of fatal accidents documented (Arndt, 1971; Myers, 2002).

The introduction of the ROPS, typically a passive means of operator protection in respect to alternative approaches, was supported by the research carried out firstly in Sweden (Moberg, 1973) and the efficacy has been documented by the decrease of the number of fatalities observed in Europe in the following years (Thelin, 1998). Nonetheless, recent analyses in US have pointed out that tractor rollover is still the first cause of fatalities, with an average number of 120 events per years (Reynolds e Groves, 2000, Harris et al, 2010) and relevant economic and social effects (Myers, 2002).

Tractors ROPSs need to be submitted by the manufacturers to official strength tests carried out according to international standard procedures for the particular tractor (Directive 2003/37/EC, which replaced the previous Directive 74/150/EEC). The normalised tests comprise a series of energy (force-displacement) and force requirements whilst ensuring that the survival volume has not been encroached. ROPS tests are performed within Europe according to the Codes of the Organisation for Economic and Co-operation Development (OECD) or the equivalent EC Directives. In the late 1970s the Code 4, based on a static testing procedure was introduced and it is still used (OECD Code 4, 2008). Other codes have since been added as Code 8 for track-laying tractors (OECD Code 8, 2008), with a testing procedure derived from the testing strength requirements originally studied for the ROPS fitted on earth-moving machinery (ISO 3471:2008).

According to the requirements of the Directive 2006/42/EC, if manufacturers of agricultural machinery, such as combines, grape harvesters, sprayers, provide a ROPS on the machine they have to give evidence of the ROPS strength performance. Performing appropriate tests or using a computer simulation of the machine rollover behaviour are the possible options. The first approach, the most common, has a crucial issue: the lack of dedicated standardised procedures for the specific type of agricultural machinery considered.

However standards for earth-moving machines and agricultural tractors are in use and could be adopted to give an answer to the need of self-propelled machines whilst the proper standards are developed. The subject concerns the new model of machines but also the "in-use" machines. In the United States for the in-use tractor models the usefulness in developing retrofitted ROPS was studied together with the need for increasing the acceptance and the use of protective structures among farmers. (Reynolds, 2000). A similar approach should be adopted for the in-use self-propelled machines, mainly when these are used on slopes, typical of the Italian environment, where a high risk of a rollover event exists. The occurrence of accidents involving the agricultural operators in Italy requires the fitting of ROPS structures to all machines at risk of rollover, both the new and the old models.

Protective structures retrofitted on in use grape harvester were tested according to the requirements of the OECD ROPS Codes. The purpose was to assess the behaviour of these structures during the tests so as to evaluate criticisms of the normalised procedures in testing rollover protective structures fitted on machinery differing from the tractors.

Materials and methods

Strength tests on two ROPS protective structures (CASES 1 and 2), fitted on two different in-use grape harvesters, were carried out at the laboratory of the Department of Agricultural Economics and Engineering (DEIAgra) of the University of Bologna, according to the provisions of the OECD Codes 4 and 8. Originally the two machines were marketed with cabs aimed at protecting the driver from environmental conditions. The manufacturers, so as to prevent injury to the driver during a rollover, designed dual pillar ROPS retrofitted behind the cab originally mounted (Figure 1).

Figure 1. Tested ROPSs. (a) CASE 1 (b) CASE 2

The ROPS structures were subjected to the sequence of strength tests foreseen by the normalised procedures.

<u>*Normalised testing procedures*</u>

Codes 4 and 8 foresee loadings based on energy and/or force requirements, calculated on the basis of the reference mass (M [kg]) of the machine. Both standardised procedures indeed are based on a linear relationship between the test energy/force and the machine mass (Table 1).

The reference mass is defined by the manufacturer with the only limitation to be at least equal to the mass of the tractor in running order, without driver, ballasts and implements.

<u>*OECD ROPS Code4*</u>

The OECD ROPS Code 4 is applicable to wheeled or track-laying tractors, with an unballasted mass not less than 600 kg and a minimum track width of the rear wheels generally greater than 1150 mm.

The sequence of loadings are: Longitudinal loading; First crushing (vertical loading); Side loading; Second crushing (vertical loading); Second longitudinal loading (only applied in case of folding or tiltable protective structures).

<u>*OECD ROPS Code 8*</u>

The OECD ROPS Code 8 is applicable to track-laying tractors with an unballasted mass not less than 600 kg and a ground clearance not more than 600 mm beneath the lowest point of the front and rear axles.

The horizontal and vertical loading are foreseen in the following order: Side loading; Crushing test; Longitudinal loading test.

The code procedure in case of the tractors fitted with a rollbar ROPS placed in front of the driver considers the rear hard point as a component of the protective system.

<u>*Arrangements of the tests*</u>

Longitudinal and side loads were applied to the tested structures by means of a hydraulic cylinder fitted with a load cell and a linear displacement transducer to measure the loading force and the ROPS deflection under loading. The vertical loadings were carried out using a rigid beam linked to two hydraulic cylinders fitted with load cells. The loading tests were stopped when the energy and/or the force absorbed by the protective structure was equal to or greater than that required (Table 2). The crushing tests were stopped when the force applied to the structures was equal or greater than the required force, shown in Table 1, and the force was maintained for 5 seconds after cessation of any visually detectable movement of the ROPS. The tests were accepted if the ROPS during the test did not infringe or leave the driver's survival volume unprotected. The clearance zone represents for Code 4 the safety volume for the driver in case of a rollover event while Code 8 refers to the Deflection Limit Volume (DLV). The DLV is a volume related to the operator and it is an orthogonal approximation of the dimensions of a large seated operator (ISO 3164:1995).

Table 1. OECD Codes 4 and 8 - Energy and Force equations

OECD CODE 4	**Required Energy and Force**	**OECD CODE 8**	**Required Energy and Force**
Longitudinal loading	1,4·M [J]	Side loading (Force)	$70000\cdot(M/10^4)^{1.2}$ [N]
First crushing test	20·M [N]	Side loading (Energy)	$13000\cdot (M/10^4)^{1.25}$ [J]
Side loading	1,75·M [J]	Crushing test	20·M [N]
Second crushing test	20·M [N]	Longitudinal loading (Force)	$56000\cdot (M/10^4)^{1.2}$ [N]
Note M [kg]		Rear hard fixture test	15·M [N]

The reference mass (M) used to define the test energies and forces was 8000 kg for the CASE 1 and 8160 kg for CASE 2. These masses were defined considering the machines in running order, with all tools and equipment fitted when in its traditional agricultural tasks.

The tests for CASE 1 were carried out according to the OECD ROPS Code 4. The original cab fitted on the grape harvester was submitted to an additional longitudinal loading applied in front of the cab, according to the provisions of the Code 4 (Table 2).

CASE 2 was tested according to the procedure of Code 8 (Table 2). The front-bottom part of the original cab was regarded as a protective point in the event of a sideway or rear overturning. In accordance with Code 8 this fixture was tested applying a downward force equal to 15M, extending the same testing procedure foreseen in Code 8 for the rear hard fixture in tractors fitted with a rollbar ROPS in front of the driver.

Table 2. Energy [J] and Force [N] values required by OECD Codes 4 and 8

OECD CODE 4	**CASE 1**	**CASE 2**	**OECD CODE 8**	**CASE 1**	**CASE 2**
Longitudinal loading	11200 J	11424 J	Side loading	9458 J 48000 N	10082 J 54844 N
First crushing test	160000 N	163200 N	Crushing test	156880 N	163200 N
Side loading	14000 J	14280 J	Longitudinal loading	38400 N	43875 N
Second crushing test	160000 N	163200 N	Front hard fixture loading	--	122400 N

Results and considerations

<u>*Results CASE 1*</u>

The longitudinal loading test according to Code 4 was carried out successfully. The roll-bar structure absorbed the energy foreseen by Code 4 and reached the force required by the Code 8. The total energy absorbed during the longitudinal loading was 11249 J, corresponding to a force of 136299 N. In the following crushing test the force reached the value of 163901 N.

Problems were raised during the side loading (Figure 2a). The structure was designed extremely rigid, due to the need of a retrofitting to an existing cab, and the absorption of the required energy involved elevated force. Figure 3 shows force versus displacement during the test.

Figure 2. Protective structures subjected to the side loading (a) CASE 1 (b) CASE 2

The side loading test was stopped when the force reached 178084 N, due to the unsuitability of the testing equipment to so high force values. The corresponding absorbed energy was 9517 J, too low for the Code 4, with an energy required of 14000 J, but in line with the requirements of Code 8 in the side loading.

The absorbed energy in the longitudinal loading carried over the original cab fulfils the requirement of Code 4. In this test, the force measured was 36563 N when the energy absorbed was 11277 J. During all tests neither the original cab nor the roll-bar retrofitted infringed the safety volume.

<u>*Results CASE 2*</u>

The roll-bar structure fulfilled the energy and force required by Code 8 (Figure 2b). The total energy absorbed during side loading was 10330 J in correspondence of a force equal to 69904 N (Figure 3). During the crushing test the force reached 173000 N. The longitudinal loading was stopped when the force was 45523 N. The front hard fixture test showed the strong behaviour of the bottom front part of the original cab, properly reinforced and linked to the retrofitted rollbar. The force reached was 124082 N, with a displacement less than 60 mm.

Tests were carried out without breakages and the safety volume was not infringed.

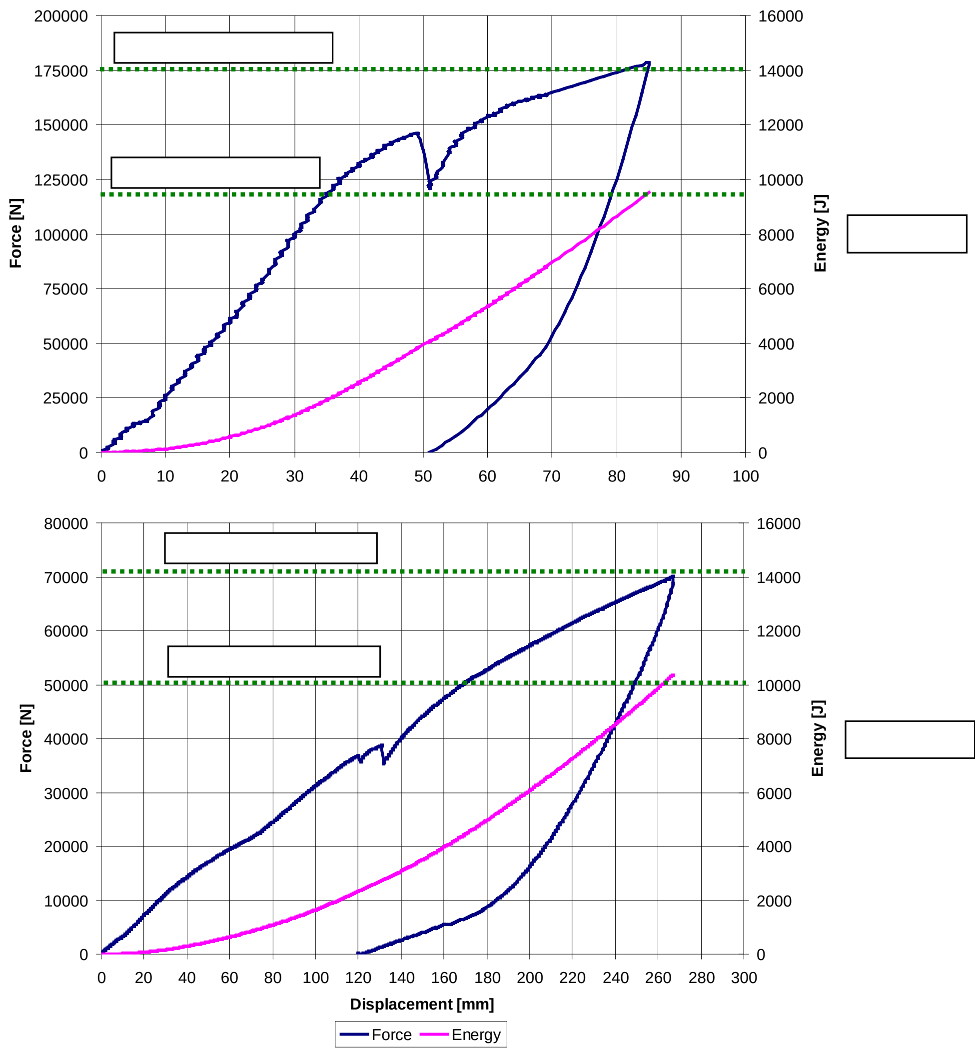


Figure 3. Force and Energy measured during the side loading tests

Considerations

The testing procedures considered in the tests present clear differences in the criteria adopted. Indeed Code 4 is essentially based on an energy to be reached in the horizontal loadings, while a force has to be sustained by the protective structure during the vertical loadings. Code 8 has the same approach in the vertical loading, but in both horizontal loadings a force requirement is introduced; only the side loading considers an additional energy to be reached. That means Code 8 deals mainly with a ROPS designed to be robust (i.e., rigid). The force requirement foreseen in Code 8 is the consequence of its derivation from a testing procedure originally studied for the ROPS fitted on earth-moving machinery.

The sequence of horizontal loadings applied to the tested CASE 1 demonstrated that the use of a procedure based on an energy criterion was not suitable due to the high rigidity of the structure. The ROPS was designed to be highly stiff because it had to be fitted behind an existing cab and in the intention of the manufacturer a high rigidity contributed to preserve the cab in case of rollover of the machine increasing the driver's safety level. The additional test applied frontally on the cab showed a certain strength of the cab itself, but this did not guarantee its behavior in case of hitting onto the ground.

On the basis of the results of the CASE 1 tests, the CASE 2 was subjected directly to the sequence of loadings foreseen by Code 8 with a general positive result.

The additional test on the front hard fixture was carried out in order to verify the strength of a portion of the machine that could be considered as a component of the protective structure. Indeed in the general arrangement of the grape harvester quite often the driver's position is suspended laterally on a platform and in front of the driver there is not a real hard point, as for example the outer portion of the bonnet in the case of the agricultural tractor, able to sustain the machine when overturned. Therefore, in order to complete the protection of the driver, the basis of the original cab in the CASE 2 was properly reinforced and tested extending the same procedure foreseen by Code 8 for the strength requirement of the rear hard point when the tractor is fitted with front ROPS.

An additional consideration is related to the definition of the reference mass to be used for the test, both Codes did not consider the equipment fitted on the vehicle but simply refer to the empty tractor in running order. It could be appropriate to refer to the requirement of the ISO 3471:2008 procedure in selecting the reference mass of the vehicle including all attachment in operating condition, tools and ROPS, and excluding the material carried or handled.

Conclusions

The results of the tests carried out on the two dual pillar ROPS fitted behind the cabs originally designed for the two in-use grape harvesters demonstrated the difficulties in adapting standardized testing procedures originally studied for ROPS fitted on the tractors. The CASE 1 tested appeared extremely rigid and it did not fulfill the provisions of a testing procedure based on an energy requirement criterion, as specified by Code 4. CASE 2 showed a higher deflection but generally the ROPS designed to be retrofitted on the in-use machine has to be rigid enough to avoid a large displacement that could involve the original cab and cause possible injury to the driver during the vehicle rollover.

The Code 8 procedure was more suitable for evaluating the strength performance of the ROPS retrofitted on the tested grape harvesters. However the results demonstrated also some points where the testing procedures need to be modified in order to match the specific characteristics of the considered machine.

In a more general context it seems advisable to study an ad hoc standardised procedure for such machines as the grape harvesters, providing strength criteria based on an energy or a force requirement depending on the characteristics of the ROPS designed and fitted on the machinery.

Another point to be solved is the clear indication of the reference mass to be considered for the strength tests.

Acknowledgements

The authors acknowledge the entire staff of the Laboratorio di Meccanica Agraria of the Department of Agricultural Economics and Engineering, University of Bologna.

References

Arndt J F. 1971. Roll-over protective structure for farm and construction tractors – A 50 years review. SAE Technical Paper Series, 718508, Warrendale, PA

Devis D, Rehkuger G. 1974. Agricultural Wheel-Tractor Overturns. Transactions of the ASAE. 17(3), 477-483

Directive 150, 1974. Directive 74/150/EEC on the approximation of the laws of the Member States relating to the Type-approval of wheeled agricultural or forestry tractors European Parliament and Council Of The European Union.

Directive 37, 2003. Directive 2003/37/EC relating to Type-approval of agricultural or forestry tractors, their trailers and interchangeable towed machinery, together with their systems, components and separate technical units. European Parliament and Council Of The European Union.

Directive 42, 2006. Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC. European Parliament and Council Of The European Union.

Harris J R; McKenzie E A; Etherton J R; Cantis D M; Ronaghi M. 2010. ROPS performance during field up-set and static testing. Journal of Agricultural Safety and Health, 16(1), 5-18

ISO 3471:2008. Earth-moving machinery - Roll-over protective structures - Laboratory tests and performance requirements. International Organization for Standardization.

Moberg H A. 1973. Dynamic testing of tractor protection cabs: development of method, practical experiences. Proceedings National Combined Farm Construction and Industrial Machinery and Fuels and Lubricants Meetings, New York, 13 September 1973

Myers J.R., Snyder K. A. 1995. Roll-over Protective Structure Use and the Cost of Retrofitting Tractors in the United States, 1993. Journal of Agricultural Safety and Health 1(3):185-197.

Myers M L. 2000. Prevention effectiveness of rollover. Journal of Agricultural Safety and Health, 6, 29-70

Myers M L. 2002. Tractor risk abatement and control as a coherent strategy. Journal of Agricultural Safety and Health, 8(2), 185-198.

OECD Code 4, 2008. OECD Standard code for the official testing of protective structures on agricultural and forestry tractors (Static test). Organisation for the Economic Co-operation and Development. Paris. www.oecd.org

OECD Code 8, 2008. OECD standard code for the official testing of protective structures on agricultural and forestry tracklaying tractors. Organisation for the Economic Co-operation and Development. Paris. www.oecd.org

Reynolds S. J, Groves W. 2000. Effectiveness of roll-over protective structures in reducing farm tractor fatalities. American Journal of Preventive Medicine, Volume 18, Issue 4, Supplement 1, Pages 63-69.

Thelin A. 1998. Rollover Fatalities -Nordic Perspective. Journal of Agricultural Safety and Health, 4(3), 157-160.

Aspects of Safety in the Stretching of Plastic Film During Greenhouse Covering

Caruso L., Pennisi A., Balloni S., Conti A., Camillieri D., Schillaci G.
University of Catania. DIA, Mechanics Section
Via Santa Sofia, 100 – 95123 Catania, ITALY.
Tel. +39 095 7147512, Fax +39 095 7147600, giampaolo.schillaci@unict.it

Abstracts

The "Mediterranean greenhouse" is widely used for food and ornamental crops. In south-eastern Sicily alone it covers 7000 ha -7500 ha, for 13200 ULA (working days per years) and with a gross saleable production of € 255˙000˙000. Over the course of time the wood or cement supporting structure has been replaced with steel structures. In all cases the cover consists of polyethylene film (PE, PVC, EVA, and so on) and is replaced annually or at most every two years. The positioning of the film on the greenhouse frame represents an accident risk, with falls from a height, and the stretching of the film may provoke even fatal accidents. The equipment used contributes to such accidents. The objective of this work is to identify the cause of accidents occurring during the stretching of the plastic film and to propose solutions. To measure the force involved during tightening, a torsiometer was used. The characteristics of this were established through preliminary trials and a procedure was set up for its correct use. An analytical model was prepared to verify the forces in play. The results show the significance of the forces used during stretching and indicate the danger involved in the operations. The research shows the need to set out guide lines, scrupulously train the operators, re-examine the devices in place in greenhouse structures to hold the film during stretching as well as the tools used by operators, as impact of these with parts of the body can have fatal consequences.

Keywords: torsiometer, covering, safety procedure, plastic film

Introduction

Positioning plastic film over the structures of the "mediterranean greenhouse" may provoke high number of the accidents at workers involved in (Miranda and Martinez, 2005).
Preliminary investigations conducted by the Authors in the south-east of Sicily confirm the high risk of this activity, but underestimated, because accidents are not always reported.
Some researchers propose a system that allows the coverage of the structure, working from the ground and then lift the whole covered structure so until final height. Where applicable, the system shows a drastic reduction in accidents during the coverage phase of the structures (Carreno, 2009). According to the author, the working hours dedicated to these tasks and therefore the risk exposure are reduced as well.
Besides being subjected to the typical risks of working at heights, the workers employed for covering activities use home-made and often very rudimentary equipment, which are a source of danger or even death.
The target of this research is to experimentally measure the magnitude of the forces involved during the stretching of the plastic film as roof of the greenhouse, to interpret and suggest a model confirming the experimental results, and to detect and evaluate the procedures and the tools used to achieve useful information for risk reduction.

Materials and Methods

Materials

Greenhouses. Greenhouses where the tests were performed (referred in this work with the first five letters of the alphabet) are of tunnel type with multiple spans and a symmetric curved roof; they are the most common greenhouses used in south-east of Sicily.
They have lateral windows, a main structure (carrier) and a secondary (for connection) made by galvanized steel and a roof made in plastic film (see Table 1).

Rif.	Width [m]	Span [n.]	Depth [m]	Eaves height [m]	Ridge height [m]	Surface [m^2]
A	56	7	19	2.70	4.30	1064
B	48	6	19	2.70	4.30	912
C	56	7	25	2.70	4.30	1400
D	56	7	30	2.70	4.30	1680
E	56	7	32	2.70	4.30	1792

Tab 1 - The greenhouses

The used plastic film (EN 13206, class A) is the ADDITIVATO®, with long-term characteristics, nominal thickness of 0.15 mm and coil width of 9.20 m. It is usually replaced every two years.

The torque transducer. In order to measure the torque required to tighten the film on the rod, it was used a static torque TRS (AEP transducers) compliant to the standards EN 61326-1 and EN 61010-1 (2001) with which it is possible to measure torque ratings from 0.5 to 1000 Nm (Fig. 1).
It is equipped with a digital torque DTR (digital torque indicator), with input for strain gauge torque transducers. Thanks to the peak function, the indicator provides:

a positive value (clockwise peak torque)
a negative value (counterclockwise peak torque)

Fig. 1 – The torsiometer and the digital torque indicator

Methodology

In all tests it was measured the heights of the wrapping groups (terminal device and ending part of the rod), with respect to the floor, as these involve different postures and procedural approaches of the operators during the installation of the plastic film (e.g. use of ladders, more or less raised arms, etc.).

In each test, the torque transducer was interposed between the wrapping groups and the hollow rod that protrudes from the "rosette" (fig. 2). Then the lever is connected to the transducer in order to apply a force by hand with the purpose of wrapping the film around the bar itself (Fig. 3).

Through the torque transducer, which was reset for each reading, the measurements were performed during the wrapping phase.

As the display of the DTR allows the reading of the torque in real time, in case of abnormal records it was possible to make an immediate investigation by questioning operators, exchanging point of views with members of the research group, examining the results on the precise moment or later from the movie of the operations.

Fig. 2 - The wrapping groups: the "rosetta" and its 8 curved points, the hollow end of the rod, the blocking systems with the hinged mobile tooth; the whole rod is not visible here

Fig. 3 - The long lever used for stretching the film, with the pawl,
the torsiometer and the square key to insert in the hollow end of the rod

Results

Work organization. The step of fixing the plastic film necessary to cover the greenhouse was performed by a team of 7-8 workers, two of whom work on the ground and operate for the withdrawal of the film from the reel, provide for the cutting of the film and moving the tractor that carry the film reel; four of these provide arranging the film on the coverage moving at height, two ensure the clamping of the film to the greenhouse structure by placing some clips and to a first tightening of the film, by using a pawl.

The two operators, located at each end of the span, act in unison, each with its own wrench, on a "wrapping group". The final tensioning of the film takes place during the hottest hours of the day to avoid that low temperature early in the morning may provoke breaks in the film or incomplete stretching.

Wrapping groups. The "wrapping groups" are located both front and side of the greenhouse. Each group consists of a rod made in cold galvanized steel and a device ("wrapper") located at each end of the rod. The rod is at the height of 2.7 m with respect to the floor, cross - section square (30 x 30 mm, thickness 2 mm) and some tens of meters long (max 50 m).

The 'wrapper' and the wrench used to wrap the film are the heart of the system. The wrapper group allows the insertion of a wrench for rotating the rod and it is equipped with a device that allow to rotate the wrench without unplugging it.

The device consists of a toothed wheel called "rosette" made of cold galvanized steel 6 mm thick. Both terminal parts of the rod protruded from its own rosette and here it is possible to insert the wrench. Each rosette has 8 curved points with special shape in order to allow the smooth functioning of the locking device. This consists of a mobile tooth hinged at one extremity and able to prevent the opposite rotation when the wrench is disconnected or when the shaft of the wrench (that bring a pawl at its extremity) is rotating between a tightening and the successive one (the device should act as a rudimentary free wheel of a normal bicycle).

The wrench (equipped or not with a pawl) used to wrap the plastic film on the rod is usually self-built by operators or, more rarely, by manufacturing companies of materials for greenhouses. In the considered case study it was represented by a steel lever 1.08 m long. At one end of this lever a pawl with a male spanner (25 mm x 25 mm) is mounted; the spanner is suitable to be inserted inside the hollow terminal of the rod, nearby the rosette.

The torque values detected. In the table (Tab. 2) it is shown for each greenhouse the peak torque values measured by the electronic device:

Rif.	Rod lenght [m]	Minimum torque value [N·m]	Maximum torque value [N·m]	Average torque value [N·m]	Standard deviation
A	19	252	347	313	30.20
B	19	249	388	318	41.56
C	25	354	526	450	56.58
D	30	340	572	448	64.28
E	32	414	498	458	25.60

Tab. 2 – The peak torque measured values

It is possible to observe as the torque values in question have a range from a minimum of 249 Nm to a maximum of 572 Nm. The most common values of torque are those between 300 ÷ 350 Nm and between 400 ÷ 500 Nm (Fig. 4).

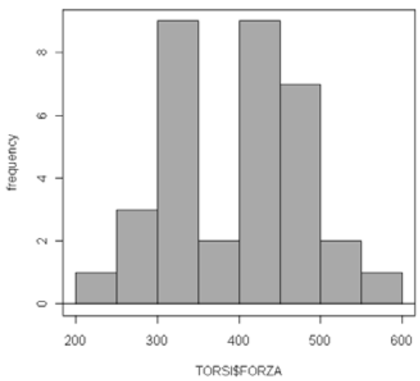


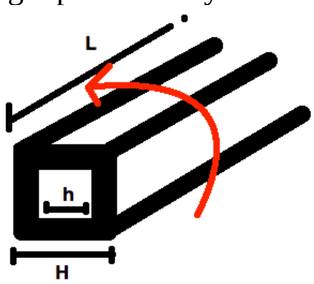
Fig. 4 - Distribution of the frequency

Analyzing the torque peak data, made separately for each greenhouse, is pointed out that in some greenhouses were reported values of 15-20% more than the average values.
These values, which can be defined as "exceptional", were measured in 4 of the 35 examined cases. In particular, a case was registered in the greenhouse B (peaks of 388 N* m, above the average of 22%), two in the greenhouse C (peaks of 526 and 517 N* m above its average of 17 and 16%), one in the greenhouse in D (peak of 572 N* m above the average 25%). The survey has indicated the cause in the lack of synchronism between the operators during the tightening procedure.
The analytical model and the forces at play. Assuming that the rod and plastic film are under elastic behaviour (the rod and the film are not under a strain over their elastic limit), the energy supplied by the operator to tighten the film is stored by the system and therefore the torque released by the rod in the following instant the release of the locking device could be assumed equal to that exerted to tighten the plastic film.
If the locking system doesn't work properly, as sometimes happens, at the time of release the system would give off a maximum speed; part of the energy would be after dissipated in static and viscous friction: these components can be considered negligible compared to the involved torque values.
It is possible to highlight two different cases:

1) The movement of the two operators is fully synchronous (ideal case). In this case there will not be a twist of the metal rod but only traction of the plastic film.
2) The movement of the two operators is asynchronous or even one of the ending parts of the rod is locked. The last circumstance occurs when an operator acting alone and acts alternately at either end of the rod. In this case there will be both: the twist of the metal rod and the traction of the plastic film.

The system can therefore be modelled as consisting of two springs:

A torsion spring represented by the rod with the following features:



H=30 mm; h= 26mm; L= 25 m

A linear spring represented by the plastic film that gradually envelops the rod

Summing:

*F=K1*Theta_torsion+ K2*Xdef*

Where:

K1: spring constant of the metal rod

K2: spring constant of the plastic film

Since it is not easy to calculate the coefficient of elasticity for the two different materials, it was carried out considering:

the torsion elasticity modulus (known for the steel rod and independent from the geometry)

the stress arising from the traction of the plastic film, needed to tighten itself.

In the case of the square hollow rod having the characteristics listed above, the torque will be:

$$Mt = \Theta * Jp * G/L$$

Where:

Θ is the twist angle in radians

Jp is the polar inertia moment of the section;

G is the torsion elasticity modulus (in the case of steel is a known quantity equal to 27 GPa = 27 N / m ^ 2)

L is the lenght of the rod (L = 47 m)

To calculate the polar inertia moment it was used the following equation:

$$Jp= 2*J= (H^4-h^4)/6$$

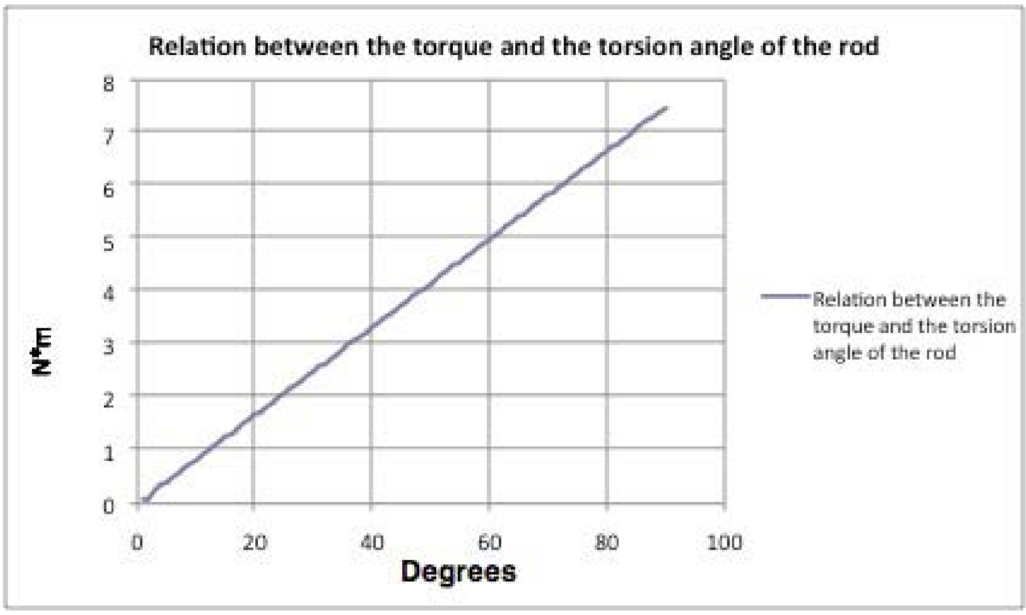


Fig. 5

Increasing the twist angle (generated by the asynchronous movement of the two operators or by the fact that one end is locked) will increase the torque value and then the energy returned from the system (Fig. 5).
For example, when the torsion angle is 10° the torque would result about 1 N * m (this corresponds to apply a force of 66 N on one side of the lever).
The following expression is useful to calculate the torque of the plastic film

$$Mt = F_{traz} * r$$

Where F_{traz} is obtained from: F_{traz} /A = .
With:

F_{traz}: the traction strenght exerted in the plastic film from the operator that wrap itself.

A: surface in wich it is exercised F_{traz} (equivalent to the section of plastic film: thickness * length).

σ is defined as the effort exerted on the plastic film and it is measured in pascal.

r: distance between the point where the traction is exercised and the axis of rotation (0.015 m).

From the mechanical parameters of the material used it is possible to know the breaking strength applied on the film (such as the thermal films AGRILUX that have an breaking strength ≥ 18 kN / m ^ 2).
Well below this value, the behaviour of the film is plastic and it is possible to calculate the torque generated:

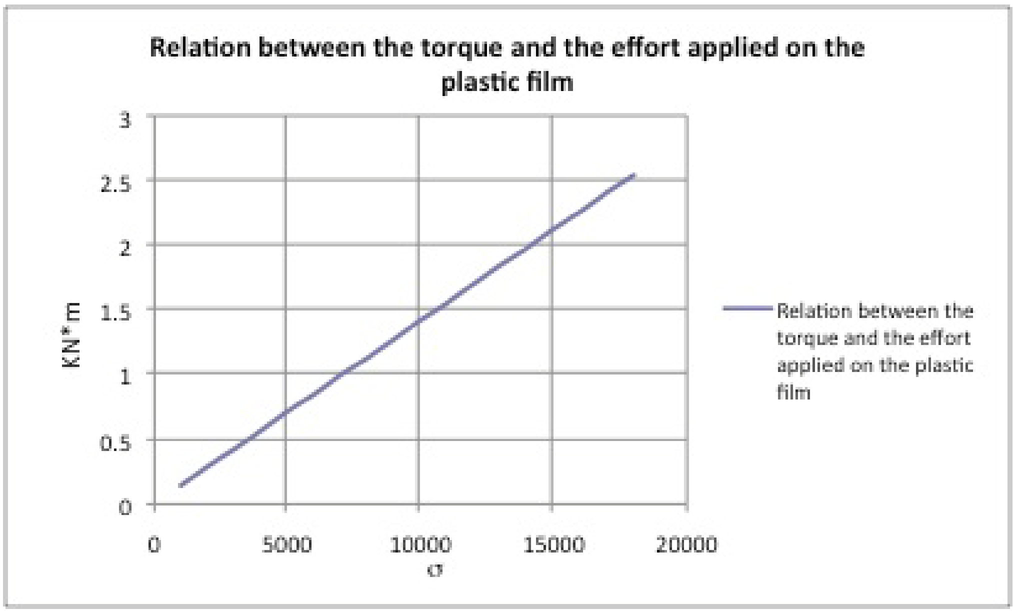


Fig. 6

Increasing the effort applied on the plastic film (18000 is the breaking strength) will increase the maximum torque exerted by the same (order of kN * m) (Fig. 6).
Analyzing the results, the predominant component in terms of resultant torque is generated by the plastic film.
The sum of the two components (rod and film) shows how under certain conditions the resulting torque is comparable with that measured experimentally (500 Nm).

Conclusions and prospects
The "wrapping group" (terminal device and ending part of the rod) is the heart of the system under review, with the tool (wrench) and the procedures used.
The rough construction of the group and of the wrench, and the improvised nature of the adopted procedure makes very difficult to adopt safety standards and all together they help to explain the frequency of accidents during the plastic film tightening phase; furthermore, the magnitude of forces involved, that the research allowed to quantify, justifies the severity of the injuries.
Both the rosette and the lock system should be redesigned more appropriately, the materials should be chosen with a greater care, the construction methods (stamping or cutting) revised.
The procedures, often incorrect, give rise to serious and even lethal risks, especially when the head of the operators (helmet is often not used) may be affected by the lever used for tightening the plastic film when, due to an accident, the operator lose the grip and consequently the control on the lever.
Maximum attention should be placed on the staff training and on the provision of appropriate PPE (Personal Protection Equipment).
The proposed analytical model, finally, gave results comparable with those observed and appears to correctly represent the types and the intensity of the forces involved experimentally measured. A further effort should be direct towards a complete verification of the possibility of pulling the plastic film using pairs of compact electric actuators, with low voltage and electronic control.

Noise Levels for Modern Hazelnut Harvesters

Cecchini M., Monarca D., Guerrieri M., Lingero E., Bessone W., Bedini R., Menghini G.
Dept. Gemini, University of Tuscia, via San Camillo de Lellis – 01100 Viterbo, Italy, phone: +39 0761 357357, fax: +39 0761 357453, e-mail: ergolab@unitus.it

Abstract
A research has been carried out to assess the noise exposure for workers during mechanized harvesting of hazelnuts. The survey has been performed in the years 2006 and 2007 in four farms in Piemonte (Italy) in the province of Cuneo, in the typical area of the cultivar "Tonda Gentile of Langhe".
The noise samplings were carried out on hazelnut harvesters and during the use of blowers or swathers: three tractor mounted picking harvesters; four self-propelled harvesters (three vacuum harvesters and one picking harvester); one towed vacuum harvester; one swather; two blowers. For the sound pressure measurement a personal dosimeter Larson-Davis 705 was used. The noise levels obtained from this study have been compared with the law currently in force in Italy.
The data elaboration allowed to determine the values of the daily noise exposure level ( ) for workers. All the results show the exceeding of the exposure limit value fixed by legislative decree 81/2008 in 87.0 dB(A). The highest peak value, equal to 126,6 dB(C), is below the limit values fixed by the above-mentioned law.

Keywords: noise exposure, hazelnut harvesting, work hygiene

Introduction

Noise is one of the main risk factors for agricultural workers during hazelnuts' harvesting; it is due to the use of machines. The problem of noise exposure is still not completely resolved, although the introduction of cabin could reduced exposure to levels below the lower action value provided by legislative decree 81/08.

The choice of the machine must be done carefully, considering not only the work performance (operational capabilities, "quality" of work, etc.), but also and above all safety and hygiene aspects (Monarca *et al.*, 2005). Who buys a machine should therefore pay attention to the values of sound pressure (and power) level declared by the manufacturer, preferring the models with less production of harmful physical agents.

Materials and methods

The survey has been performed in the years 2006 and 2007 in four farms in Piemonte (Italy) in the province of Cuneo in the typical area of the cultivar "Tonda Gentile of Langhe":

- Cravanzana: altitude 585 m above sea level (min 369; max 716) – latitude 44° 34'32"52N;
- Torre Bormida: altitude 391 m a.s.l. (min 269; max 680) – latitude 44° 33'49"32N;
- Bosia: altitude 484 m a.s.l. (min 340; max 700) – latitude 44° 36'12"24N;
- Feisoglio: altitude 706 m a.s.l. (min 475; max 823) – latitude 44° 32'40"92N.

The surveyed farms have different characteristics in term of the type of corporate form, of extension, of used machines, of availability of labor and harvesting procedures.

Before the campaign survey 2006 for each company was made a statement on the company structure (total areas and nut area, number of plots, etc.), the characteristics of the orchard (plant distances and age), cultural practices and used equipment and machinery (data not reported).

During the two years two campaign of measurements were carried out: the first one during the main harvesting (last decade of August); the second one during the first decade of September. The harvesters used during the campaign of measurements are reported in table 1.

Table 1. Tested machines

Machine	Manufacturer	Model
Tractor mounted picking harvester (connected with mechanical transmission to the tractor Carraro TRX7400)	G.F.	Jolly 1800
Tractor mounted picking harvester (connected with hydraulic transmission to the tractor New Holland TN 75 FA)	G.F.	Jolly 1800
Tractor mounted picking harvester (connected with mechanical transmission to the tractor Carraro TRX7400)	Rivmec	Smart 1800
Towed vacuum harvester	Facma	Cimina 300T
Self-propelled vacuum harvester	Facma	Cimina 300S
Self-propelled vacuum harvester	Facma	Cimina 200S
Self-propelled vacuum harvester	Facma	Cimina 380S
Self-propelled picking harvester	Agrintem	Perla 55
Swather	BCS	-
Blower	Shindaiwa	EB 8510
Blower	Echo	PB 6000

a) b) c)

Figure 1. Some of tested machines: a) Facma 380S, b) Rivmec Smart 1800, c) GF Jolly 1800 (courtesy of manufacturing companies).

The reference laws for the assessment of workers noise exposure is the Title VIII (Physical agents), Chapter II (Protection of workers against the risks of exposure to noise at work) of the legislative decree 81/08. Table 2 shows the reference levels established by law.

The daily ($L_{EX,8h}$) and weekly ($L_{EX,w}$) noise exposure level are defined by law as follows:

daily noise exposure level ($L_{EX,8h}$) (dB(A) ref. 20 μPa): time-weighted average of the noise exposure levels for a nominal eight-hour working day as defined by international standard ISO 1999: 1990, point 3.6. It covers all noises present at work, including impulsive noise;

weekly noise exposure level ($L_{EX,w}$): time-weighted average of the daily noise exposure levels for a nominal week of five eight-hour working days as defined by international standard ISO 1999:1990, point 3.6

The peak sound pressure (p_{peak}) is defined as the maximum value of the 'C'-frequency weighted instantaneous noise pressure.

Table 2. Legislative limits

Limit value	$L_{EX,8h}$ or $L_{EX,w}$ (dBA)	p_{peak} (Pa)	p_{peak} (dBC)
Exposure limit value	87.0	200	140.0
Upper action value	85.0	140	137.0
Lower action value	80.0	112	135.0

The measurements was carried out with a class 1 data-logging personal sound level meter model "Noise Badge 705" produced by Larson Davis (3425 Walden Avenue Depew, New York 14043 USA) (figures 2 and 3). The personal sound level meter can measure the noise dose to which a person is exposed in a given period of time. Dose means the sound level limit (*'A'* weighted) at which a worker may be exposed during an eight hours working day, without the risk of hearing loss. The device is small with limited thickness and weight, so it can be comfortably worn by the operator. The supplied microphone is wire connected to the instrument and is placed on a metal rod fixed to a helmet so that the distance between the microphone and the ear is about 10 cm.

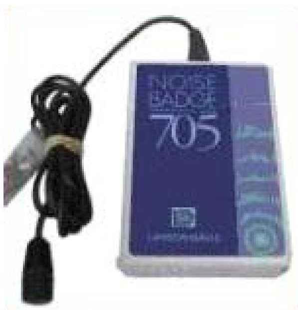


Figure 2. Personal Sound Level Meter "Noise Badge 705" (courtesy of Larson Davis)

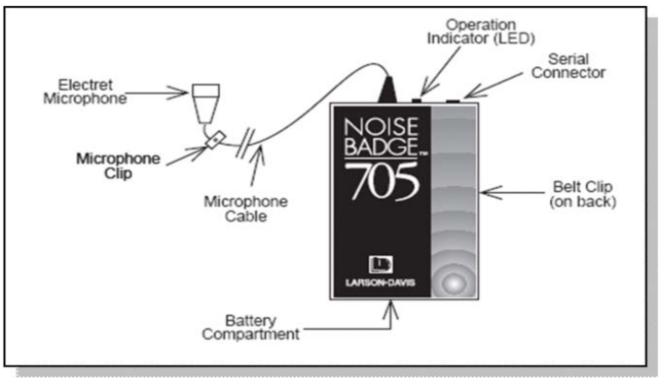


Figure 3. Components of personal Sound Level Meter "Noise Badge 705" (courtesy of Larson Davis)

Apparatus, before being used for data acquisition, should be initiated through the software provided by the manufacturer. A calibration of the instrument should be done before any measurement campaign. For this purpose a class 1 sound calibrator model CAL 200 produced by Larson Davis was used.

Through the supplied cable, the instrument was connected to the computer's serial port for its programming. Once the data were acquired it was necessary reconnecting the sound level meter to the computer for their downloading.

The software automatically process the collected data allowing to provide the L_{Aeq} values used to calculate the daily noise exposure levels ($L_{EX,8h}$). Figures 4 and 5 show some screens provided by the software.

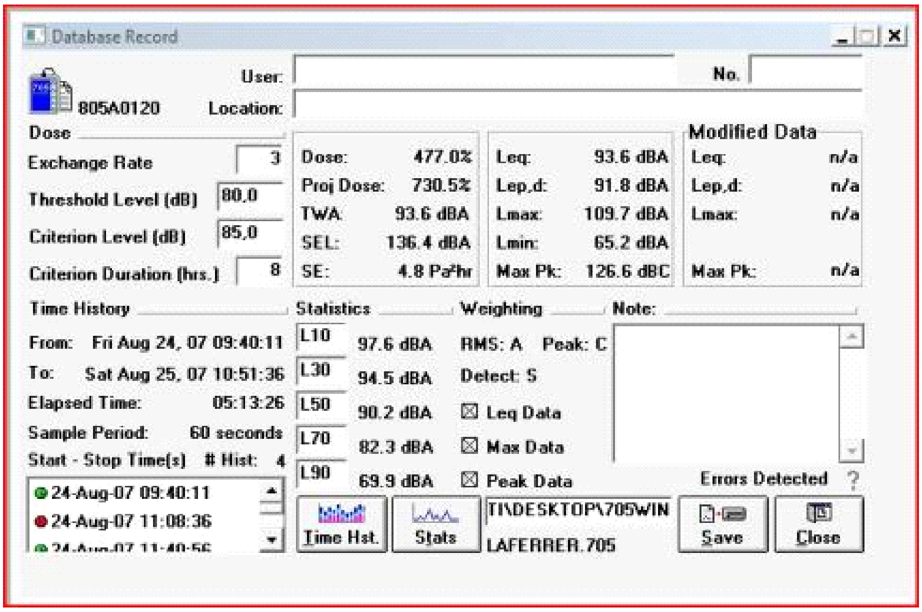


Figure 4. Sample screen for processing the file (software Larson Davis)

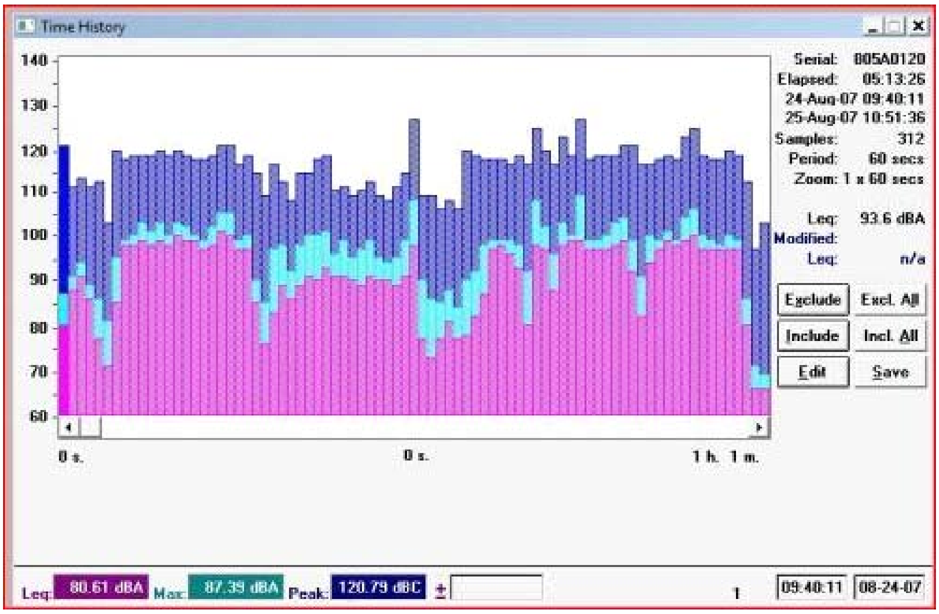


Figure 5. Example of graph processed by the software Larson Davis

Once carried out the measurements the daily noise exposure levels ($L_{EX,8h}$) for workers involved in hazelnut harvesting were calculated, using the formula:

$$L_{EX,8h} \quad L_{Aeq,Te} \quad 10\log(Te/To) \qquad \text{dB(A)} \qquad (1)$$

Results

The data processing performed using the Larson Davis software allows to extrapolate the values of L_{Aeq} levels for each test. The data, processed with a spreadsheet, have determined the average daily noise exposure values $L_{EX,\ 8h}$, which show the exceeding of the daily exposure limit value set by decree 81/2008 in 87 dB(A). The highest peak value equal to 126.6 dB(C) is instead widely below the limits values.

Table 3: Sound pressure levels ( ) and daily noise exposure level ( )

Machines	L_{Aeq} (dBA)	$L_{EX,8h}$* (dBA)
Tractor mounted picking harvester G.F. Jolly 1800 connected with mechanical transmission to the tractor Carraro TRX7400	90.8 ÷ 91.4	91.1
Tractor mounted picking harvester G.F. Jolly 1800 connected with hydraulic transmission to the tractor New Holland TN 75 FA	86.9	86.9
Tractor mounted picking harvester Rivmec Smart 1800 connected with mechanical transmission to the tractor Carraro TRX7400	94.1	94.1
Towed vacuum harvester Facma Cimina 300T	90.7 ÷ 94.3	92.9
Self-propelled vacuum harvester Facma Cimina 380S	92.6	92.6
Self-propelled vacuum harvester Facma Cimina 300S	89.1 ÷ 95.0	93.0
Self-propelled vacuum harvester Facma Cimina 200S	91.4	91.4
Self-propelled picking harvester Agrintem Perla 55	91.3 ÷ 94.8	93.4
Swather BCS	95.1	93.9
Blower Shindaiwa EB 8510	95.8	94.6
Blower Echo PB 6000	93.8	92.6

**harvesters: Te = 8h; swather and blowers: Te = 6 h.*

The greatest daily exposure level in harvesting operations was obtained with the use of tractor mounted Smart 1800, and the lowest exposure level (except the test on a tractor with cab) with the tractor mounted GF Jolly 1800. The two harvesters (Jolly 1800 and Smart 1800) are very similar. So we can underline that tractor is very important in determining the noise levels eared by workers.

Another important observation emerging from data collected is that, at current technology status, the only solution to reduce noise exposure levels below the limit value is to use machines with cab (e.g.: tractor New Holland TN 75 FA). The influence of the kind of used transmission (hydraulic or mechanical) could have a great influence on sound pressure levels, but available data do not allow evaluating their incidence on noise production.

The harvesting is not the only dangerous operation (from the point of view of noise exposure): also the previous operations of raking (with the use of swathers or blowers) show noise exposure levels exceeding the limit of 87 dB(A).

Conclusions

The use of personal sound level meter Larson Davis Noise Badge 705, given to workers involved in hazelnut harvesting, allowed to assess their noise exposure levels.

The daily noise exposure levels during hazelnut harvesting, calculated without taking into account the use of individual protection devices, ranged from 86.9 to 94.4 dB(A), with peak values ranging from 122.8 dB(C) and 126.6 dB(C).

In all the samples (except the test on a tractor with cab) was exceeded the exposure limit value set at 87 dB(A) by the legislative decree 81/08, but not for the sound pressure peak, which was always under the lower action value.

Analyzing sound pressure levels by type of machine, self-propelled show an average of 92.7 dB(A), towed harvesters an average of 94.4 dB(A) and tractor mounted harvesters an average of 95.5 dB(A). For the latter the contribution due to noise from the tractor used is very important, and is perhaps more correct to analyze the matching machine-tractor. The use of cab tractors can significantly reduce the noise exposure of workers.

Noise exposure levels exceed the limit of 87 dB(A) also during the use of blowers and swathers for raking operations.

It should be emphasized that noise exposure, resulting from the use of machinery for tillage and hazelnuts harvesting, is limited to 15-20 days/year for larger companies and to few days for smaller ones (Monarca and Zoppello, 1993).

These exposure levels require employers to take immediate preventive measures to bring exposure levels below the exposure limit value. Reducing the exposure time does not seem to be a feasible measure, given the limited duration of the harvesting period. So workers must wear apposite individual protection devices (ear muffs, inserts), and they must be informed and trained as provided by the directive 2003/10/CE on the protection of workers from exposure to noise.

The manufacturer, given that the examined machines are characterized by sound pressure levels greater than 85 dB(A), must report on the "utilization and maintenance" manual, as required in the "machinery directive", the value of sound power of the machine.

Furthermore, the manufacturer should hypothesize and implement various interventions that may reduce the value of sound emissions of the machine. Thus, deep surveys to individuate all sources of sound emission on the machine are needed and an enhancement program must be implemented.

It is possible to work on noise sources and on noise propagation. As it regards these last interventions, it is important to be aware that the noise emitted by any source can be directly spread by air or by solid (for instance, through the machine frame).

Interventions on sources are always to be favoured because they remove the noise (risk) directly at the source (Monarca *et al.*, 2009). It is necessary to look for the application of noiseless functioning systems on the machine and try to decrease the high noise of some sources.

In order to do so a deepen study on all the components of the machine is needed (for instance through the measure of sound intensity), thus the possible intervention points can be highlighted. If the noise of the sources is caused by lacks in the designing phase, these must be immediately removed or corrected. Then, the noise origin must be determined:

- if the noise has a mechanic origin (rotating elements, transmission elements like gears and bushes, metallic collisions), speed and load must be reduced, so as the vibrations transmitted to the surfaces must be eliminated;
- if the noise has an aerodynamic origin, beside the utilization of sound dampers, it is necessary to correct the loops and the fan functioning; rotation noises and fluid vorticity must be reduced.

Interventions on propagation can be realized through different strategies:

damping pads: are necessary in case of vibrations transmitted to the frame from the engine or the fans used for air suction. The same kind of intervention can be used to eliminate the continuity of extended metal structures.

Integral shrouding: is an intervention to be done when it is no longer technically possible to reduce the noise of the source. It is required when a big noise reduction is needed (at least 15-20 dB). It is a very effective kind of intervention, but the costs are often high and it is not always technically feasible.

Partial shrouding: it can be useful when it is not possible to close all the machine, when the decrease needed is not greater than 15 dB, when the frequencies to be lowered are medium-high. Interventions of partial shrouding can determine reduction of sound power for the operator ear between 3-5 dB and 12-15 dB.

Worker isolation: in same cases it can be useful to isolate in a sound-insulating cabin the operator (such intervention can be also useful against other risks, like dust). It is a feasible and advisable kind of intervention for many noisy machines for which a reduction of noise at the source or integral shrouding are not reasonably practicable. For the self propelled nut harvester the driving cab is not easily realizable because the machine must operate in orchards, but first models of self propelled harvesters with cab are nowadays on the market (figure 6).

Figure 6. A nut harvester with cab (courtesy of Asquini)

References

Monarca D., Cecchini M., Antonelli D. (2005). Innovations in harvesting machines. Acta Horticulturae. 686, 343-350.

Monarca D., Cecchini M., Colantoni A. (2009). Strategie ed interventi per il contenimento del rischio da rumore nel settore agroforestale. In: dBA incontri 2009 Interventi per la riduzione del rischio rumore. Legislazione, normative, tecnologie, esperienze. Modena, 24 settembre 2009.

Monarca D., Zoppello G. (1993), Il problema delle polveri e dei rumori in ambiente agricolo. Atti del V Convegno nazionale AIGR. Maratea 7-11 giugno 1993, (4) 383-390.

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

Dust Exposure for Workers During Hazelnut Harvesting

Cecchini M., Monarca D., Guerrieri M., Lingero E., Bessone W., Colopardi F., Menghini G.
Dept. Gemini, University of Tuscia, via San Camillo de Lellis – 01100 Viterbo, Italy, tel. +39 0761 357357, fax +39 0761 357453, e-mail: ergolab@unitus.it

Abstract
A research has been carried out to assess the dust exposure for workers during mechanized harvesting of hazelnuts. The survey has been performed in the years 2006 and 2007 in four farms in Piemonte (Italy) in the province of Cuneo in the typical area of the cultivar "Tonda Gentile of Langhe". The samplings of the dust have been performed for workers during mechanized harvesting of hazelnut (four towed self-propelled vacuum machines and a towed picker-up). The results have been compared with ACGIH (American Conference of Governmental Industry Hygienist) threshold limit value (TLV), usually adopted as reference value for risk evaluation.
The results of the samplings highlighted an average exposure, for the year 2006, of 27.71 mg/m^3 and for 2007 of 2.58 mg/m^3. During 2006, 85.7 % of the analyzed samples exceeded the referring value advised by the ACGIH (3 mg/m^3) for respirable dusts. Analyzing the data for every type of harvesting machine employed it appears that the biggest concentrations were found in 2006 for the towed picker-up, with maximum value of 77.80 mg/m^3, while lower values were registered for towed and self moving vacuum machines. Analysing the swathing with backpack blowers it appears that, even in unfavourable conditions as in 2006, the average values of exposure are inferior as to machines and equal to 4.14 mg/m^3 for 2006 and 1.25 mg/m^3 for 2007. Finally, even if the harvesting is limited to few days, to avoid the onset of diseases to the respiratory system, it is advisable for workers employed with harvesting machines and blowers to use the right individual protection devices.

Keywords: dust, hazelnut harvesting, work hygiene

Introduction

The laws in safety and work hygiene subjects impose the assessment of the risks which the operators are exposed and the realization of prevention and protection's measures to improve the working conditions. Besides, the whole process of prevention, from the identification of the dangers to the measures of improvement, must be based on the consultation and the share of all the working subjects in the work place.

The aim of this survey is to analyze one of the main risk factors derived by the mechanized activity of harvest of the hazelnuts as the workers' exposure to the inorganic respirable particles spread in the air (Biondi et al., 1992; Monarca et al., 2005).

This survey refers to dusts that are absorbed during the respiration and that are not expelled through cough or secretion of mucous, which are particles that are not intercepted by the first respiratory ways and which, therefore, reach the bronchial and pulmonary hollow.

The nature of airborne can be the most varied: silicon, zinc oxide, carbonaceous particles, combustion smokes, radioactive substances, asbestos, insecticides, organic substances as well as those that derive from the cereals, etc. The word "concentration" means the quantity of particles in suspension in one cubic meter of air: it is generally expressed in mg/m^3, in g/m^3 or in ppm (parts per million: volume of the contained particles in 10^6 volume unit).

The granulometry points out the dimensions of the particles: a diameter *d* is defined, expressed as the arithmetic average of the three dimensions of the particle (length *l*, width *b* and thickness *s*).

In the study of the dangerousness for inhalation, great importance however has the subdivision between respirable dusts and non-respirable dusts, depending on their aerodynamic diameter. This represents the diameter of a sphere of unitary density (1 g/cm^3) that has the same terminal sedimentation speed of the particle in examination. The PM10 (particulate matter, with an aerodynamic diameter inferior to 10 m) represents the dusts able to penetrate into the superior part of the respiratory apparatus; while the PM 2.5 represents the dusts able to penetrate into the inferior part of the respiratory apparatus (pulmonary alveolus).

These last ones are the most dangerous because they are able to deposit themselves in the pulmonary system provoking inflammations, fibrosis and cancer.

The dusts with pathological action in humans are classified in two categories: pneumoconiogen dusts and non-pneumoconiogen dusts (Monarca and Zoppello, 1993). The first ones are those that expound their action to the level of the respiratory apparatus provoking pneumoconiosis which consists of an accumulation of dusts in the lungs and consequent reaction of the pulmonary tissue.

The pneumoconiogen dusts can be divided in “inactive” and “fibrogenic” dusts. The first ones don't alter the structure of the respiratory apparatus; the second ones can provoke more serious alterations modifying the structure of the alveolus and provoking a fibrogenic reaction of the tissue (Biondi et al., 1993).

These pathologies are subject to further worsening, even after the exposure, up to the appearance of illnesses as silicosis (provoked by dusts of silicon dioxide), asbestosis (provoked by asbestos dusts) and byssinosis (provoked by cotton dusts).

The non-pneumoconiogen dusts however can result as harmful because they bring particular substances or active principals able to pass into the circulation of the organism through the emo-lymphatic system. Given the dangerousness of the aforesaid dusts, in the last years (and it is predictable also for the next ones) there has been an increase of studies, researches, normative with the purpose to avoid, to prevent or to reduce the harmful effects on the health and on the environment.

The ACGIH identifies specific limits for coal dust, dust of cereals, dust of glass fibers, wood dust and cotton dusts. Other dusts are gathered under the name "(insoluble) particles not otherwise classified" (P.N.O.C.) and for these the ACGIH nowadays speaks of "guidelines", rather than of TLV; in the past, TLVs fixed for the P.N.O.Cs have been used wrongly and applied to any non available particle in the lists.

The ACGIH, today, specifies that the recommended limits for the P.N.O.Cs are applied to particles that: haven’t a specific applicable TLV; are insoluble or poorly soluble in water (or, preferably, in the pulmonary fluids if available data have been given); have low toxicity. For the aforesaid particles (in 2009) limits of aerial concentrations of 3 mg/m^3 in the case of the respirable particles are recommended.

Material and methods

The survey has been performed in the years 2006 and 2007 in four farms in Piemonte in the province of Cuneo in the typical area of the cultivar “Tonda Gentile of Langhe”:

- Cravanzana: altitude 585 m above sea level (min 369; max 716) – latitude 44° 34'32"52N;
- Torre Bormida: altitude 391 m a.s.l. (min 269; max 680) – latitude 44° 33'49"32N;
- Bosia: altitude 484 m a.s.l. (min 340; max 700) – latitude 44° 36'12"24N;
- Feisoglio: altitude 706 m a.s.l. (min 475; max 823) – latitude 44° 32'40"92N.

During the two years two campaign of measurements were carried out: the first one during the main harvesting (last decade of August); the second one during the first decade of September. In every orchard samples of soil were collected. These samples were analyzed at the "Coldiretti" Lab in Cuneo, obtaining data of soil humidity.
The harvesters used during the campaign of measurements are reported in table 1.

Table 1. Harvesters used during tests

Farm	Machine	Harvesting technique	Displacement	Working capacity (kg/h)
Moscone	Rivmec Smart 1800	Picking	Tractor-mounted	n.d.
Busca	Facma Cimina 300T	Aspirating	Pulled	600
Bertone	Facma Cimina 300S	Aspirating	Self-propelled	1000
La Ferrera	Facma Cimina 300S	Aspirating	Self-propelled	1000
"	Facma Cimina 380S	Aspirating	Self-propelled	1400

The pulled harvester Cimina 300T was equipped with one lateral aspirating device. Samplings were carried out also during the use of same blowers.

The samplings of dust have been effected using personal samplers built by SKC (SKC Inc. 863 Valley View Road, Eighty Four, PA 15330 U.S.A.): particularly the model Airchek® 52 has been used to constant course during the sampling (figure 1) (pump set to a course of 1,9 l/minute through a bubble flowmeter) and a cyclone SKC (figure 2) for the selection of the respirable convention as defined by the EN 481 standard "Workplace atmospheres. Size fraction definitions for measurement of airborne particles".

The cyclone is realized in conductive plastics and it exploits a system of removable and reusable cassette sampling; inside the cassette the filter is supported on a homogeneous grilled surface, to exploit in a uniform way the filtering surface and at the same time to facilitate the manipulation of the filter before and after the sampling.

Filters (figure 3) have been employed in cellulose nitrate with a porosity of 0,8 m and a diameter of 25 mm. The filters have been weighted, before and after the sampling, through an analytical balance Sartorius (Sartorius Mechatronics India Pvt. Ltd. #10, 3rd Phase, Peenya 6th Main, KIADB Industrial Area Bangalore - 560 058 INDIA) mod. BL 2105, with precision equal to 0,1 mg and a maximum of 120 g (figure 4).

Before weightings, for every filter a conditioning of 24 hours in a checked environment has been anticipated.

The samplers have been submitted to the workers during the normal harvesting job, positioning the orifice of entrance of the sampler parallel to the body and at the same height of the respiratory zone.

Figure 1. SKC Pump™

Figure 2. SKC cyclone for respirable fraction

Figure 3. SKC MCE filters

Figure 4. Analytical balance Sartoius

The sampling times have been timed and verified with the times pointed out by the counter in endowment to the pump. The choice of the samplings duration is founded on the observation of the filtering membranes: particularly the sampling was concluded when on the membranes a light visible layer of dust resulted, without reaching excessive accumulations of particles that during the transport of the filters would have been able to cause a loss of part of the samples and consequent under-estimation of the values of concentration.

For the transport of the samples a stuffed handbag has been used, to guarantee an elevated protection against the bumps that would have been able to provoke the separation of the particles sampled by the membranes (events that would have distorted the results of the tests); the handbag was manoeuvred with particular attention.

Given the sampling time t_c (min), the volume flow rate of sampling Q (m^3/min), the initial mass of the filter M_i (mg) and the mass of the dust-filled filter M_f (mg) (values gotten after the conditioning of the membranes) the value of the dust concentration Ct_c is obtained through the formula (CEN, 2005):

$$Ct_c = \frac{(M_f \quad M_i)}{Q \quad t_c} \qquad (\mathrm{mg/m^3}) \qquad (1)$$

Regarding the times of exposure (to dusts) of the workers employed in the harvest, a fundamental factor for the evaluation of the risk, it's necessary to underline that these are influenced by the dimensions of the surfaces to be harvested, the orographic characteristics from the conditions of the ground and from the plant distances.

Nevertheless in all the examined firms an exposure time practically coincident with the whole working shift is noticed, (equal to the 8 daily hours). This has allowed to be able to directly compare the average values of concentration noticed with the limits defined by the ACGIH.

Results

Tests in both seasons occurred in the absence of rainfall, so facilitating the harvesting, but also the development of dust during operations. The orchards in Alta Langa are not watered, and are generally not turfed: this contributes negatively to the dust production.
The visual feedback on the airborne particles was found misleading and it has not confirmed by exposure data for operators. In fact, the self-propelled Cimina 380 S showed much lower exposure than the picking machine Smart 1800, a sign of careful design of flows for removing dust from the operator area.
Tables 2 and 4 show relative humidity data of soil samples and the RH of the field obtained as the average of data.

Table 2. Relative humidity of sampled soils (2006)

Nr.	Sampling date	Farm	RH (%)	Av. RH (%)	Nr.	Sampling date	Farm	RH (%)	Av. RH (%)
1	30/08/2006	Bertone	10.16		1	11/09/2006	Bertone	7.56	
2	30/08/2006	″	8.33	10.46	2	11/09/2006	″	4.38	6.03
3	30/08/2006	″	12.89		3	11/09/2006	″	6.14	
1	30/08/2006	Moscone	8.06		1	11/09/2006	Moscone	6.37	
2	30/08/2006	″	6.70	7.89	2	11/09/2006	″	4.66	5.12
3	30/08/2006	″	8.92		3	11/09/2006	″	4.32	
1	31/08/2006	La Ferrera	10.85		1	11/09/2006	La Ferrera	4.87	4.54
2	31/08/2006	″	4.90	7.88	2	11/09/2006	″	4.91	
3	31/08/2006	″	7.89		3	11/09/2006	″	3.85	
1	29/08/2006	Busca	4.11						
2	29/08/2006	″	7.35	5.83	*(Busca didn't made second harvesting)*				
3	29/08/2006	″	6.02						

Data in table 2 show, for August and September 2006, a low value of relative humidity due to scarcity of rainfall (between late August and early September there were no rainfalls – table 3). This situation favored the development of dust during harvest, leading to higher values of dust concentrations than in 2007.

Table 3. Weather during the sampling days (2006) (Source: Sistema Piemonte)

Date	T min (ºC)	T max (ºC)	Av. T (ºC)	RH min (%)	RH max (%)	Av RH (%)	Rain (mm)
26/08/2006	11.2	25.2	18	44	94	75	0.2
27/08/2006	12.8	26.9	19.1	29	93	69	0
28/08/2006	10.9	22.8	16.6	55	94	79	0.2
29/08/2006	12	23.8	17.7	40	94	75	0
30/08/2006	9.2	25.5	16.9	18	92	52	0
31/08/2006	6.7	24.5	16	21	77	45	0

Table 4. Relative humidity of sampled soils (2007)

Nr.	Sampling date	Farm	RH (%)	Av. RH (%)
1	24/08/2007	Busca	20.23	
2	24/08/2007	″	19.95	20.44
3	24/08/2007	″	21.15	
1	24/08/2007	Moscone	18.29	
2	24/08/2007	″	17.55	18.41
3	24/08/2007	″	19.39	
1	24/08/2007	Bertone	19.51	
2	24/08/2007	″	16.99	17.78
3	24/08/2007	″	16.83	
1	25/08/2007	La Ferrera	22.12	
2	25/08/2007	″	23.4	24.05
3	25/08/2007	″	26.62	

Table 5. Weather during the sampling days (2007) (Source: Sistema Piemonte)

Date	T min (ºC)	T max (ºC)	Av. T (ºC)	RH min (%)	RH max (%)	Av. RH (%)	Rain (mm)
20/08/2007	12.7	20.6	15.8	66	92	85	8.4
21/08/2007	12.6	18.9	14.4	61	93	85	8.8
22/08/2007	12.3	18	14.7	65	92	84	1.0
23/08/2007	10.2	22.6	15.5	47	93	79	0.2
24/08/2007	11.7	24.1	17.4	45	93	74	0.2
25/08/2007	13.0	28	22.8	46	93	77	0

In total, during the two seasons, 18 samples were collected:
- nr. 7 during the swathing with blowers (6 with backpack blowers and 1 with blower connected to the tractor);
- nr. 2 were collected on workers who have performed the swathing and the harvesting;
- nr. 9 during the harvesting.

11 samplings were collected during harvesting:
- nr. 3 on the tractor mounted Rivmec Smart 1800;
- nr. 2 on the pulled aspirating Facma Cimina 300 T;
- nr. 6 on the self propelled aspirating Facma Cimina 300 and 380.

Table 6 shows results of all the tests in chronological order. Graphs in figures 5 and 6 show the exposure levels respectively for workers on harvesters and those involved in the swathing, reporting also levels of soil relative humidity.

Tabella 6. Tests results

Date	Farm	Operation	Machine	Sampling time (min)	Aspirated volume (l)	Dust weight (mg)	Soil RH (%)	Dust concentration (mg/m^3)
29/08/2006	Busca	blowing+harvesting	Facma Cimina 300 T	25	47.50	0.15	5.83	3.20
29/08/2006	Busca	blowing	-	9	17.10	0.10	5.83	5.80
30/08/2006	Moscone	harvesting	Rivmec Smart 1800	34	64.60	2.10	7.89	32.50
30/08/2006	Bertone	blowing+harvesting	Facma Cimina 300 s	107	203.30	7.00	10.46	34.40
30/08/2006	Bertone	blowing	-	65	123.50	6.00	10.46	4.90
31/08/2006	La Ferrera	harvesting	Facma Cimina 380 s	64	121.60	1.80	7.88	14.80
31/08/2006	La Ferrera	blowing	-	78	148.20	0.30	7.88	2.00
11/09/2006	Moscone	harvesting	Rivmec Smart 1800	23	43.70	3.40	5.12	77.80
11/09/2006	Bertone	blowing	-	30	57.00	0.20	6.03	3.50
11/09/2006	Bertone	harvesting	Facma Cimina 300 s	45	85.50	2.45	6.03	28.70
11/09/2006	La Ferrera	blowing	-	35	66.50	0.30	4.54	4.50
11/09/2006	La Ferrera	harvesting	Facma Cimina 380 s	50	95.00	2.15	4.54	2.60
24/08/2007	Busca	harvesting	Facma Cimina 300 T	80	152.00	0.20	20.44	1.30
24/08/2007	Moscone	harvesting	Rivmec Smart 1800	40	76.00	0.20	18.41	2.60
24/08/2007	Bertone	blowing	-	58	110.20	0.10	17.78	0.90
24/08/2007	Bertone	harvesting	Facma Cimina 300 s	30	57.00	0.25	17.78	4.40
25/08/2007	La Ferrera	harvesting	Facma Cimina 300 s	80	152.00	0.30	24.05	2.00
25/08/2007	La Ferrera	blowing	-	80	152.00	0.25	24.05	1.60

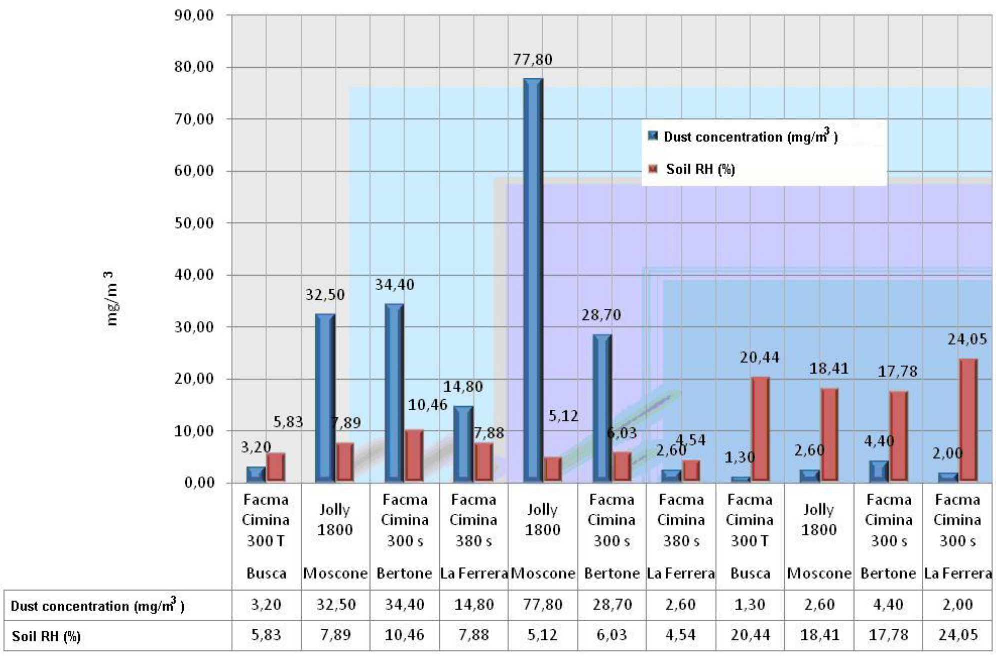
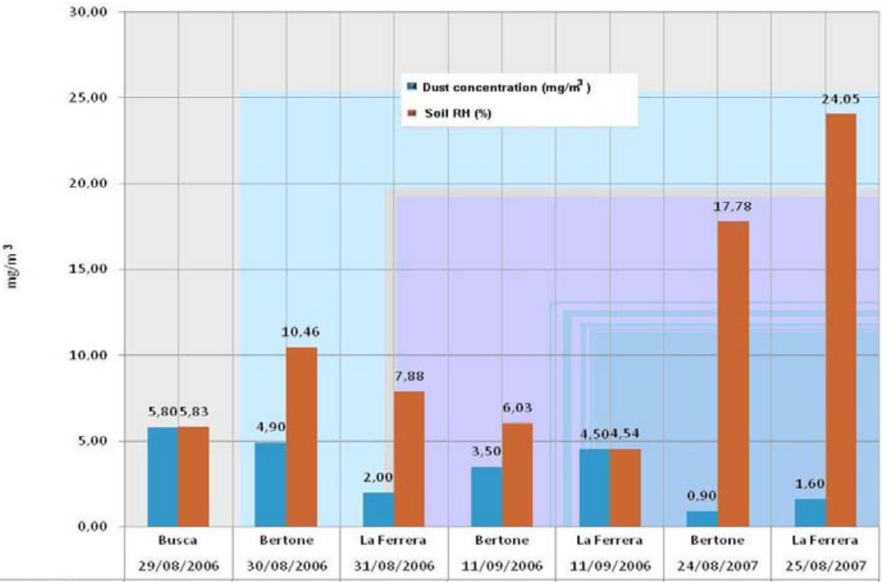


Figure 5. Dust concentration during hazelnut harvesting



	Busca 29/08/2006	Bertone 30/08/2006	La Ferrera 31/08/2006	Bertone 11/09/2006	La Ferrera 11/09/2006	Bertone 24/08/2007	La Ferrera 25/08/2007
Dust concentration (mg/m³)	5,80	4,90	2,00	3,50	4,50	0,90	1,60
Soil RH (%)	5,83	10,46	7,88	6,03	4,54	17,78	24,05

Figure 6. Dust concentration during hazelnut swathing with blowers

Discussion

Data analysis shows values of dust exposure, for workers involved in hazelnut harvesting and blowing, very variable between the years 2006 and 2007.
The exposure for workers during harvesting ranged from a minimum of 1.30 mg/m^3 to a maximum of 77.80 mg/m^3, depending on the machines used and the conditions of soil (humidity, influenced by rainfall).
The overcaming of the level set by ACGIH to 3 mg/m^3 (respirable dust), occurred in 7 out of 11 samples (63.6%). The highest values, as has been found in previous tests (Monarca et al., 2008), are those recorded on the picking machine Smart 1800 in 2006.
The analysis of aggregate data for different types of machines (table 7) confirms the higher values attributed to the picking machines. Among the aspirating machines, the self-propelled Facma Cimina 380S, although has no cyclones, shown exposure values often less than the 300S model: this could be due to a system for dust removing from the driver's area.

Table 7. Average dust concentration during harvesting with different type of harvesters

Type of harvester	Average (mg/m^3)	St. Dev. (mg/m^3)
Aspirating with cyclons	12.33	15.03
Aspirating without cyclons	8.70	8.63
Picking	37.63	37.86

As for dust exposure of workers involved in the swathing, the data show that 4 out of 7 samples exceeded the reference value of 3 mg/m^3.
The demonstration of the importance of the soil RH and therefore the relationship with the dust concentrations is demonstrated by the sample data. Those for the year 2006, showing high levels of exposure to dust, are related to very low levels of soil RH ranging from 4.54% to 10.46%. In 2007, significantly lower levels of exposure are related to humidity levels much

higher with values between 17.78% and 24.05%. The meteorological conditions during 2007 was caracterized by more rainfall than during 2006. Furthermore, data about regional weather station in Cravanzana recorded few days before the start of testing (24 and 25 August), a value of 17.2 mm of rain fell on 20 and 21 August.
Another factor which may have influenced the persistence of dust in the worksite and then the workers exposure is the difference in vegetative development of orchards. The orchards of "La Ferrera", featuring the latest plantation, regular plant distances and farming conditions suitable to allow the movement of air in rows, have found lower levels of dust exposure than other older plants.
Particularly in orchards of farms "Bertone" and "Moscone", with 30 years and more old plants characterized by a dense vegetative growth with low movement of air between the plants, especially in the year 2006 have presented higher values of dust exposure for workers.

Conclusions

From the data shown in table 6 and figures 5 and 6, a constant overcaming of the limit values defined by the ACGIH is deduced, in the case of the harvest of the hazelnuts, although the technologies used for the mechanized harvest of this product result to be characterized by a high degree of innovation (ACGIH, 2009).
The average concentration of dusts found in the tests during harvesting is equal to 18.6 mg/m^3 (with a great standard deviation, in comparison to the results, equal to 23,6 mg/m^3), against a value defined by the "guidelines" recommended by the ACGIH equal to 3 mg/m^3. During blowing tests show an average dust concentration equal to 3.3 mg/m^3 (st. dev. 1,85 mg/m^3).
The research has also analyzed the importance of the variables involved during a typical harvest: particularly it assumes notable influence the soil humidity, while other variables as the planting distances, the dimension of the fields, the organization of the work, primarily engraves on the times of exposure to the specific agent of risk.
During hazelnuts harvesting, to avoid the onset of possible illnesses of the respiratory apparatus of the workers the use of individual protection devices (IPD) for the protection of the respiratory ways, is fundamental.

Figure 7. A nut harvester with cab (courtesy of Asquini)

However, for the reduction of the risks it seems evident the benefits brought by solutions like for instance: the substitution of the technique of the worked ground with that of the grass

covered ground, the reduction of the number of employees (with passage from the traditional system with hauled machines and three or four employees to the harvest, to the self moving ones usable by a single operator), while the employment of picking machines rather than vacuum machines doesn't appear as an evident system of prevention anymore (Biondi et al., 1994; Cecchini et al., 2005).
More drastic solutions to the problem such as the adoption of semi-cab machines, even though desirable, result difficult as an application for the peculiarities of the work (necessity to pick up under the tree). However first models of harvesters with cab are nowadays on the market (figure 7).

References

ACGIH (2009), Valori limite di soglia. Indici Biologici di Esposizione, ACGIH 2009. Giornale degli Igienisti Industriali, AIDII, Milano, aprile 2009.

Biondi P., Monarca D., Zoppello G. (1992), Il problema delle polveri nella raccolta delle nocciole con macchine aspiratrici. Rivista di Ingegneria Agraria 23 (4), 228-236.

Biondi P., Monarca D., Zoppello G. (1993), Il problema delle polveri nella raccolta delle nocciole. Macchine e Motori agricoli, 50 (4), 63-69.

Biondi P., Monarca D., Zoppello G. (1994), Dust control in hazel harvesting with vacuum harvesters. Atti III International Congress on Hazelnut, Alba 14-18 settembre 1992. Acta Horticulturae, gennaio, 351, 513-519.

Cecchini M., Monarca D., Biondi P., Colantoni A., Panaro A. (2005), Il rischio da esposizione a polveri per gli addetti alla raccolta delle nocciole. Convegno AIIA2005: l'ingegneria agraria per lo sviluppo sostenibile dell'area mediterranea. Catania, 27-30 giugno 2005.

CEN (2005), EN 529:2005 "Respiratory protective devices - Recommendations for selection, use, care and maintenance - Guidance document"

Monarca D, Biondi P, Cecchini M., Santi M, Guerrieri M, Colantoni A (2008). Evaluation of respirable dust exposure during hazelnut and chestnut mechanized harvesting. In: Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems. Ragusa, 15-17 settembre 2008.

Monarca D., Cecchini M., Antonelli D. (2005). Innovations in harvesting machines. Acta Horticulturae. vol. 686, pp. 343-350 ISSN: 0567-7572.

Monarca D., Zoppello G. (1993), Il problema delle polveri e dei rumori in ambiente agricolo. Atti del V Convegno nazionale AIGR. Maratea 7-11 giugno 1993, (4) 383-390.

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

Exposure to Pesticides: a Survey on Sicilian Greenhouse Operators

Cerruto E., Emma G.
Dipartimento di Ingegneria Agraria (DIA), Via Santa. Sofia, 100 – 95123 Catania, Italy
Tel. +39 0957147514, Fax +39 0957147600, ecerruto@unict.it

Abstract
Greenhouses are microcosms aimed at providing physical environments suitable for increase growth and production of crops and pesticide application is a common practice to improve quality and quantity of agricultural products. Unfortunately, the enclosed conditions makes sure that greenhouse workers are more exposed to higher levels of plant protection products than general agricultural workers. This paper reports the results of a survey of pesticide application in greenhouses of South-East of Sicily carried out at the Department of Agricultural Engineering of the Catania University.
The survey covers several aspects: statistics on farms, machinery used, number of applications per year, operating parameters, operator safety, and environmental impact. The results show that the most widespread machinery is the hand held high pressure (20 bar) spray lance or spray gun. The majority of operators (62%) make more than 16 application per year, spraying volume rates ranging from 700 to 1000 L/ha. The machinery maintenance is very poor: 19 percent of pressure gauges were broken and 86 percent have never been checked, as well as 19 percent of nozzles and 43 percent of filters have never been replaced. The use of PPE isn't widespread as it should be: during mixture preparation, when concentrated pesticides are to be manipulated, only 43 percent of operators use waterproof gloves, 19 percent wear appropriate overalls, and 14 percent protects respiratory tract by means activated carbon masks. Finally, the attention towards environmental aspects isn't adequate, especially as regards the management of the waste products from pesticide applications (mixture remnants, water used for sprayer cleaning, empty containers).

Key words: safety, environment, spray lances

Introduction

According to the Italian Central Statistics Institute (ISTAT, 2006), in Italy there are some 35000 ha of vegetables (tomatoes, lettuces, zucchini) and some 5000 ha of ornamental (roses, chrysanthemums, carnations) protected crops. Sicily account for some 8800 ha and 430660 t, mainly located in the province of Ragusa (4750 ha and 272650 t). Greenhouses, given the peculiar structural and climatic conditions (confined space, high temperature, high relative humidity), are very specific agro-ecosystems with respect to the open field so, to ensure high productions, massive energetic and chemical (fertilizers and pesticides) inputs are necessary.

Therefore, greenhouse workers' exposure to pesticides is one of the main sanitary problems. A recent survey of the Superior Italian Public Healthcare Institute (Settimi *et al.*, 2007), reports 2798 instance of poisonings in Italy in 2005, among which 1280 are related to agricultural pesticides. The region with the highest occurrence is Sicily (223, the 17.4%), where the consumption of agrochemicals is very high (20000 t in 2005, the 12.80% of the overall Italian consumption). Moreover, the usually high values of temperature and relative

Research developed within the MIUR project *Machinery and their adjustment for a sustainable pest control in glasshouses*.

The Authors equally contributed to the present study.

humidity inside greenhouses make it unpleasant to wear proper protective equipment, so the risk of exposure can increase.

Exposure can occur during mixture preparation, its application to the crops, machinery cleaning, and post-treatment operations connected to the re-entry in greenhouse (Aprea *et al*., 2002). Several Authors (Bjugstad and Torgrimsen, 1996; Tuomainen *et al*., 2002; Garrido Frenich *et al*., 2002; Cerruto *et al*., 2009) report that the human exposure is affected by a number of factors: spraying equipment, operating mode, drop size, crop features. Surveys carried out in Turkey (Ergonen *et al*., 2005), Spain (Sànchez-Hermosilla *et al*., 1998) and Italy (Cerruto *et al*., 2007) show that the handling of chemical products is done without taking all precautions to prevent exposures (inadequate use of personal protective equipment—PPE) and there is a marked unawareness about their danger and toxicity.

Moreover, pesticides have great impact on the environment (air, soil and water) (van der Werf, 1996) and contaminations can be both diffused (due to drift during the applications) and localised (due to mixture preparation and cleaning of the equipment usually in the same small area, not properly adequate). The recent European directive 128/2009/CE intends "establishing a framework for Community action to achieve the sustainable use of pesticides" and to this end encourages, among other things, the promotion of "research programmes aimed at determining the impacts of pesticide use on human health and the environment … at European and national level". Moreover, the directive 127/2009/CE imposes the necessity of using sprayers correctly regulated in order to minimise environmental hazards.

The present research is in agreement with these programs as reports the results of a survey carried out in the South-East of Sicily, where greenhouse crops are very widespread, that takes into account several aspects regarding operator safety and environmental contamination during pesticide applications in greenhouses.

Materials and Methods

A questionnaire was prepared and submitted to the owners of 21 greenhouse farms in the South-East of Sicily. It covered several aspects related to pesticide applications in greenhouse, among which:

- Farm statistics: cultivated areas, main crops, number, age, surface and structure of greenhouses;
- Machinery used: type of sprayer and its maintenance, nozzle type, tank capacity and mixing system;
- Operating parameters: type of pesticides, number of applications, volume rates, working pressure, walking direction when using spray lances;
- Operator safety: use of personal protective equipment (PPE) during loading and distribution of the mixture and during the post treatment operations (cleaning of the equipment);
- Environmental impact: management of empty containers of pesticides, remnants after treatments, and waste water.

The replies were statistically analysed, computing the distributions of the main quantities. All statistical analyses and graphical representations were carried out by means of the open source software R.

Results and Discussions

Farm statistics

The 21 farms surveyed are in the provinces of Ragusa (15), Siracusa (1), and Caltanissetta (5). Their cultivated area ranges from 1700 m^2 up to 12 ha, with a mean value of

3.19 ha; the area of 90 percent of them is less than 5.5 ha (Figure 1). Tomato is the most widespread crop, present in 20 out of 21 farms, and its surface extend over 43 out of 67 ha (64.2%), followed by zucchini (8 farms, 10.7 ha), eggplants (6 farms, 6.5 ha), and peppers (7 farms, 5.8 ha). Roses are present in only one farm, extending over 1 ha.

The number of greenhouses per farm ranges from 3 up to 21 and is related to the total cultivated area as reported in Figure 2. From the graph it emerges that when the total farm area is less than roughly 50 ha, the area covered by each greenhouse is about 2500 m^2, while in larger farms is about 5000 ha. The latter case refers to younger greenhouses (less than 6 years) with a metallic component in their shell, while the former refers to older greenhouses, mainly with concrete and wooden shell (Figure 3).

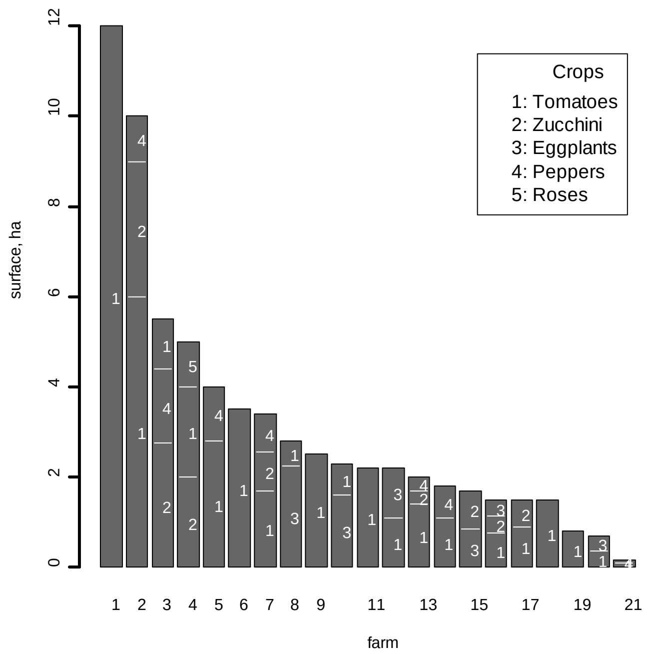


Figure 1. Cultivated area and crops present in the surveyed farms.

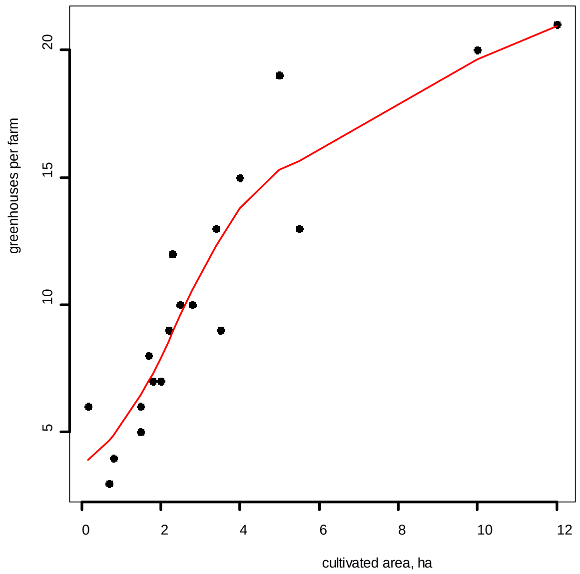


Figure 2. Number of greenhouses per farm vs. farm area.

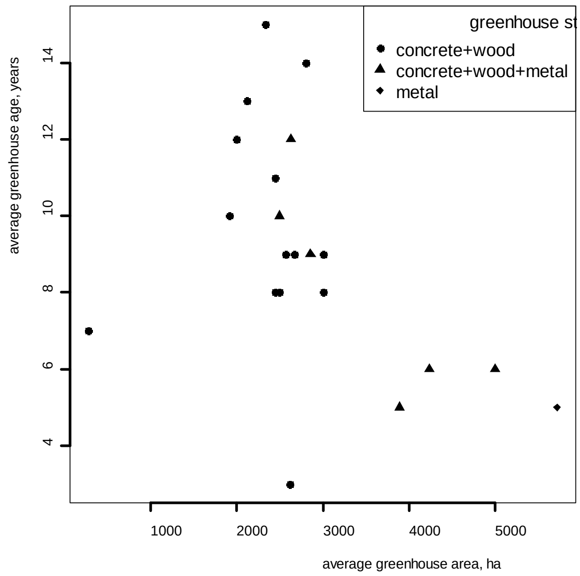


Figure 3. Age vs. greenhouse area.

Spraying machinery

In all surveyed farms, pesticide application is performed by means of hand held high pressure spray lances or spray guns, whose length ranges from 45 to 80 cm (mean 55 cm). In most cases (67%) the pump is fixed, whereas in other cases (33%) it is driven by the power take off (pto) of a tractor. Small farms (roughly below 3 ha) use fixed pumps, whereas larger farms use pumps driven by pto (Figure 4). The pump age ranges from 3 up to 15 years (mean 8.9 years) and the lance age from 2 up to 12 years (mean 5.7). Almost always (88%) the pump age is greater than the lance age (Figure 4). The spray lance is mostly (90%) equipped with 2 turbulence nozzles and in other cases with only one nozzle. The nozzle material is mainly steel (35%), followed by brass (25%), ceramic (25%) and synthetic. The mixture tank capacity ranges from 200 to 1000 L: small tanks (around 200 L) are metallic, whereas the bigger ones are made with fibreglass (33%) and polyethylene (57%) (Figure 5). Tank capacity and farm area are quite uncorrelated (Figure 5). Finally, the mixture mixing is realized manually (62%) or hydraulically (38%).

Working parameters

Pesticide applications, both fungicides and insecticides-acaricides, are performed almost all over the year in all farms (in 94% for more than 9 months per year). In detail, 40 percent of the interviewed carry out between 10 and 15 treatments per year, 52 percent between 16 and 20, and 8% more than 20.

The spraying time ranges from 40 to 60 minutes per 1000 m^2 of treated area, with the greatest percentage (71%) from 40 to 45 minutes (Figure 6 a). The working pressure ranges from 10 to 20 bar (48% from 18 to 20 bar, Figure 6 b), and the volume rate from 700 to 1000 L/ha (52% from 750 to 800 L/ha, Figure 6 c).

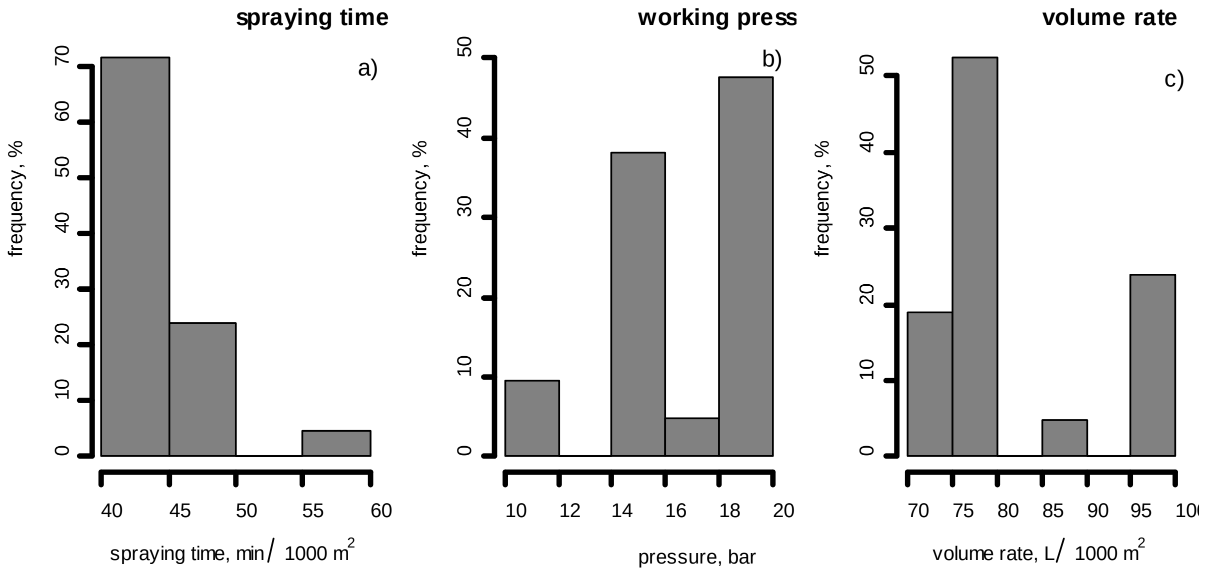


Figure 6. Main working parameters.

Operator safety

Pesticide application by means of spray lances is usually carried out by two operators: the former sprays the crops by moving amidst the rows and using the lance, the latter unwinds and rewinds the feeding hose-pipe. During spraying, the operator walks forward, even if this operating mode greatly increases his/her dermal exposure with respect to the walking backwards (Cerruto *et al.*, 2009).

In all the surveyed cases, operators were male, whose age ranged from 24 to 45 years. Their safety was assessed by analysing the re-entry time in greenhouse after treatments and, mainly, the use of personal protective equipment (PPE) during the main phases of a pesticide application: mixture preparation, mixture application, post-treatment operations (cleaning of equipment). The re-entry time was on average 15 hours, ranging from 2 to 24 hours. Fifty percent of the interviewed answered they went into the greenhouses for crop activities in the treated area 24 hours after spraying.

The use of PPE is summarized in Figure 7. From it emerges that a high percentage of operators don't wear appropriate PPE during the three phases took into consideration. For example, during the preparation of the mixture, when concentrated pesticides are to be manipulated, operators don't use at all gloves (19%), or use latex (24%) or textile (14%) gloves (textile gloves, when wet with pesticide, can become very risky). Moreover, no one protects his/her lower limbs by means of boots, and only 19 percent wear appropriate waterproof overalls for body protection (57 percent wear textiles boiler suit and 24 percent don't wear any specific PPE for body protection). Even lower is the head protection: 85 percent of operators don't wear any PPE, while the others wear inappropriate hoods or caps. The protection of respiratory tract during mixture preparation is also very low: only 14 percent of operators use activated carbon masks, while 5 percent wear simple respirators and 81 percent any protection.

none
textiles
latex
rubber

none
textiles
latex
rubber

none
textiles
latex
rubber

view, the same study shows that, while spraying 1000 L/ha on full developed tomato plants, the operator's body collects about 220 mL/h of mixture. The greatest increase in using PPE is observed in protecting the respiratory tract: the use of activated carbon masks, in fact, increases from 14 to 81 percent (from 5 to 14 percent that of respirators).

Finally, the post-treatment operations (cleaning of the equipment) is considered the less dangerous phase, as the percentage of operators that don't wear PPE at all is the highest: hands (81%), body (48%), head (100%), and respiratory tract protection (95%).

Environmental aspects

The environmental aspects here considered regard cleaning and management of the empty containers of pesticides and management of residual mixture after treatments and waste water after cleaning sprayers.

All the operators clean the containers of pesticides and add the washing water to the mixture, but only 48 percent transfer the empty container to specialised collecting centres for their correct disposal (the others—52%—don't provide any reply). All the operators declare that when treatment is finished, a certain amount of mixture remains unsprayed inside the tank and this remnant is reused for next application, even if this operating mode could imply miscalculations in pesticide concentration if added to a new mixture. The majority of operators (86%) wash the spraying equipment, but with highly variable frequency: randomly (56%), when change active ingredient (33%), at the end of crop season (11%). The amount of used water isn't monitored and it is drained on the ground, without any caution, so increasing the risk of pollution from point sources.

Conclusions

The survey highlights some aspects of pesticide application in greenhouses of South-East Sicily that can be so summarized:

- high number of spray applications per year (60 percent more than 16);
- very poor level of mechanization, as the prevailing equipment is the hand held high pressure spray lance, with one or two turbulence nozzles;
- high working pressures (48 percent from 18 to 20 bar) and high volume rates (from 700 to 1000 L/ha and more, according to plant growth and pest severity);
- poor knowledge of the effective working parameters as the pressure gauge is broken (19%) or not visible during spray applications (24%) or never checked (86%);
- poor maintenance of the spraying equipment: use of brass-made nozzles, very subject to wear and tear (25%), non-substitution of nozzles and filtering devices since many years or not at all (19% and 43%, respectively), irregular cleaning;
- little regard for safety aspects, especially during mixture preparation, when concentrated pesticides are to be manipulated: high percentages of operators, ranging from 24 to 85 percent, no make use at all of personal protection equipment for body, hands, head, and respiratory tract. Mixture application is considered more dangerous than mixture preparation, as the percentage of operators that wear PPE is always higher;
- not adequate attention towards environmental aspects, especially those related to the management of the waste products from pesticide applications (mixture remnants, water used for sprayer cleaning, empty containers).

This general picture shows that pesticide application in greenhouses should be improved, increasing the professional know-how of the operators through specific training courses and requiring a mandatory inspection of the sprayers. Both aspects are examined by the cited European directives 127 and 128/2009/CE, which are expected to play an important role in the direction of research and innovation for sprayers and crop protection in a more eco-compatible agriculture (Balsari and Oggero, 2009).

References

Aprea C., Centi L., Lunghini L., Banchi B., Forti M.A., Sciarra G. 2002. Evaluation of respiratory and cutaneous doses of chlorothalonil during re-entry in greenhouses. Journal of Chromatography B, 778 (2002) 131–145.

Balsari P., Oggero G. 2009. Macchine per la protezione delle colture: ricerca e innovazione. Mondo Macchina - Machinery World, Roma, 10–11, october–november 2009, 52–56.

Bjugstad N., Torgrimsen T. 1996. Operator safety and plant deposits when using pesticides in greenhouses. J. Agric. Engng Res. (1996) 65, 205–212.

Cerruto E., Balsari P., Oggero G., Friso D., Guarella A., Raffaelli M. 2007. Operator safety during pesticide application in greenhouses: a survey on Italian situation. ISHS Acta Horticulturae 801, 25 November 2008, vol. 2, 1507–1514.

Cerruto E., Emma G., Mallia I., Manetto G. 2008. Evaluation of dermal exposure to pesticides in greenhouse workers. Proceedings on CD-ROM of the International Conference on "Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems, Ragusa, Italy, 15–17 September 2008.

Cerruto E., Emma G., Manetto G. 2009. Spray application to tomato plants in greenhouses. Part 1: effect of walking direction. J. of Ag. Eng.—Riv. di Ing. Agr., 3, 41–48.

Directive 2009/127/CE of the European Parliament and of the Council of 21 October 2009 amending Directive 2006/42/EC with regard to machinery for pesticide application.

Directive 2009/128/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides.

Ergonen A.T., Salacin S., Hakan Ozdemir M. 2005. Pesticide use among greenhouse workers in Turkey. Journal of Clinical Forensic Medicine 12 (2005) 205–208.

Garrido Frenich A., Aguilera P.A., Egea Gonzalez F., Castro Cano M.L., Martinez Galera M., Martinez Vidal J.L., Soler M. 2002. Dermal exposure to pesticides in greenhouses workers: discrimination and selection of variables for the design of monitoring programs. Environmental Monitoring and Assessment 80, 51–63.

R Development Core Team. 2007. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria, ISBN 3-900051-07-0, URL http://www.R-project.org.

Sánchez-Hermosilla J., Pérez R., Díaz M. 1998. Study of labour risks due to the application of phytosanitary products protected crops. Ageng 98, Oslo, paper no. 98-G-033.

Settimi L., Davanzo F., Marcello I. 2007. Sistema nazionale di sorveglianza delle intossicazioni acute da antiparassitari: osservazioni effettuate nel 2005. Reports ISTISAN 2007, 07/51.

Tuomainen A., Makinen M., Glass R., Kangas J. 2002. Potential exposure to pesticides in nordic greenhouses. Bull. Environ. Contam. Toxicol., 69, 2002, 342–349.

Van der Werf, H.M.G. 1996. Assessing the impact of pesticides on the environment. Agricultural, Ecosystems and Environment 60 (1996) 81–96.

Vibrations Produced by Electric Shakers for Olive Harvesting

Cerruto E., Manetto G., Schillaci G.
Dipartimento di Ingegneria Agraria (DIA), Via Santa. Sofia, 100 – 95123 Catania, Italy
Tel. +39 0957147514, Fax +39 0957147600
ecerruto@unict.it; gmanetto@unict.i; gschilla@unict.it

Abstract

The paper reports the results of some experimental tests aimed at evaluating the effects of several manual electric shakers for olive harvesting on the vibrations transmitted to the hand-arm system. Three harvesting heads, different for number and arrangement of operating tools and oscillating system, each applied to three types of bars, different for material (carbon fibres and aluminium), diameter (35 and 40 mm) and length (2010 and 2210 mm), were considered. The vibrations were measured in two points, next to the hand positions on the bar in working conditions, at varying the bar inclinations (vertical, inclined at about 45 degrees, and horizontal). To smooth the influence of external factors, the machines were idle operated by the same person.

The main results show that global accelerations are quite high (about 20 m/s^2) and comparable with those measured when using mechanic or pneumatic machines, that the oscillating mechanism of the harvesting head affect the accelerations, that carbon fibre bar provide a significant reduction in accelerations with respect to the aluminium (16.3 vs. 21.2 m/s^2), that the bar inclination does not affect the vibration level, and that the accelerations on the bar are greater than those on the handgrip (21 vs. 16 m/s^2).

Keywords: safety, hand-arm system, facilitating machines

Introduction

Drupe harvesting is the most expensive phase of the olive production, so the use of handheld vibrating machines is very widespread to increase productivity, mainly when full mechanisation is not possible (Famiani *et al*., 2008). Unfortunately, the increase in the mechanization level introduces additional sources of risk for operators, as noise, vibrations, and fatigue due to the weight of the shakers (Iannicelli and Ragni, 1994; Blandini *et al*., 1997; Deboli *et al*., 2008; Pascuzzi *et al*., 2008).

The effects of vibrations on the hand harm system can lead to the well-known Raynaud syndrome, a disease which demands attention from all medical personnel (Chetter et al., 1998). The byodinamic response of the hand-arm system is affected by several factors, among which acceleration, vibration direction, frequency, posture, grip force, operating tool, and handle sizes can be cited (Dewangan and Tewari, 2008; Aldien *et al*., 2006; Monarca *et al*., 2003; Buström, 1997). Moreover, some of these factors are correlated with the effectiveness of anti-vibrating tools (Dong *et al*., 2005), which can reduce strongly the acceleration transmitted, so reducing in the same time work stress (Tewari and Dewangan, 2009).

Beside the use of anti-vibratory tools, the best protection against vibrations lies in adopting working practices aimed at prevention. Employers should ensure that workers at risk of developing hand-arm vibration syndrome receive adequate health education. This aspect,

---

The Authors equally contributed to the present study.

unlike the industrial environment, is often underestimated among agricultural farmers, due to the typical variability of the working conditions. As an example, the use of handheld shakers for drupe harvesting is limited in time, so the harvest capacity is the main characteristic that influences the purchase. Even so, machines powered by electric motors have been marketed for some years, mainly to reduce noise and increase operator's comfort (Biocca *et al*., 2008), so trying to respect the limits imposed by the recent regulations (government decree of August 19, 2005, no. 187; government decree of April 9, 2008, no. 81). Their development has involved changes in shape and dynamics of the harvesting system, as well as in the material for their construction (introduction of carbon fibres to reduce weight). These variations can affect the accelerations transmitted to the workers during their use, so different levels of vibration should be expected.

This research aims to evaluate the vibrations transmitted to the hand-arm system when using electric shakers at varying material and diameter of the bar, configuration of the harvesting head, and inclination of the bar during the use. A first study was proposed in Cerruto *et al*., 2009a and Cerruto *et al*., 2009b, which is here developed more in detail by increasing number of replicates and by performing a carefully frequency analysis.

Materials and Methods

Electric shakers

Experimental tests were carried out by using electric shakers powered by 12 V d.c. motors. Three harvesting heads and three bars were tested, so to give rise to a full factorial design. The three harvesting heads (Figure 1) are different for number and arrangement of the operating tools, as well as for direction of the oscillations. The first (H1) and the second (H2) have 8 operating tools, while the third (H3) 12. All operating tools are in carbon fibres and are of the same size (diameter = 5 mm, length= 370 mm). In H1 and H2 the operating tools are fixed to a 36-centimetre bar orthogonal to the motor shaft, while in H3 the bar is parallel to the motor shaft, so the oscillating planes are orthogonal. Number and arrangement of the operating tools can be modified, so the three harvesting heads can be assembled by the user according to his/her needs. The main features of the harvesting heads are reported in Table 1.

Figure 1. The three harvesting heads (H1, H2, and H3 from left to right).

Table 1. Harvesting head and bar features.

Harvesting heads			Bars				
	Operating tools, no.	Mass, kg		Material	Diameter, mm	Length, mm	Mass, kg
H1	8	1.545	B1	Aluminium	35	2010	1.356
H2	8	1.545	B2	Carbon fibre	40	2210	1.342
H3	12	1.365	B3	Aluminium	40	2210	1.416

The three bars tested are different for material, diameter, and length, as reported in the same Table 1. By comparing bars B2 and B3, the effect of the material (aluminium and carbon fibres) on the vibrations can be evaluated, while by comparing bars B1 and B3, the effects of diameter (35 and 40 mm) and length (2010 and 2210 mm) can be evaluated. The thickness of the material (2 mm) is the same for all the bars.

The electric motor (maximum power of 900 W and rotating speed of around 6000 rpm, fixed by a electronic card) is the same for all the three harvesting heads. It is feed by means of an external 12 V battery and the electric cable is lodged inside the bar, from which it emerges near the handgrip equipped whit the activation switch. The motor shaft is connected to a box that, with the same gear ratio of 10:58, gets the operating tools moving with frequency of around 18 Hz.

Measurement equipment

Vibrations measurements were carried out 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 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 (Figure 3).

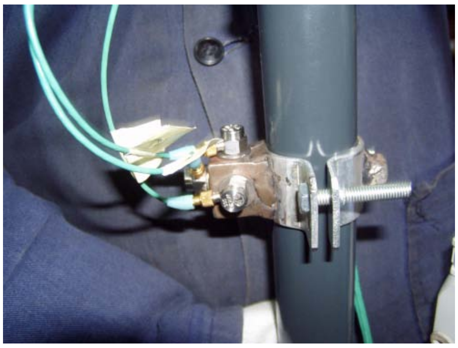


Figure 2. Positioning of the accelerometers on the bar.

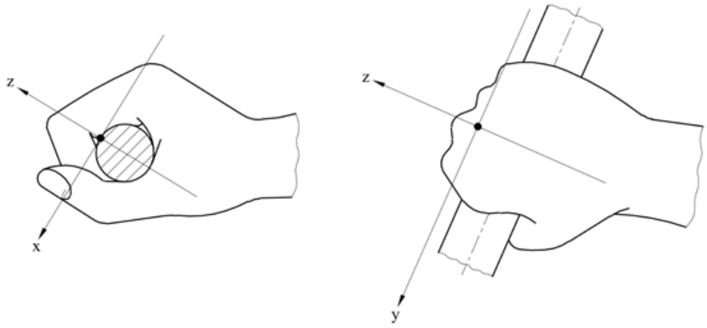


Figure 3. Reference axes for vibration measurement.

The accelerometer signals were amplified by means of three amplifiers MESA, model C24, and then recorded on digital tapes by means of a four channel digital audio tape (DAT) recorder. Subsequently they were analysed by using a PC based 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.

Experimental design and data analysis

The experimental activity was aimed at evaluating the influence of harvesting head, bar features (material and geometry), and bar inclination, on the vibrations transmitted to the hand-arm system. To this end, a full factorial experimental design with three factors was developed: harvesting head (three levels: H1, H2, and H3), bar type (three levels: B1, B2, and B3), and bar inclination (three levels: 0° (horizontal), 45° (inclined), and 90° (vertical)). Moreover, the accelerometers were placed, at different times, in two points next to the positions of the hands in ordinary working conditions, as reported in Figure 4.

Fifty-four measurement sessions were carried out (3 harvesting heads × 3 bars × 3 inclinations × 2 measurement points), each lasting about 5 minutes. To reduce the influence of external factors, during the tests all the shakers were idle operated by the same person. To simulate some replications, from each measurement session 4 samples of 1 minute were extracted. 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 and by computing the frequency weighted accelerations for each axis (a_{hwx}, a_{hwy}, and a_{hwz}) and then the global acceleration a_{hw}:

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

from which the daily vibration exposure value, A(8), standardized to an 8-hour reference period was obtained:

$$A(8) = a_{hw}\sqrt{T / T_0} ,$$

being T_0 = 8 hours and T the total exposure time associated with a_{hw}.

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 statistically analysed to detect differences related to harvesting heads and/or to bar type and/or bar inclination. Statistical analyses and graphical representations were carried out by using the open source software R.

Bar	MP1	MP2
B1	25	87
B2	−2	104
B3	−2	104

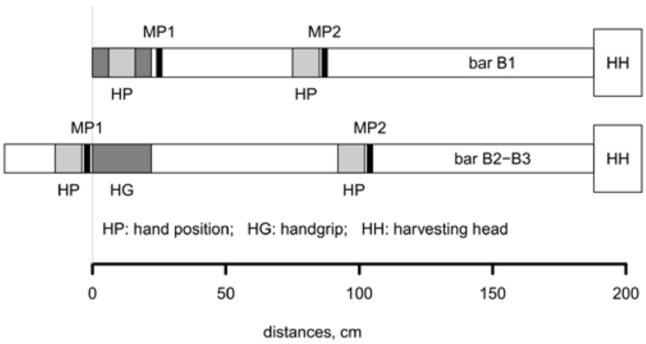


Figure 4. Measurement point (MP) position: distances in centimetres.

Results and Discussions

Global weighted acceleration

Weighted acceleration values were computed via the 1/3 octave analysis. Comparing global values for each harvesting head, bar type, bar inclination and measurement point, Figure 5 was obtained. It shows global weighted acceleration values quite high (approximately 20 m/s^2), meaning the vibration level is mainly affected by the kinematic system rather than the power source (electric, mechanic or pneumatic). Moreover, it suggests some differences, to be validated from the statistical point of view, among bars, harvesting heads, and measurement points, but not among inclinations. In fact, the Kruskal-Wallis test (being samples pseudo-replicates, data were analysed by means of non parametric tests) produced the results reported in Table 2, which confirms first of all the lower vibrations for the carbon fibre bar with respect to the aluminium one with the same diameter (B2 vs. B3,), as well as no differences between the two aluminium bars (B1 vs. B3). These results strengthen (p-level = 1.372e–5) those presented in Cerruto 2009b, due to the higher number of samples extracted from each measurement session. The differences among the harvesting heads are significant too. The highest vibrations are produced by H1, whose operating tools are spatially misaligned, the lowest by H3, which oscillates around the axis to which the operating tools are connected. This confirm that the vibration level can be reduced mainly acting on the mechanism that moves the operating tools.

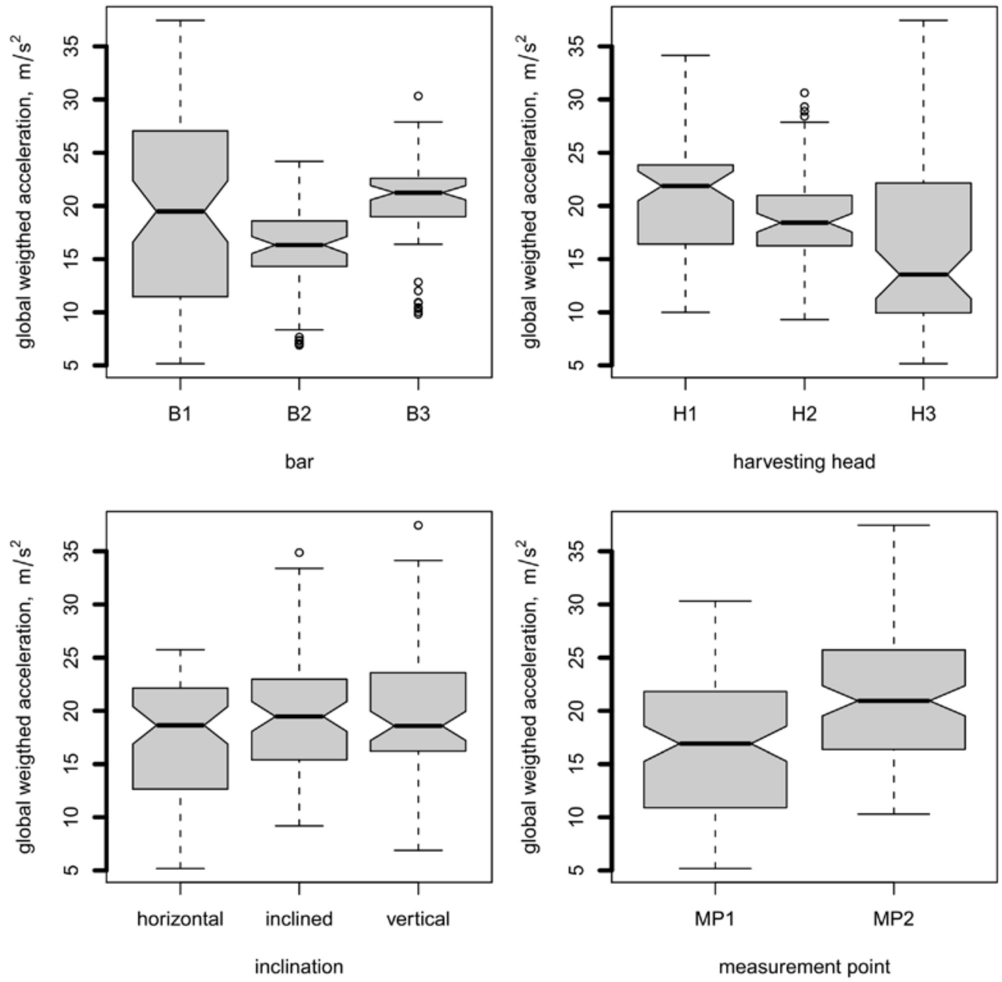


Figure 5. Global weighted accelerations.

Table 2. Median values (m/s^2) of global weighted acceleration (median separation by Kruskal-Wallis test at p=0.05).

Bars		Harvesting heads		Inclinations		Measurement points	
B1	19.5^{a}	H1	21.9^{a}	Vertical	18.6^{a}	MP1	16.9^{b}
B2	16.3^{b}	H2	18.4^{b}	Inclined	19.5^{a}	MP2	20.9^{a}
B3	21.2^{a}	H3	13.6^{b}	Horizontal	18.6^{a}		

The differences among the bar inclinations are negligible (from 18.6 to 19.5 m/s^2), whereas are significant those between the two measurement points. On average, the hand which holds the bar (MP2) is more exposed than that near the handgrip (MP1). Probably the lower vibration measured near the handgrip is due to its greater distance from the source of vibration (the harvesting head).

These accelerations are much higher than the daily limit and action values established by the European directive 2002/44/CE. By considering as an example the range 13.6–21.9 m/s^2 inside which fall the median values of the three heads, the daily limit exposure time should range from 0.1 up to 0.3 h and the daily action exposure time should range from 0.4 to

1.1 h (Figure 6): all times are clearly incompatible with the length of a standard work-day in agriculture, so the use of appropriate personal protection equipment should be taken into consideration.

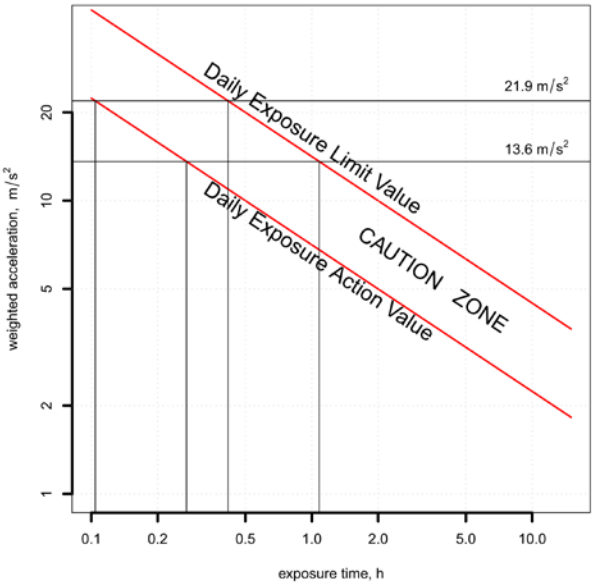


Figure 6. Daily exposure values.

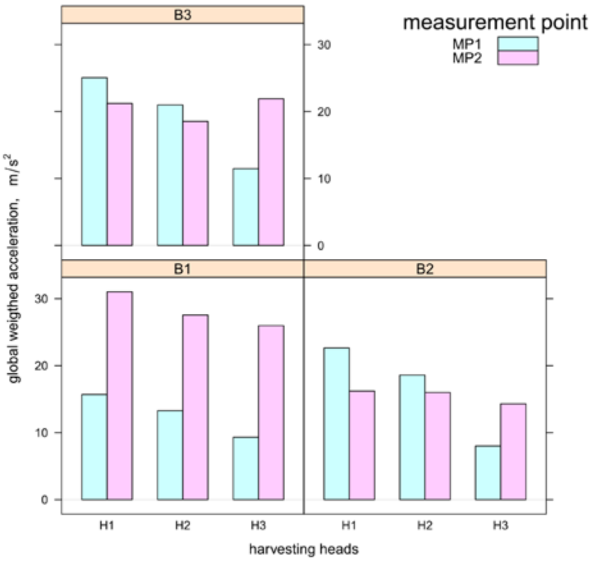


Figure 7. Global weighted accelerations: interactions among bars, harvesting heads and measurement points.

The interactions among bars, harvesting heads and measurement points are reported in Figure 7. It shows that the higher values of acceleration measured on the bar (MP2) are mainly due to the bar B1. As this behaviour is present with all the harvesting heads, most likely it is the lower diameter that makes bar more flexible and than more subject to vibration in its central part.

Acceleration components

The weighted acceleration components are reported in Figure 8. The lowest vibrations were always those along the bar axis (*y* direction), whose values ranged from 0.93 up to 6.56 m/s^2. For each harvesting heads there was always a dominant component: *z* direction for H1 and H2, ranging from 8.29 to 33.20 m/s^2, and *x* direction for H3, ranging from 2.71 to 36.40 m/s^2. This difference in the direction of greater vibration is due to the different plane of oscillation of the harvesting heads H1 and H2 with respect H3.

FFT analysis

Figure 9 reports some examples of FFT spectra in the range 0–250 Hz for the three directions. Similar spectra were found for all the other measures. They show the first harmonic at about 14.6 Hz for bar B1 and at about 17.0 Hz for bars B2 and B3. This harmonic corresponds to the motor speed: in fact, taking into account the gear ratio of 10:58, the motor speed results 5080 rpm for bar B1 and 5920 for bars B2 and B3. As the motor speed is fixed by the electronic circuitry placed inside the handgrip of each bar, it follows that the electronic card was running differently for bar B1.

Finally, the spectra show some other appreciable harmonics in the range 100–200 Hz, mainly in *x* and *z* directions, but their contribution to the global acceleration is negligible due the weighing filter. Analogous results can deduced from the 1/3 octave spectra, that show the greatest weighted RMS values in the 16 and 31.5-hertz bands.

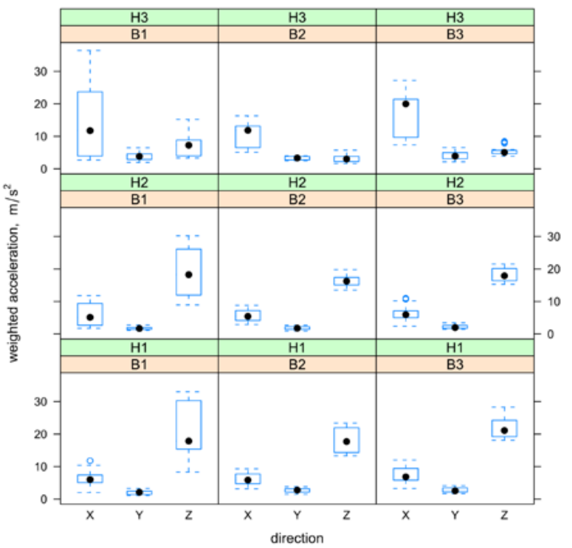


Figure 8. Weighted acceleration components for bars and harvesting heads.

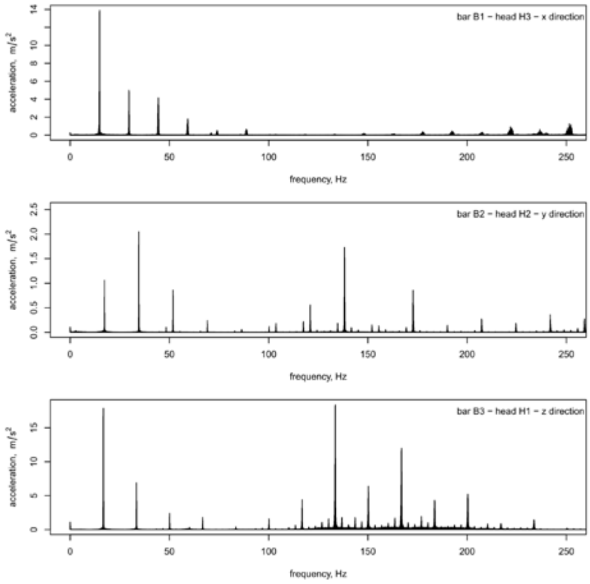


Figure 9. Examples of FFT spectra.

Conclusions

The study allows for the following considerations, susceptible to be integrated by further investigations:

The measurement procedure proved effective in ascertaining the vibrational level of the shakers. Comparisons among different machinery should be carried out in standard conditions, keeping constant all external factors (operator's influence, operating modes, load parameters). The effective daily operator's exposure should be measured during harvesting tests, as an influence of the tree canopies on the vibrations transmitted to the hand-arm system is expected.

Global weighted accelerations are quite high for all the shakers applied to any bar: this means that the vibration level is mainly affected by the kinematic system that gets moving the operating tools rather than the power source. Probably this is the key aspect to be investigated to reduce the vibrations at source. Actually, electric systems increase the operator's comfort by reducing weight and noise with respect to the mechanic or pneumatic systems.

Carbon fibre bars have a positive effect in reducing the vibrations transmitted to the hand-arm system with respect to the aluminium ones. This has also a positive effect on the comfort of the operators as reduce the global weight of the machinery.

The inclination of the bar during the use of the shaker has little effect on the global weighted acceleration, so recommendations to operators are unnecessary from this point of view.

References

Aldien Y., Marcotte P., Rakheja S., Boileau P.-É. Influence of Hand Forces and Handle Size on Power Absorption of the Human Hand-arm Exposed to z_h-axis Vibration. Journal of Sound and Vibration 290 (2006) 1015–1039.

Biocca M., Fornaciari L., Vassalini G. 2008. Noise Risk Evaluation in Electrical Hand-Held Picking Machines for Olive Harvesting. Proceedings on CD-ROM of AGENG 2008.

Blandini G., Cerruto E., Manetto G. 1997. Rumore e vibrazioni prodotti dai pettini pneumatici utilizzati per la raccolta delle olive. Proceedings of AIIA, Ancona, September 11–12, 1997, vol. 4, 229–238.

Burström L. 1997. The Influence of Biodynamic Factors on the Mechanical Impedance of the Hand and Arm. Int Arch Occup Environ Health (1997) 69:437–446.

Cerruto E., Manetto G., Schillaci G. 2009a. Electric Shakers to Facilitate Drupes Harvesting: Measurement of the Vibrations Transmitted to the Hand-Arm System. Proceedings of CIOSTA, Reggio Calabria (RC), June 17–19, 2009.

Cerruto E., Manetto G., Schillaci G. 2009b. Vibrazioni trasmesse al sistema mano-braccio da macchine agevolatrici elettriche per la raccolta di drupacee. Proceedings on CD-ROM of AIIA, Ischia Porto (NA), September 12–16, 2009.

Chetter I.C., Kent P.J., Kester R.C. 1998. The Hand Arm Vibration Syndrome: a Review. Cardiovascular Surgery, vol. 6, no. 1, 1–9.

Deboli R., Calvo A., Preti C. 2008. The Use of a Capacitive Sensor Matrix to Determine the Grip Forces Applied to the Olive Hand Held Harvesters. Proceedings on CD-ROM of the International Conference on "Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems", Ragusa, September 15–17, 2008.

Decreto Legislativo 19 agosto 2005, n. 187. Attuazione della direttiva 2002/44/CE sulle prescrizioni minime di sicurezza e di salute relative all'esposizione dei lavoratori ai rischi derivanti da vibrazioni meccaniche.

Decreto Legislativo 9 aprile 2008, n. 81. Attuazione dell'articolo 1 della legge 3 agosto 2007, n. 123, in materia di tutela della salute e della sicurezza nei luoghi di lavoro.

Dewangan K.N., Tewari V.K. 2008. Characteristics of Vibration Transmission in the Hand-arm System and Subjective Response during Field Operation of a Hand Tractor. Biosystem Engineering (2008) 535–546.

Dong R.G., McDowell T.W, Welcome D.E., Smutz W.P. 2005. Correlations between Biodynamic Characteristics of Human Hand-arm System and the Isolation Effectiveness of Anti-vibration Gloves. International Journal of Industrial Ergonomics 35 (2005) 205–216.

Famiani F., Giurelli A., Proietti P., Nasini L., Farinelli D., Guelfi P. 2008. Sì alla raccolta agevolata in oliveti tradizionali ed intensivi. L'Informatore Agrario, 2008, 4, 103–107.

Iannicelli V., Ragni L. 1994. Agevolatrici vibranti per la raccolta delle olive. Rivista di Ingegneria Agraria, vol. 25, n. 4, 248–256.

Monarca D., Cecchini M., Vassalini G. 2003. Vibrations Transmitted to Hand-arm by the main Chainsaws Models Sold in the Italian Market. Rivista di Ingegneria Agraria, 1, 53–64.

Pascuzzi S., Santoro F., Panaro V.N. 2008. Study of Workers' Exposures to Vibrations Produced by Portable Shakers. Proceedings on CD-ROM of the International Conference: "Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-Food Systems" September 15–17, Ragusa.

R Development Core Team. 2007. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria, ISBN 3-900051-07-0, URL http://www.R-project.org.

Tewari V.K., Dewangan K.N. 2009. Effect of Vibration Isolators in Reduction of Work Stress during Field Operation of Hand Tractor. Biosystem Engineering (2009) 146–158.

UNI EN ISO 5349-1:2004. Vibrazioni meccaniche—Misurazione e valutazione dell'esposizione dell'uomo alle vibrazioni trasmesse alla mano – Parte 1: Requisiti generali.

The Project "Safety Prevention in Agriculture": Main Results of a Triennial Survey

Dioguardi L.[1], Ariano E.[2]

[1]*Department of Agricultural Engineering, Università degli Studi di Milano, via Celoria 2 Milan, Italy, Phone +39 02 50316857, Fax +30 02 50316845, loredana.dioguardi@unimi.it*
[2] *PSAL, ASL of Lodi, place Ospitale 10 Lodi, Italy*

Abstract

The health and safety prevention measures in agriculture have achieved important results as far as organisation, and effectiveness are concerned. In fact the prevention campaigns have been planned on the basis of the specific context of Lombard agriculture.

Prevention system is based on an approach that combines information activities firstly, followed by check-up in the farms. Thus the concept of priorities through the progressive application of the rules is introduced. The rate of accidents was effectively reduced throughout the region. The survey – carried out in the years 2006-2008 on a sample of one thousand farms per year - involved all PSAL (Health and Safety in work premises) of the region.

The methodology is based on different action plans:

- **Definition of certain key features of agriculture in the Lombardy region;**
- **Development of monitoring devices for safety at farm level;**
- **Identification of priority actions;**
- **Implementation of selected prevention campaigns to reduce serious and fatal accidents;**
- **Monitoring and promoting the implementation of safety standards.**

The starting situation on safety in agriculture was defined in the first year of farm monitoring. Establishing the priority of intervention made it easier to plan prevention campaigns in order to reduce the number of fatal and serious accidents.

This project – based on information and subsequent control activities – proved to be a valuable means to ensure safety since most objectives have been achieved. Furthermore the analysis, performed at the territorial level, has helped to focus prevention activities where the need is the greatest.

Keywords: agricultural facilities, machines, equipments, PPE

Introduction

In accordance with regional policies for health and safety promotion in the workplace, the Local Health Unit of Lodi has started up the project "Safety prevention in agriculture" with the aim to develop a close integration between check-up, risk management and training of workers in order to improve the prevention system in agriculture, where there is a high rate of accidents. In particular, an Observatory to prevent the occupational accidents in agriculture and promote the health and safety in the workplace, has been activated with the aim to collect and organise all the information necessary to understand the accidents, implement the policies to reduce the risk, and monitor the achieved results (Ariano *et al*., 2006).
The implementation of prevention campaigns based on emerged results, has been successful, leading to an overall decrease of injuries in agriculture, especially in the province of Lodi (where since 2001 to 2007 a reduction of 53% of accidents was recorded), and of sanctions in the farms (Dioguardi & Ariano, 2009).

Materials and methods

This paper describes the results of a project, carried out in the Lombardy region, on the implementation of safety prevention systems in agriculture. In particular, the project has investigated the implementation of safety management programs, and assessed the compliance of farms with safety requirements in the workplace. The survey has been conducted in the years 2006-2008 on a sample of farms engaged in different patterns. A total of 2,236 farms, splitted at provincial level as shown in Figure 1, was examined.

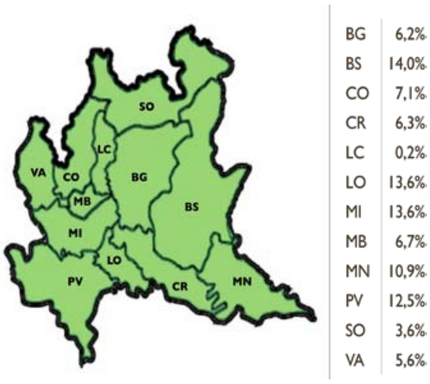


Figure 1. Percentage of analysed farms per province

Information on farms and their safety management have been acquired by using a checklist in order to identify the main non-conformity concerning buildings, machines, risk assessment and implementation of prevention programs.

The checklist, created by PSAL of Local Health Unit of Lodi, is articulated into two sections. The first one contains information useful to classify the sample of farms in the production context with respect to labour, activities, crops, cultivated areas, livestock, buildings, machines, plants and equipments.

The second one is devoted to assess the compliance of buildings, machines and equipments with safety requirements, the environmental hygiene, and the use of good practices in the most hazardous activities (pesticide treatments and bull handling).

Buildings, machinery and equipment

On a sample of farms a census of agricultural facilities (silos, hay barns, dryers, feed mills, wineries, dairies, workshop, etc.), machines (tractors, tillers, lawn mowers, chainsaws, mobile elevated platforms, etc.) and equipments has been made. Tractors were further classified by type (presence of cab and anti-rollover protection frames).

Safety devices are checked on facilities, machines, and equipments (e.g. hay barns, cattlesheds, ladders, tractors, transmission shafts, power take off, moving mechanical parts, and electrical systems).

Safety requirement

The following safety requirements according to the law 81/2008, were evaluated:

Appointment of persones responsible for safety in the farm (Responsible of the Service for Prevention and Protection, Occupational First Aider, Fire Warden, Workers' Representative for Safety) and assessment of their training;

Presence of compulsory documentation;

Health surveillance;

Personal Protective Equipment;
Toilet and changing room;
Hygiene of the workplaces and services.

Use of pesticides

Targeted investigations were carried out on pesticide management as it represents one of the most critical risk for workers' heath. The following issues were examined: number of employees with license to use pesticides, register of pesticide treatments, purchase invoices for pesticides, type of tractor used for treatments (with conditioned or non-conditioned cab, or without cab), personal protective equipments used during treatments, characteristics of pesticide room.

The interpretation of collected information allows to know certain key features of agriculture in the Lombardy region, safety implementation at farm level, and the most critical factors on which focus the most appropriate prevention policies and training programs.

Results

Characteristics of the sample

A total of 2,236 farms (representing 4% of the number of Lombard farms in the year 2007) was checked. The corresponding Utilized Agricultural Area (UAA) is 128,182 hectares (representing 13% of the Lombard UAA). Just over half of farms employs 2-5 workers (Table 1), unlike the firms engaged in maintenance of green areas who have the greatest number of employees, about twenty, of which almost 60% are employees.

Table 1. Characteristics of the sample of farms

Classes of workers	% Farms	% SAU	% Employees	% Cattle breeding	% No. cow	% Pig breeding	% No. pig
1	11,5	4,1	0,8	10,2	3,9	9,2	5,2
2-5	51,5	43,0	15,0	58,9	50,5	52,3	33,7
6-10	21,3	26,0	19,2	22,4	28,8	24,6	22,8
>10	15,7	26,9	65,0	8,5	16,8	13,8	38,2

The total workforce of observed farms, amounts to 17,119 employees, of which 16% are foreign workers. Employees which represent 47% of workforce (Figure 2), are mainly employed in companies with more than 10 workers.

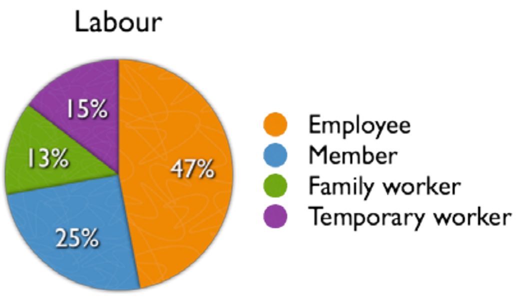


Figure 2. Type of workforce in the farms

Farms engaged in different productions (agriculture, animal husbandry, floriculture, maintenance of green areas, horticulture, viticulture, olivicolture, etc.) were observed. In particular, the sample was composed mainly of 59% of breedings, 16% of farms, and 18% of firms engaged in maintenance of green areas and floriculture, as showed in Figure 3.

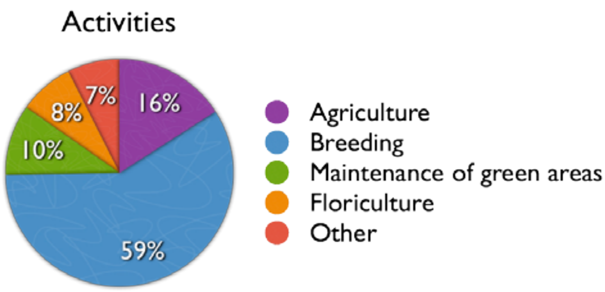


Figure 3. Main activities of sample of farms

<u>*Structures, machines and equipments*</u>
The most common facilities in the farms are vertical silos (65%), trench silos (50%), hay barns (46%) and workshops (34%).
Farms with raised barns are less than 40% of those observed, while the number of raised barns are almost one quarter of those observed. 90% of farms with raised barns, are in mountain areas.
The following issues in the hay storage were assessed:

- stacking bales (maximum 4 bales);
- compliance of buildings (parapet and maximum load of floorings in raised barns);
- use of appropriate devices for hay handling;
- presence of verbal or written procedures for hay handling.

The evaluation of good practices in the hay storage is comforting (Figure 4). 71% of farms stacks less than 4 bales, 91% uses appropriate handling devices, but 52% does not have defined procedures for hay handling. Where defined, there is not substantial difference between written ones (25%) and oral ones (23%). The greatest safety problems were found out in raised barns: 59% of them does not have the indication of maximum load of the floor, and 82% is not provided with adequate parapet.

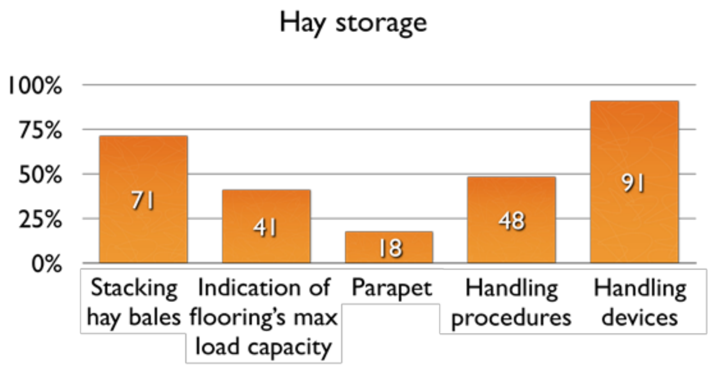


Figure 4. Safety prevention measures in the hay storage

The outcomes of observations on safety devices in breeding are illustrated in Figure 5.

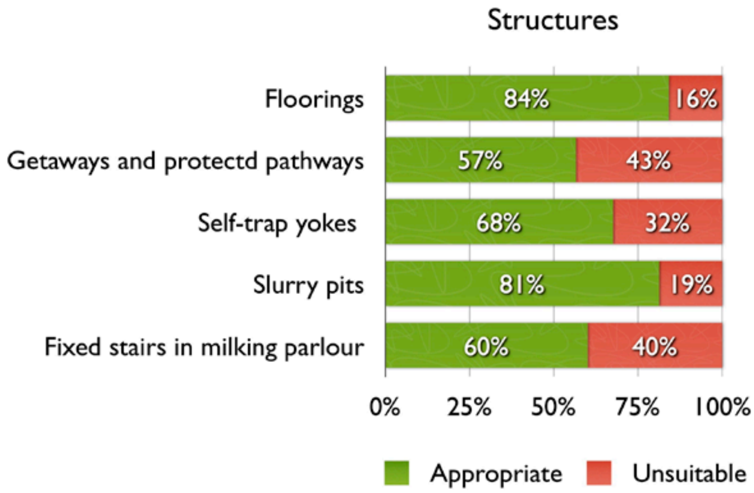


Figure 5. Structures equipped with safety devices

Washable or anti-slipping floorings were detected in 84% of farms. Since 2006 transit surfaces which are in compliance with hygiene and safety requirements, are increasing. The most of farms with adequate floorings was observed in mountain areas.
Getaways and protected pathways were detected in 70% of farms, but in 19% of which in insufficient number.
Appropriate self-trap yokes were found out in 68% of farms without significant differences between those located in plain and hill. Self-traps yokes are less frequent in mountain farms where there are cattle sheds with fixed stabling.
14% of slurry pits is not consistent with safety requirements. There are nonconformities in 19% of farms.
The access at the milking pit is provided with stairs equipped with anti-slip steps and handrails in 60% of farms. In the remaining farms there are stairs with or anti-slip steps or handrails (35%), and without any safety devices (5%). From 2006 to 2007 an increasing number of suitable stairs, was highlighted as a result of prevention campaigns.
Ladders are not safe (lack of anti-slip devices at the bottom of the two uprights, hooks or anti-slip supports at the top of the uprights) in more than 30% of farms. 30% of ladders is not consistent with safety requirements.
The most used agricultural machines, in addition to tractor, are equipments for the maintenance of green areas (chainsaws, hedge trimmers, brush cutters, lawn mowers).
8,546 tractors were considered, distinguishing if equipped with conditioned or non conditioned cab, or without cabs but with anti-rollover protection frames (ROPS), or without any kind of protection device. There are not significant differences by relating the type of tractor with the farm size. On the contrary, there is a prevalence of tractors with conditioned cab (38%) in the plain, with only anti-rollover protection frames (38%) in the hill, and with non conditioned cab (44%) in the mountain (Figure 6).
Although the tractors not equipped with anti-rollover protection frames are numerically 2% of observed agricultural machines, they were detected in 18% of farms, of which 14% are located in hilly areas.

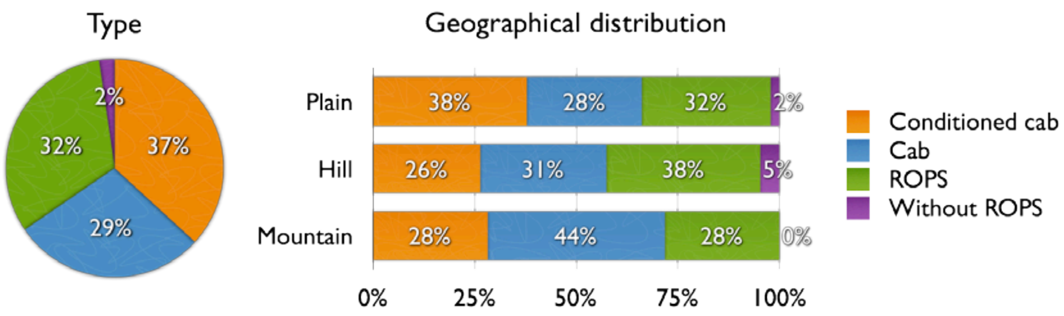


Figure 6. Type and geographical distribution of tractors

The check-up on safety devices has showed situations of non-compliance in 19% of transmission shafts, and in 16% of power take off and moving mechanical parts.
Altogether more than 30% of farms is not in compliance with transmission shaft and power take off and nearly 60% for unprotected moving mechanical parts. The most of non conformities were usually found out in mountain area.
The safety requirements of mobile elevated platforms and chainsaws were observed given the high number of firms engaged in the maintenance of green areas. The survey has revealed that more than 75% of machines and equipments are consistent with maintenance, documentation and are equipped with safety devices.
Regarding the electrical systems more than 70% of farms is provided with declaration of conformity, 54% with project of the installations and 92% checks periodically the ground wiring. The conformity of electrical systems is major in the big farms and since 2006 it is increasing.

Safety requirements
The compliance of farms with the law 81/2008 (Figure 7) is satisfactory.

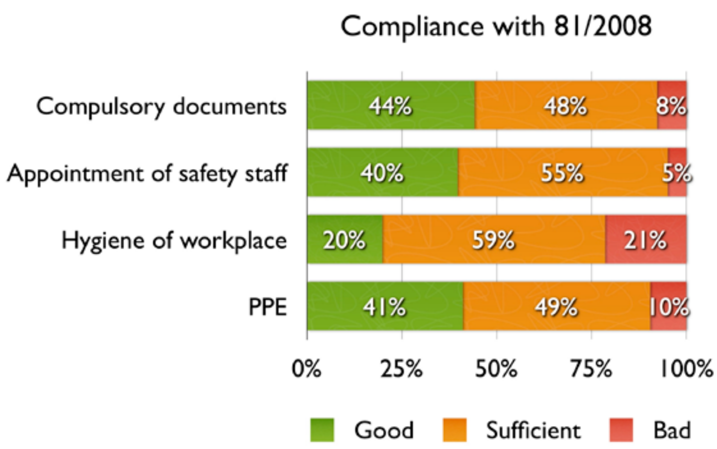


Figure 7. Percentage of farms in compliance with 81/2008

In more than 90% of farms there are the compulsory documents for safety, especially the document of risk assessment and the accident register. However several farms have not assessed the fire risk (34%) and do not have the fire prevention certificate (20%).

Regarding the safety staff, about 90% of farms have appointed the Responsible of the Service for Prevention and Protection (RSPP), the Occupational First Aider and the Fire Warden. Where RSPP is appointed, the employer covers this task in farms with fewer than 10 employees, while an employee or external consultant in ones with more than 10 employees.
The roles for first aid and fire prevention are usually covered by employer if the company has fewer than 10 employees, or by employees in the big farms.
The Workers' Safety Representative has not been appointed in 30% of farms, particularly in those with fewer than 10 employees.
An adverse opinion on training of safety staff was issued in 22% of farms.
There is the Occupational Health Physician in 44% of farms. In 64% of cases, where the health surveillance is practiced, there is a health protocol.
On average 10% of companies have inappropriate PPE, this situation is most evident in farms with only an employee, and in ones producing wine. 70% of farms is provided with safety footwear with anti-slip sole and anti-crushing device.

Hygiene of working environment and services
In just over a fifth of farms, especially those with fewer than 10 employees, a negative opinion for sanitation facilities (changing rooms, lockers, toilets, showers) was issued. Fortunately there is evidence of improvement in function of time.

Use of best working practices
Over 80% of farms uses pesticides. In 76% of cases, farms self-perform pesticide treatments. The percentage of farms who self-perform pesticide treatments, increases proportionally with the increasing of the number of employees.
80% of employees involved in pesticide treatments has the pesticide license.
During treatments tractors equipped with conditioned cab, and calibrated equipments for pesticide distribution are used respectively in 28% and 16% of farms.
Register of treatments and purchase invoices for pesticides have been found out respectively in 85% and 93% of cases. Pesticides are stored in unaccessible places in 95% of farms, but together with other products in 17% of cases. The overall opinion on pesticide storage is positive.
The assessment of bull management has showed that on average there is a bull in 20% of cattle breedings, in 75% of cases confined in suitable pen. Inner gates were detected on average in 45% of farms. The practice to apply a ring on the nose is spread in 20% of breedings, however, it is totally absent in mountain areas.

Final evaluation
The findings of the survey have showed that:
- 18% of farms has obsolete facilities, unsafe machines, and poor hygienic conditions, is not provided with toilets, ignores the law requirements, does not have the required documents, and manages the pesticides in hazardous way;
- 34% of farms has sufficient attention to safety, but has some gaps related to hygiene and good working practice, and lacks of safety management system;
- 42% of farms has fairly attention and care of structures and machines, knows the meaning of safety legislation and their requirements, but has some deficiencies in the safety management;
- 6% of farms is safety-conscious, has excellent hygienic conditions of working environments, adopts a safety management system, and has good knowledge and attention in the use of pesticides.

Overall, smaller farms and those in mountains show the more critical factors for the implementation of the safety prevention system.

Conclusion

There is some evidence also from other countries (Solomon, 2002) that farm activity may influence the risk of accidents. In particular activities such as animal husbandry (housing and handling animals), maintenance (of machines, buildings, and green areas), tractor driving, and storage of crops were associated with the largest number of fatalities (Dioguardi *et al*., 2008; HSE, 2010).
The main approaches to prevent agricultural accidents are by engineering improvements and through education and training of the workforce. One of the most effective engineering contributions to agricultural safety has been the anti-rollover protection frame for tractors. Other safety measures include installation of handrails and parapets where people might slip or fall, and proper facilities for animal handlings as it results from different surveys (DeRoo, 2000).
Information on safety level in the farms and accident data do not make any prevention by themselves, but their use in an integrated way is useful in policymaking, prioritisation, prevention campaigns and workers' training (Jørgensen, 2008).

References

Ariano E., Mennoia V., Cortellessa G., Savi S., Ferri G., Luini M., Grazioli S., Sangiorgi F., Dioguardi L. 2006. Health and safety regulations for produce and workers. An integrated management functional model proposal. Proceedings of 16th International Congress of Agricultural Medicine and Rural Health, 18-21 June 2006, Lodi.

DeRoo L. A. 2000. A systematic review of farm safety interventions. American Journal of Preventive Medicine, 18, 51-62.

Dioguardi L., Sangiorgi F., Ariano E. 2008. Identifying physical hazard for intensive pig and cattle breeding operators and defining prevention measures. Proceedings on CD-ROM of International Conference RAGUSASHWA, 15-17 September 2008, Ragusa, Italy.

Dioguardi L., Ariano E. 2009. The analysis of work accident dynamics as planning tool for preventive policies in agriculture. Proceeding of XXXIII CIOSTA CIGR V Conference 2009, 17-19 June 2009, Reggio Calabria, Italy, vol. 2, 1499-1503

Health & Safety Executive. 2010. www.hse.gov.uk/agriculture/hsagriculture.htm.

Jørgensen K. 2008. A systematic use of information from accidents as a basis of prevention activities. Safety Science, 46, 164-175.

Solomon C. 2002. Accidental injuries in agriculture in the UK. Occupational Medicine, 52, 461-466.

Safety Level Investigation of Front Mounted Roll-Over Protective Structures on Narrow-Track Wheeled Agricultural and Forestry Tractors

Laurendi V., Gattamelata D., Vita L.
ISPESL – National Institute for Occupational Safety and Prevention – Safety Technologies – VIII U.F.
Via Fontana Candida, 1 – 00040 Monte Porzio Catone (RM), ITALY.
Tel 0039 0694181231, Fax 0039 0694181230, vincenzo.laurendi@ispesl.it

Abstract

Nowadays many narrow-track wheeled agricultural and forestry tractors are equipped with two posts front mounted Roll-Over Protective Structures (ROPS). These kind of ROPS are of two different types: fixed or completely foldable. In Italy is largely widespread the foldable type of ROPS because, in its folded configuration, it allows to work under trees or in greenhouses. Fatal accidents recently occurred in Italy involving narrow-track wheeled tractors equipped with two posts front mounted ROPS in safety position. Thus, National Institute for Occupational Safety and Prevention (ISPESL) developed an investigation in order to define the safety level of this kind of structures and design a Compact Roll-Over Protective Structure (CROPS) for this kind of tractors. For CROPS design it has been applied an iterative procedure made up of the following steps:

1. **a parametric CAD model of the structure fitted on a virtual model of a narrow-track tractor;**
2. **finite element analyses (FEA) according to OECD code 7;**
3. **optimization in order to reduce CROPS dimensions.**

Finally a prototype of the structure has been realized for performing experimental strength test and handling test in the field.

Keywords:compact roll-over protective structure, finite element analysis

Introduction

In Italy many agricultural and forestry tractors are equipped with two posts front mounted foldable ROPS. The main reason lies on the necessity to work under trees and/or in greenhouses, and a completely folded ROPS fulfils this necessity. However, from safety point of view, the use of this kind of ROPS does not comply with the required safety level with respect to roll-over risk neither in folded configuration nor in safety one. In fact, the two posts front mounted ROPS grants a lower safety level with respect other protective structures, e.g. rear mounted two posts ROPS or four posts frame, even when it is locked in safety configuration or it is not foldable at all. This is more evident considering the last fatal accidents recently occurred in Italy involving tractors equipped with two post front mounted ROPS in safety position. For these reasons, ISPESL developed a specific research activity in order to investigate the safety level of this kind of protective structures. In this paper the main results of this investigation are presented. Moreover an innovative compact roll-over protective structure (CROPS) and its design process developed by the authors are herein described. This structure, installed on the actual narrow-track wheeled tractors, allows to perform under trees or in-greenhouses working activities ensuring adequate protection against roll-over risk.

Safety level investigation

Considering that it is possible to equip narrow-track wheeled tractors both with a rear two posts ROPS, as defined in OECD code 7, or with a front two posts one, as defined in OECD code 6, a comparison between these two kinds of protective structures has been carried out. The main difference concerns the shape and the dimensions of the operator clearance zones protected by each structure. This peculiarity is also reported in the field of application of OECD code 6 which, at point 2.1.4, specifies that it refers to tractors "*being fitted with roll-over protective structures of the dual-pillar type mounted in front of the driver's seat and characterised by a* <u>*reduced clearance zone*</u> *attributable to the tractor silhouette, thus rendering it inadvisable, under any circumstances, to impede access to the driving position but worthwhile retaining these structures (fold-down or not) in view of their undoubted ease of use*". In figure 1 these two clearance zones are shown.

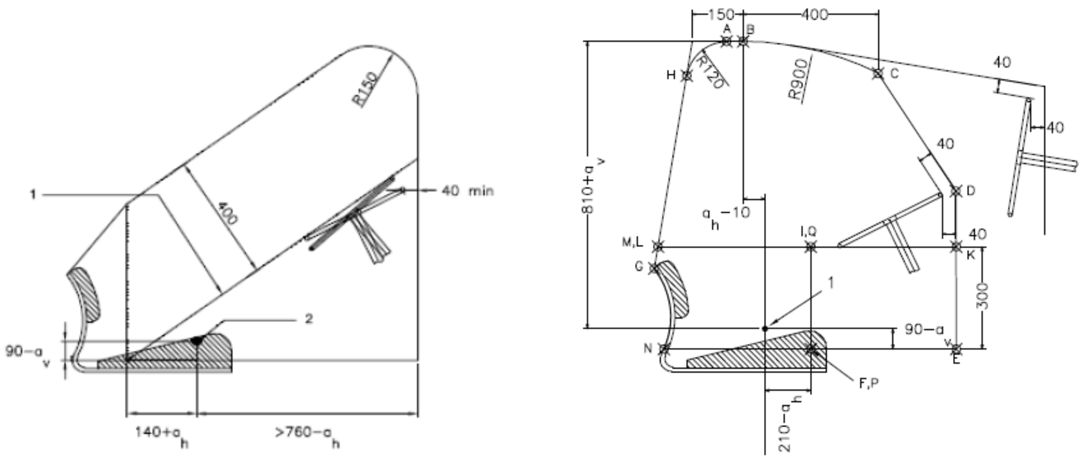


Figure 1. Comparison between operator clearance zones as defined in OECD code 6 (on the left) and in OECD code 7 (on the right)

From the comparison one can see that the clearance zone preserved by a two posts front mounted structure has a completely different shape, conformed in such a way that the operator is in safe position only if he flexes him-self forward, till touching the steering wheel during tractor rolling over. In fact, the simulated ground plane, which is represented by a straight line from the top of the front ROPS to the top of the rear hard fixture, does not intersect the operator clearance zone only if it is shaped in this manner (see figure 2, left hand side). Otherwise, considering the clearance zone defined in OECD code 7, the same front ROPS does not ensure protection in case of roll-over (see figure 2, right hand side), unless significantly increasing the height of the front roll-bar or of the rear hard fixture. Thus, it seems that the safety level guaranteed by this kind of protective structure is quite poor. This is also confirmed by recent fatal accidents occurred in Italy, concerning the roll-over of tractors fitted with foldable front mounted ROPS in safety configuration. Moreover another issue related to this kind of protective structures concerns the possibility of folding them down.

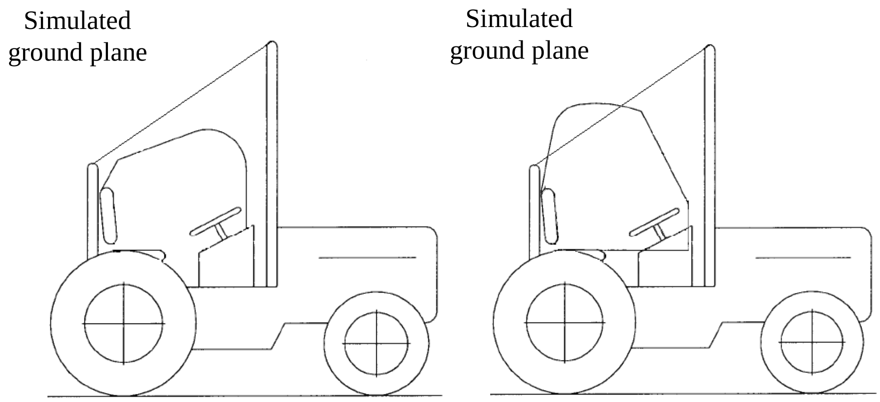


Figure 2. Simulated ground plane protection ensured by a two posts front mounted ROPS with reference to OECD code 6 operator clearance zone (on the left) and OECD code 7 one (on the right)

In many cases the folding operation is achieved by simply removing a pin by hand without the use of any specific tool. The easiness of this operation leads to fold the ROPS even during field operation, completely by-passing a fundamental safety device. Finally, the last concern with respect to front mounted ROPS refers to its application on articulated wheeled tractors. The possibility to rotate about a central pivoting axis of tractor main frame sensibly reduces the already poor safety level of this protective structures. In fact, in case of rolling over or tilting of tractor, the independent rotation of the rear part of tractor main frame, where is seated the operator, with respect to the front one, where is fitted the ROPS, could laterally expose the operator to impact with ground.

Compact roll-over protective structure design

Considering the concerns previously exposed, the National Institute for Occupational Safety and Prevention (ISPESL) designed an innovative Compact Roll-Over Protective Structure (CROPS) to be fitted on narrow-track wheeled tractors. This structure is a four posts rigid frame made of steel circular tubes with a smooth longitudinal profile, shaped in such a way to make easier the use of tractor beneath trees and preserve the OECD code 7 operator clearance zone, at the same time. The main objectives to be fulfilled with the use of CROPS are to reduce the overall height of the tractor fitted with a non-foldable protective structure and, consequently, to allow to work under trees or in greenhouses in a safer way, avoiding the misuse of foldable ROPS. The CROPS design could be summarized into the following steps:

1. reverse engineering of tractor and virtual prototyping of the CROPS;
2. finite element analysis (FEA) of CROPS according to OECD code 7;
3. shape and dimensions optimization.

Reverse engineering and virtual prototyping

First of all it has been necessary to make a reverse engineering of tractor in order to virtually reproduce the position and the relative disposition of the anchorage points suitable for the CROPS. This also allowed to faithfully reproduce the OECD code 7 operator clearance zone on tractor and to avoid interferences between protective structure and tractor itself. With reference to figure 3, the virtual model of tractor, actually fitted with a foldable front mounted protective structure, has been reproduced. In particular on the right hand side of figure 3, the OECD code 6 operator clearance zone and the simulated ground plane related to the actually fitted two posts ROPS have been represented. One can note that the actual overall height of tractor is 2370 mm from the ground.

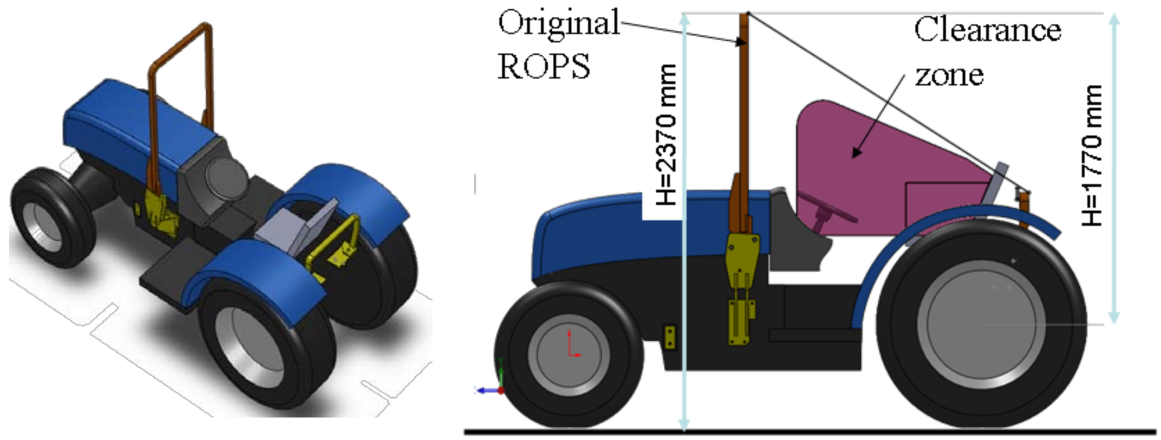


Figure 3. Tractor reverse engineering

In figure 4 left hand side, the front attachment points for CROPS are shown. In particular, they correspond to the bolts and pin joint of the foldable portion of the actual two posts protective structure. The CROPS rear mounting uses the same attachment points of the actual rear hard fixture (figure 4 right hand side).

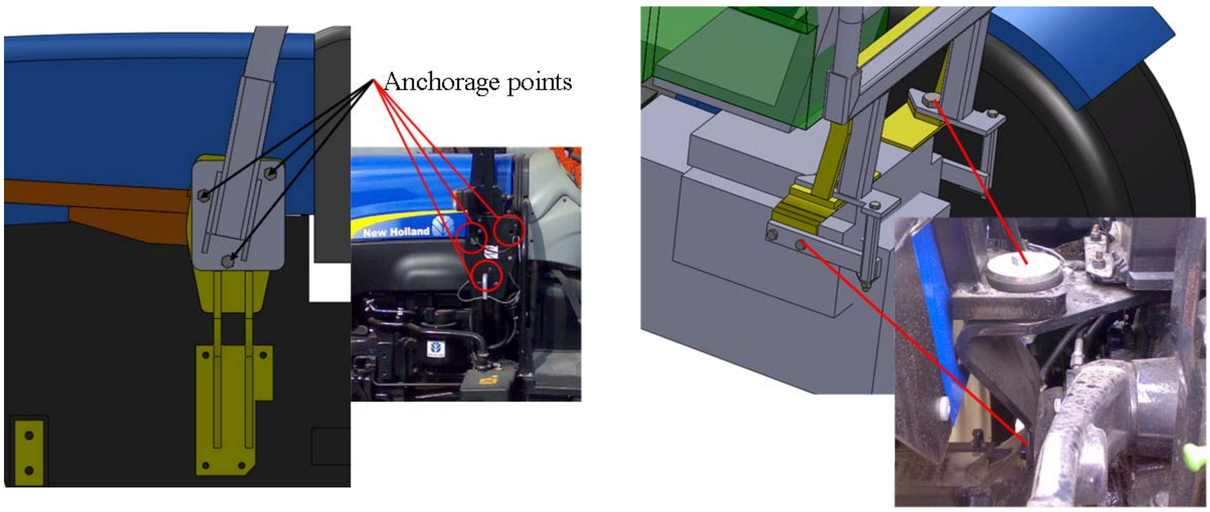


Figure 4. Front (on the left) and rear (on the right) mountings

According to ergonomic principles and safety requirements, a convex volume for CROPS has been designed. This volume has been obtained as an extrusion of a smooth profile in the middle longitudinal geometrical plain of tractor (see figure 5). Moreover it has been compared to the OECD code 7 operator clearance zone in order to verify that this one is completely included into it, as one can see from the side and back views depicted in figure 5. Starting from the convex volume, the tentative shape of the CROPS has been defined. It is represented fitted onto tractor on the left of figure 6, and in its main components in the exploded view (figure 6 right hand side). Thanks to its longitudinal smoothness, the CROPS appears more compact and suitable to work under trees or in greenhouses than the original straight two posts front mounted ROPS.

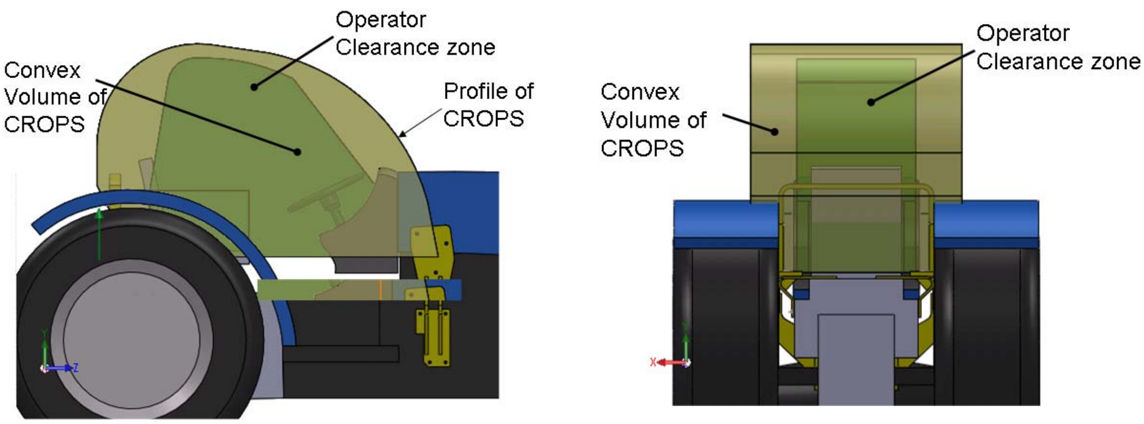


Figure 5. The CROPS convex volume side (on the left) and back (on the right) views

In any case the main function of CROPS is to protect the operator clearance zone. Thus, its size, with respect to this first prototype, has been varied according to the results of structural simulations which leads to the optimization process.

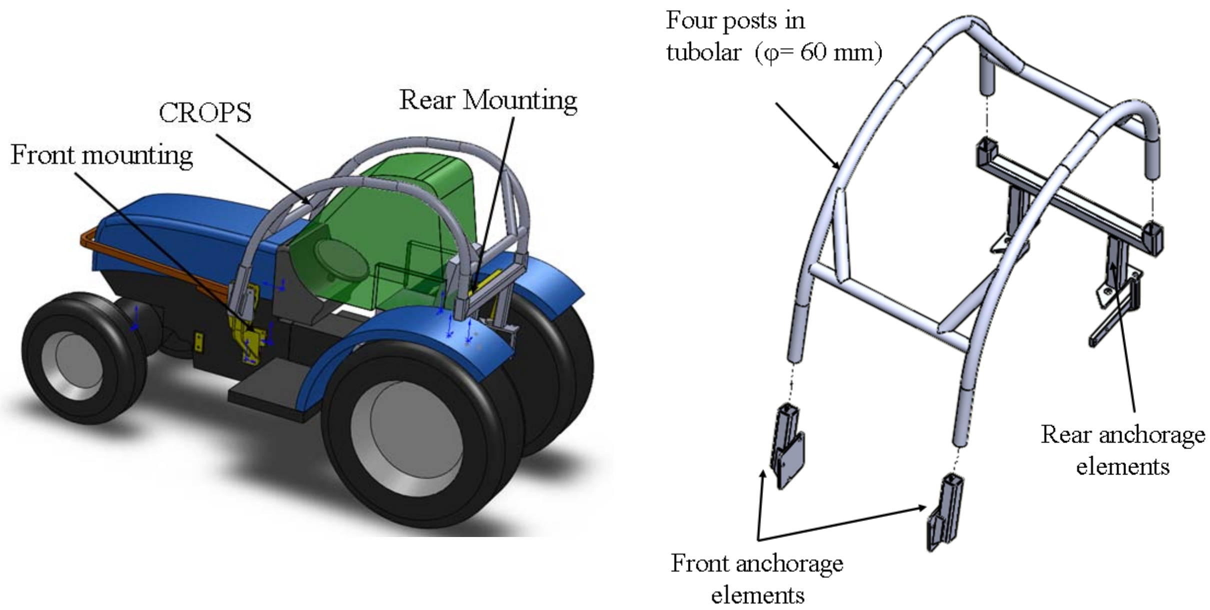


Figure 6. The first virtual prototype of the CROPS.

<u>*Finite element analysis*</u>

The first virtual CAD prototype of CROPS has been meshed in order to perform the finite element analysis on it. The geometrical properties have been modelled by means of plate elements of variable thickness. Since the OECD code 7 test procedure requires to evaluate the plastic energy absorbed by the protective structure, it is necessary to mimic the plastic behaviour of the material and to represent the large deformations which the structure undergoes. For these reasons the *Ramberg–Osgood* equation has been used for reproducing the elasto-plastic features of steel. In figure 7 the FEA model has been reproduced. In particular mountings of the actual two posts ROPS, on which CROPS attaches (see figure 4), have been not included in the model. In fact, they could be considered as significantly more rigid than the remainder of the structure. This allowed to reduce the number of elements in the model and consequently to speed up the analysis process.

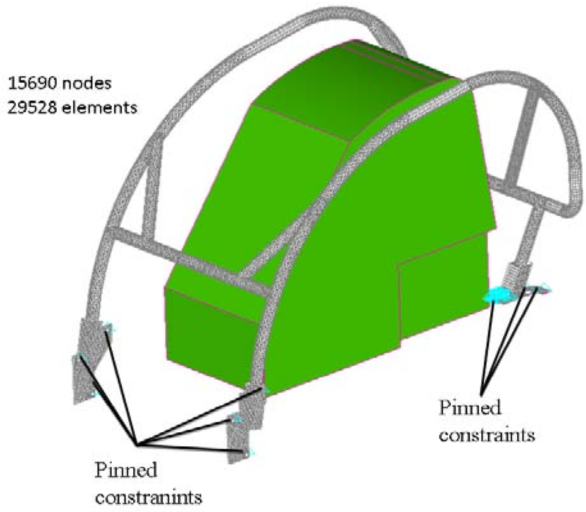


Figure 7. The finite element model of the CROPS

As the CROPS is connected to the front and rear mountings by means of threaded connections (see figure 4) the constraints in the model are of pinned type. They have been applied at the centre of each hole representing bolt by means of rigid elements (see figure 7).

Table 1. Test procedure and acceptance criteria according to OECD code 7

	TEST DESCRIPTION	**ACCEPTANCE CRITERIA**	**ACCEPTANCE VALUE**
1st test	Loading at the rear of the structure	Energy	≥ 3.055 J
2nd test	Rear crushing	Load	≥ 60.000 N
3rd test	Loading at the front of the structure	Energy	≥ 2.000 J
4th test	Loading at the side of the structure	Energy	≥5.250 J
5th test	Crushing at the front	Load	≥ 60.000 N

For what concerns the sequence of loads and the acceptance criteria, table 1 summarizes the compulsory requirements established by the testing procedure according to OECD code 7 with respect to a tractor mass of 3000 kg.

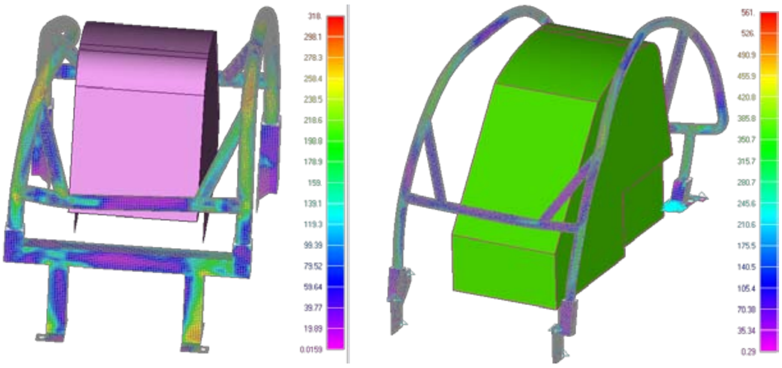


Figure 8. Contour diagram of Von Mises stress and deformations for the side load: first CROPS version (on the left) and last CROPS version (on the right)

In figure 8 an example of analysis result referring to the side load test is shown for two different versions of CROPS. On the left hand side of figure 8 the first version is depicted, while on the right hand side the last version is shown. The first version was realized by means of tubular having a circular cross section of 60 mm diameter realizaed in S235 steel, while the last version, obtained from the optimization process (see next paragraph), is made up of tubular having a reduced cross section, 40 mm diameter, but realized in S355 steel.
It is important to notice that each load of the sequence in table 1 is to be applied on the residual deformations and stresses due to the application of the previous load in the sequence. Once reached the required energy/load, one has to verify that no elements of the structures approach to the material breaking strength value and that no part of the CROPS, while deformed, leads to the infringement of the operator clearance zone or to its invasion by the simulated ground plane. For both the side load depicted in figure 8, the maximum stress recovered was sensible lower than the material breaking strength value, and the operator clearance zone was always protected.

<u>*Optimization*</u>

Different aspects are involved in the optimization process of the CROPS:

- enhancement of mechanical strength for the critical points of the structure;
- reduction of tractor overall height;
- reduction of CROPS width;
- simplify and retrench the production phase;
- use of structural members with reduced cross section to streamline the structure.

Each of the cited aspects leaded to new version of CROPS for which it is necessary a new design and finite element analysis, as previously described. So, the CROPS final version is the best compromise between structural and practical requirements, even if it probably could be still enhanced. The left hand side of figure 9 compares the first, on the bottom, and the last, on the top, versions of CROPS, where a steel tubular with a reduced cross section has been used. The right hand side of figure 9 shows that one of the effects of the optimization was the reduction of other 100 mm to the overall height of the tractor, continuing to ensure operator protection.

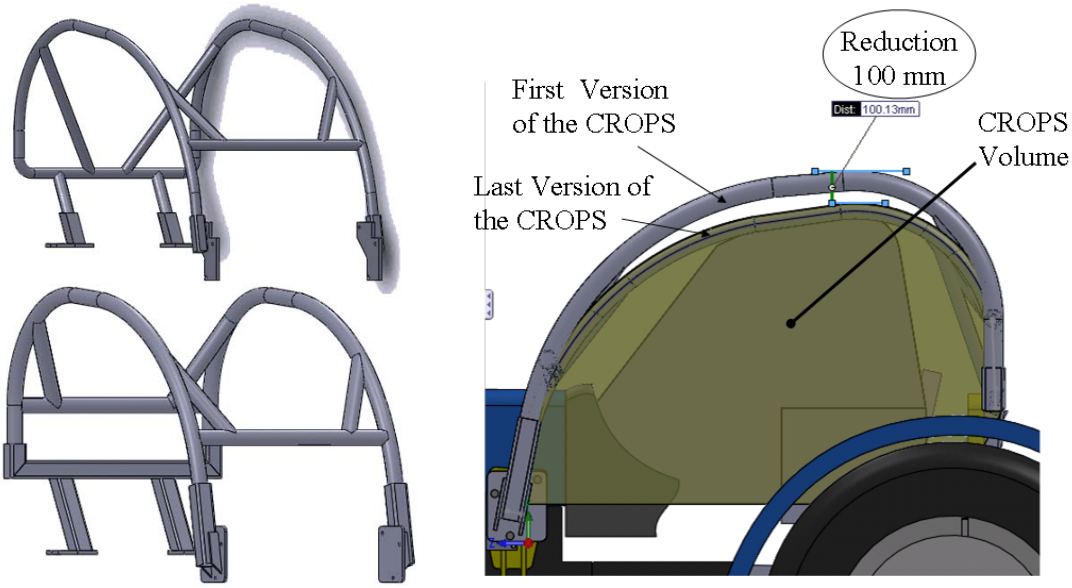


Figure 9. Comparison between first and last CROPS versions

Results and conclusions

The main result achieved in the CROPS designing process was the reduction of tractor overall height, fitted with a protective structure, of about 480 mm (see figure 10). Moreover the particular shape of the structure makes easier working under trees without damaging their branches. Finally this last prototype has been realized and structural tested at the ISPESL experimental test rig in Monte Porzio Catone research centre. The last step is to perform handling tests in the field in order to verify or at least optimize the CROPS shape for improving its performance under trees.

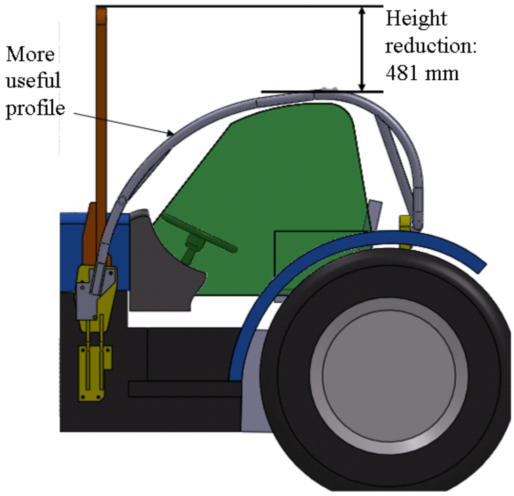


Figure 10. Overall height reduction

Reference

OECD Standard Codes for the Official Testing of Agricultural and Forestry Tractors. 2010. www.oecd.org/document/10/0,3343,en_2649_33905_34735882_1_1_1_1,00.html

Exposure to Slowly Drifting Warm Thermal Environments Inside Greenhouses

Lenzuni P.[1], Minuto G.[2], Minuto A.[2], Calvo A.[3], Deboli R.[4]
[1] *ISPESL, Department of Florence, Via G. La Pira 17, 50121 Firenze, ITALY*
Tel. +39 055 289681, Fax +39 055 210882, paolo.lenzuni@ispesl.it
[2] Liguria Regional Centre for Experimental and Technical Assistance – Chamber of Trade, Industry and Agriculture, Savona
[3] University of Turin, Department of Agricultural, Forestry and Environmental Economics and Engineering
[4] Institute for Agricultural and Earthmoving Machinery of the Italian National Research Council – Turin

abstract

An adaptation of the PHS method to slowly drifting thermal environments has been developed. The generalized PHS code has been used to predict the daily evolution of physiological responses and the maximum allowable exposure, given the detailed daily indoor evolution of temperature and humidity. Results indicate a strong dependence on outdoor meteorological conditions. Despite allowing an early morning start (7 am), the core temperature increase is usually quite fast, and exposures longer than 2.5 hours should be ruled out under most of the investigated circumstances. Exposure duration is always limited by the excessive core temperature, whereas water loss is largely inconsequential.

Results obtained using our generalized PHS model differ significantly from those of the standard (static) PHS model (i.e. using daily averages for air/radiant temperatures and humidity). A constant monitoring of the greenhouse thermo-hygrometric quantities, with time resolution not exceeding a few minutes, is a mandatory pre-requisite for reliable thermal risk assessment.

Keywords: thermal drifts, heat stress, PHS

introduction

Occupational exposure to stressing thermal environments has a significant impact on human health and is potentially lethal. Because of the seriousness of the issue, several descriptors have been developed since the 1920's (Yaglou 1927). Assessment and evaluation of exposure to hot environments is currently performed through the PHS method, originally developed in the framework of a EU-sponsored multi-national research project (Malchaire et al. 2001) and later codified in EN ISO 7933.

Greenhouses are thermally peculiar environments, showing a daily thermal evolution intermediate between outdoors and masonry indoors: thermal drifts are large enough to rule out the use of constant input values (e.g. the arithmetic mean), but small enough to be tackled by a sequence of quasi-static responses by the human body. Thermal stress due to occupational exposure inside greenhouses has been only occasionally addressed in recent years (Okushima et al. 2000, Monarca et al. 2004, Gusman et al. 2008), with some additional studies (e.g. McNeill and Parsons 1999) focusing on outdoor environments with some climatic similarities. A detailed study of the human response to the daily fluctuations of thermal conditions inside a greenhouse is still missing.

In this paper we first present a generalization of the PHS method to slowly drifting warm thermal environments; the method is then applied to the assessment of human exposure to thermal stress inside greenhouses.

method

The original PHS code included in EN ISO 7933 was developed to predict the human response to thermally stable environments. A modified version has been developed in this work to accomodate slowly drifting thermo-hygrometric data. In practice, environmental input values (t_a: air temperature, RH: relative humidity, t_g: globe temperature, v_a: air velocity) which are originally fed to the code by the user as constants, are now carried into the code from a table based on the information collected by a meteorological data logger. The native 1 minute time resolution of the code has not been changed.

Because the monitoring of meteorological conditions is usually extended over several months, the typical field acquisition rate is slower than 1 minute (10 minutes in our data). Accordingly, a 4th degree polynomial interpolation of temperature and humidity raw data has been applied. All tests have been run to track the time evolution of the rectal temperature (t_{re}) and of the cumulated water loss, in order to calculate maximum allowable exposure time both for heat storage D_{lim_tre} and for water loss D_{lim_loss} (EN ISO 7933).

Experimental data

All data presented and discussed in this paper have been collected inside the same greenhouse, part of a research centre located in north-western Italy, along the coast (43° 30' N). Continuous data acquisition has proceeded over one full year (Jan 1 – Dec 31, 2009), with a 10 minute resolution. The greenhouse is characterized by an iron and plastic case (height 3.2 m, width 8.5 m, length 36 m.) and displaying openings only on side walls, with a 10% total fractional opening surface. Measurements of indoor and outdoor air temperature and relative humidity have been carried out using probes connected to one AGRICOMP data logger located in the central cross section of the greenhouse, at a height of 150 cm above the ground. The mean radiant temperature $\bar{t}_r$, which we have not measured, has been approximated using a two-step procedure: first the globe temperature t_g has been calculated using the empirical relation $t_g = 12 + 2 \quad (t_a - 12)$ based on globe and air temperature data measured inside similar greenhouses (Monarca et al. 2004); then the forced convection equation (EN ISO 7726, equation 9) has been used to calculate $\bar{t}_r$, given t_a and t_g. The air velocity (v_a) has been set to zero. A constant clothing thermal resistance (I_{cl} = 0.6) has been estimated after visually inspecting several workers, using tables included in EN ISO 9920. Although work inside greenhouses is undoubtedly characterized by a short scale time variability (minutes), such fluctuations are inconsequential when it comes to predicting the long term (hours) evolution of the rectal temperature. Accordingly, metabolic activity (M) has been set constant at 1.4 met, based on the analysis of metabolic values listed in EN ISO 8996 for a variety of tasks.

Identification of representative days

Indoor thermo-hygrometric conditions show an obvious day to day variability due to variable outdoor climatic conditions. Our data indicate that outdoor daily high temperatures in excess of 30°C show up with a probability of about 3.5% (Figure 1), while daily high temperatures above 32°C have frequencies below 1% (2 days in all of 2009).

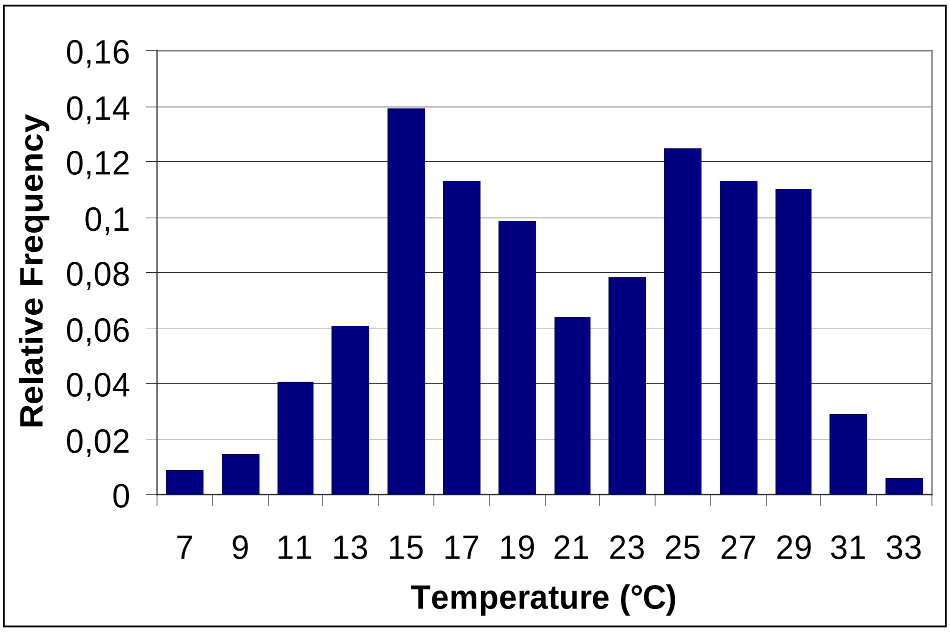


Figure 1. Histogram of 2009 daily outdoor high temperatures

Based on such data, three days with outdoor high temperatures of 28°C, 31°C and 34°C have been selected for this study. Such days, hereafter indicated with D1 D2 and D3, have been identified as a typical warm, hot and exceptionally hot summer day respectively, and the daily evolution of indoor temperature during each of those days is presented in Figure 2.

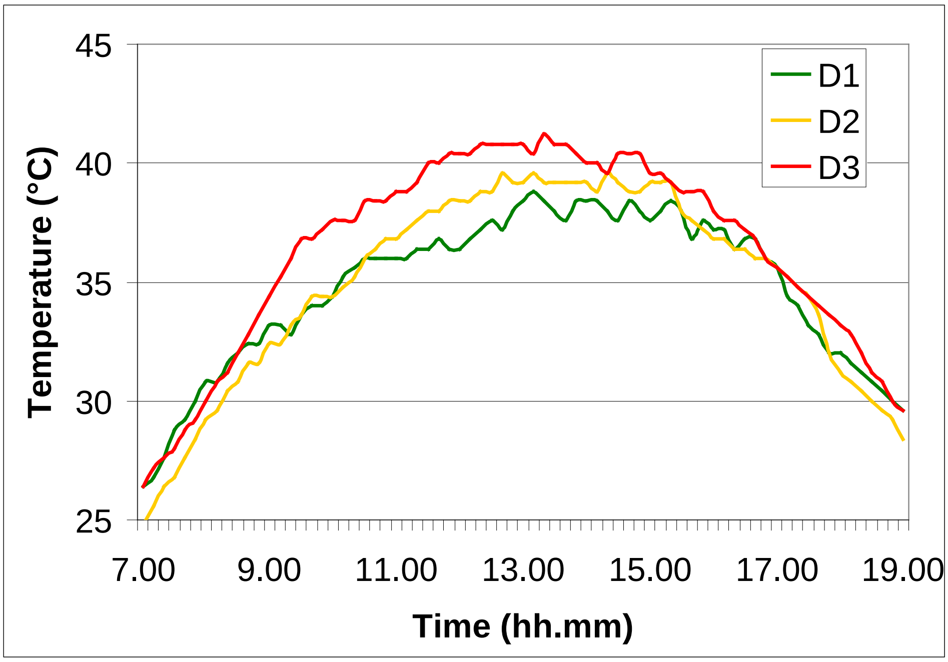


Figure 2. Indoor thermal evolution during D1 D2 and D3

It is also important to point out that what is an exception in this work (D3), may be the rule at more southern latitudes (e.g. south-east Sicily, 37° N), where greenhouses are also widespread and temperatures up to and occasionally in excess of 40°C should be expected.

results

the effect of outdoor conditions

Figure 3 shows the rectal temperature evolution during D1 D2 and D3, where work has been assumed to start (Time = 0) at 7 am. The horizontal dashed line represents the maximum tolerable rectal temperature $(t_{re})_{lim}$, set at 38°C following EN ISO 9886. All three curves display the same three-stage profile where a short initial rise quickly gives way to a plateau where t_{re} flattens out, thanks to the evaporative cooling which is able to fend off the growing heat inflow. This second phase has a variable duration, inversely proportional to the heat load.

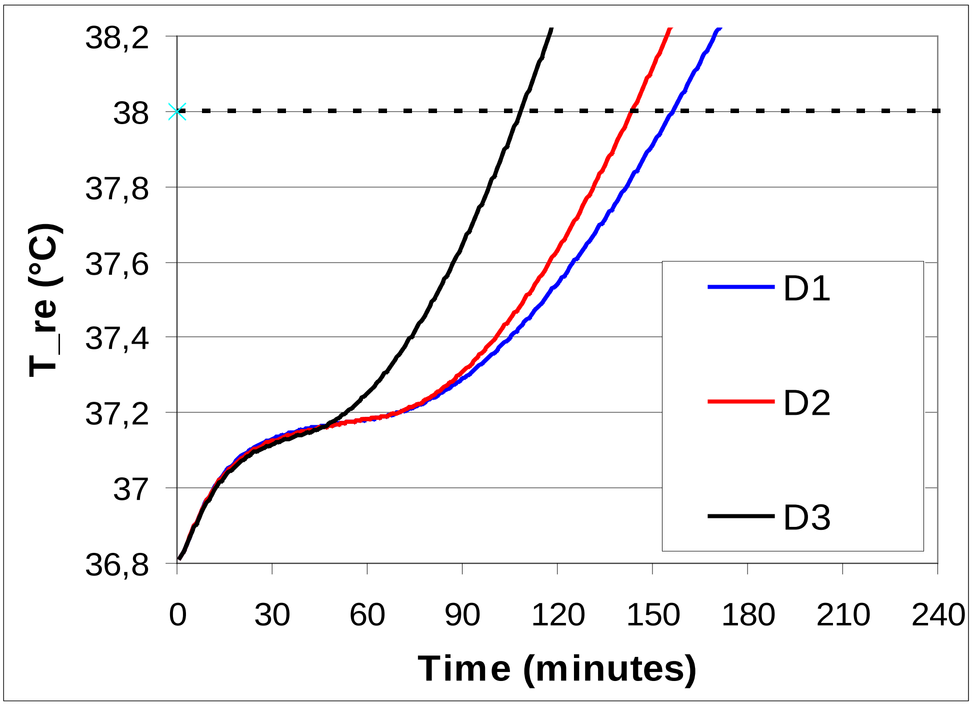


Figure 3. Rectal temperature evolution during days D1 D2 and D3

As air and radiant temperatures grow higher during the day, the maximum evaporative capacity of the body is eventually reached. Beyond this point, if the heat load keeps on increasing cooling can no longer effectively counteract the heat influx. Humidity inside a greenhouse is always large enough that loss of fluids via evaporation is severely curtailed, which explains the runaway growth of the rectal temperature in the third stage. The large humidity also implies that loss of fluids is never a factor: D_{lim_loss} is always more than twice as large as D_{lim_tre}, so that exposure duration is always set by the fast-rising rectal temperature, not by dehydration, and heat stroke is a more realistic threat that dehydration-related pathologies. The threshold $(t_{re})_{lim}$ = 38°C is crossed after 157, 144 and 109 minutes during D1, D2 and D3 respectively (that is between 8.50 and 9.40 am assuming the work starts at 7 am). The indoor air temperature at those times is between 32 and 36°C (see Figure 2). A rough extrapolation suggests that a daily high outdoor temperature around 25°C can be estimated as the critical level above which exposure becomes duration limited, that is t_{re} exceeds $(t_{re})_{lim}$ within the first four hours of morning work.

A "standard" 1.75m, 75 kg subject has been assumed. The effect associated to different physical complexion is minimal: the maximum allowable exposure of a slender, smaller subject (1.70m, 60 kg) is just 5% smaller. The size of the effect associated to heavier subjects is even smaller.

constant vs. evolving meteorological input data

Figure 4 compares the predicted rectal temperature evolution in D1, D2 and D3, resulting from two different approaches: lines with squares for predictions resulting from our time-dependent input parameters; lines with no symbols for predictions resulting from an idealised thermally stable environment, with t_a $\bar{t}_r$ and RH set at their respective diurnal (7 am – 7 pm) averages. Because t_g data are estimates, not measurements, absolute values of D_{lim} found above have limited accuracy. However, since the variable input and the constant input models share the same approximation, their comparison is unbiased.

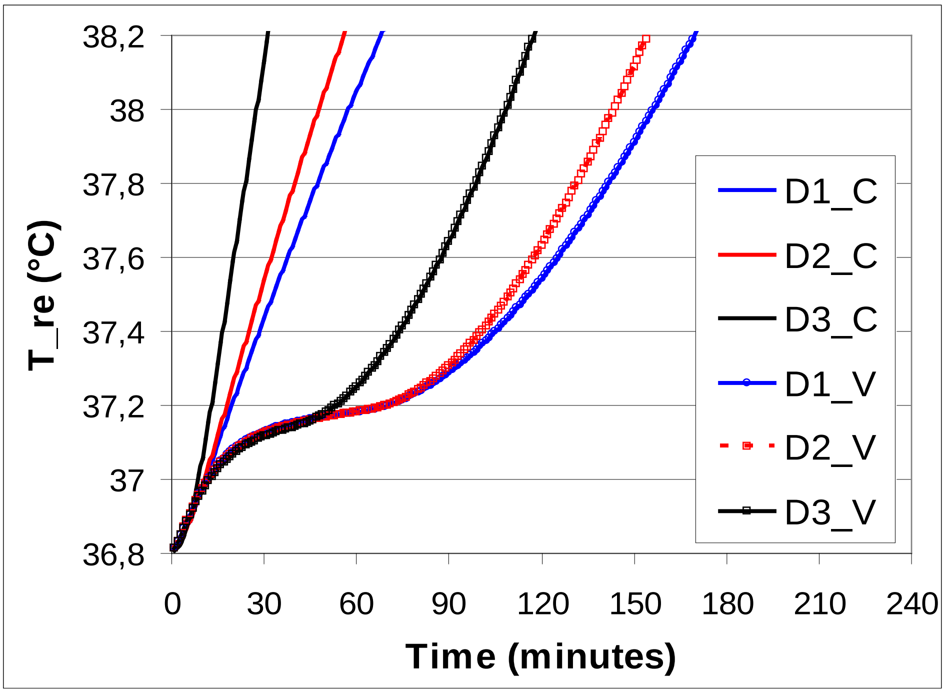


Figure 4. Rectal temperature evolution in idealized stable (constant, _C) and drifting (variable, _V) thermal environments

The constant input model systematically underestimates allowable exposure times, due to the gross overestimate of the early morning temperatures associated to the use of the average diurnal value. The accuracy of the static model can be improved by narrowing the time range over which the average is performed (e.g. 7 am – 12 am). However, it is unclear how to determine the appropriate time range, as it should depend on the (unknown) maximum allowable duration, implying an iterative procedure which is probably an unnecessary headache. Moreover, the shapes of the rectal temperature evolutions in the two models would not be reconciliated anyway, displaying a much steeper slope in constant input models. The reliability of thermally-induced stress assessments based on constant thermo-hygrometric inputs is strongly debatable.

PHS VS. WBGT

There are a few studies advocating the use of WBGT (EN 27243) as a descriptor of heat stress. In some cases the time evolution of WBGT is used to derive estimates of heat stress and acceptability of exposure. However, because WBGT is an empirical synthetic index developed to predict the mid to long term response of the human body, it is ill suited to track the short scale time evolution of thermo-hygrometric parameters typical of the system under investigation. Indeed, EN 27243 clearly mandates that assessment is to be performed using time-averaged values of relevant temperatures over a 1h range whose onset coincides with the working day start. Based on this 1h range concept, a sequence of WBGT values has been calculated here from averages of t_g and t_{nw}, (the latter approximated using the relation $t_{nw} = t_a – [14 – 0,14\ RH]$, del Gaudio and Lenzuni 2002) taken over consecutive 1h periods (7-8 am, 8-9 am, 9-10 am ……….).

Table 1. Thermal stress assessment evolution using modified PHS and WBGT

Case	D_{lim}	WBGT 7 – 8 am	WBGT 8 – 9 am	WBGT 9 – 10 am	Max Time Table A.1	Max Time Figure B.1
	(minutes)	(°C)	(°C)	(°C)	(minutes)	(minutes)
D1	157	27.5	30.4	32.7	90	180
D2	144	26.8	30.4	33.3	90	160
D3	109	28.2	32.5	35.8	60	120

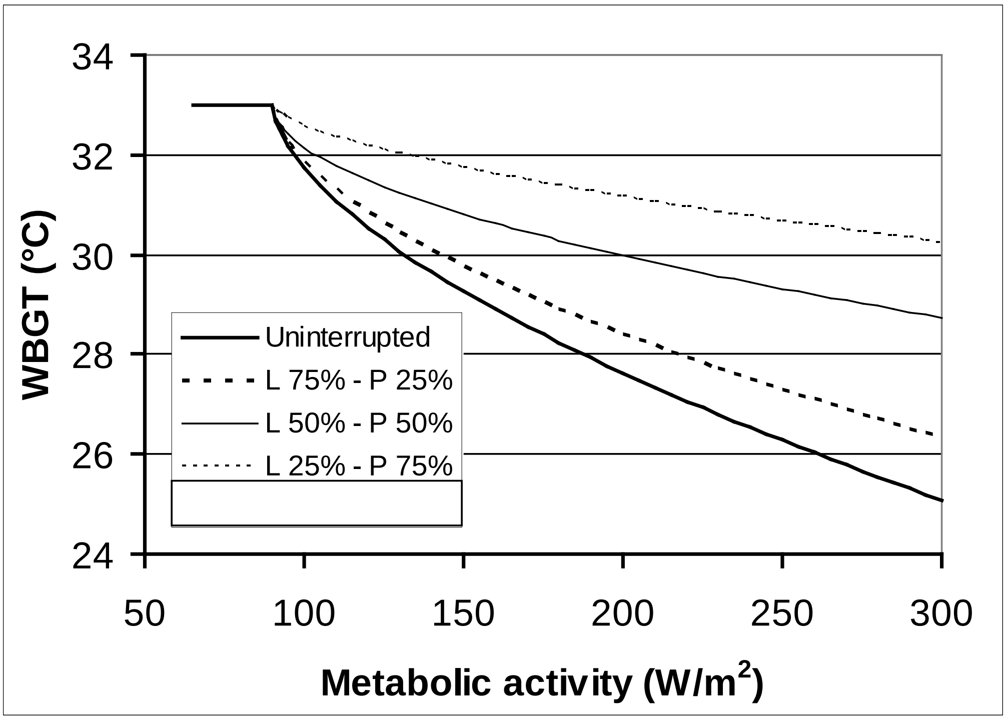


Figure 5. Low-M extrapolation of limit WBGT curves as a function of metabolism

Table 1 compares thermal stress assessments carried out using the method discussed in this paper (quantified by the maximum allowable duration of the exposure D_{lim}) and using WBGT as detailed above. Two procedures for WBGT-based assessment have been applied: in the first, a limit value $(WBGT)_{lim}$ = 30°C has been assumed, as indicated in EN 27243 Table A.1 for a metabolic class 1 (as implied by our estimate of M = 1.4 met) and an acclimated subject. WBGT values indicate that the limit is exceeded sometime in second hour of exposure (D1 and D2), and at the end of the first hour of exposure (D3). This assessment method strongly underestimates allowable exposure times, showing a behaviour similar to the constant input models discussed above. The second procedure has exploited the information displayed in EN 27243 Figure B.1. Since we have M = 1.4 met = 81 W/m^2, we need to extrapolate the four curves which appear in this Figure below their starting point at about 2 met, or 116 W/m^2. Such an extrapolation leads to predict a collapse into a single line at and below 93 W/m^2 (see Figure 5). In this "low-M limit", a sharp transition from continuous uninterrupted exposure to no exposure allowed, occurs at the threshold $(WBGT)_{lim}$ = 33°C. Estimated maximum allowable exposure times based on the crossing of this threshold, shown in Table 1, show a good agreement with the method outlined in this paper. It also picks up correctly the fact that t_{re} shows a runaway upward trend, so that no short scale work-rest cycle is helpful. This surprisingly good performance of WBGT is a direct consequence of the fact that WBGT is calculated here following its time evolution, although with a modest 1 hour resolution.

conclusions

Results obtained using the generalized PHS model differ significantly from those of the standard (static) PHS model (i.e. using daily averages for air/radiant temperatures and humidity). The static model systematically underestimates allowable exposure times (by a factor of 2 or more), due to a gross overestimate of the early morning temperatures associated to the use of the average diurnal value.

The accuracy of the static model can be somewhat improved adapting the averaging range, but this also introduces an undesired fuzziness in the method.

The use of static WBGT should be ruled out. However, the use of WBGT can lead to reliable predictions of the maximum exposure time, and as such can be used to make decisions on the work schedule, provided it can track the daily evolution of meteorological quantities.

While PHS is recognized as a much more accurate assessment method than WBGT, the choice of the descriptor is not as vital as is the ability to track the evolution of meteorological data, itself associated to the availability of continuous monitoring.

The method outlined in this paper is particularly relevant in environments, such as greenhouses, where the thermal environment can be extremely stressing, and the temperature evolution is fast.

references

del Gaudio M., Lenzuni P., 2002, Esposizione a stress da alte temperature dei lavoratori delle cave di marmo di Massa e Carrara, Proceedings of dBA 2002, Modena (in Italian).

EN ISO 7726:2001, Ergonomics of the thermal environment – Instruments for measuring physical quantities.

EN ISO 7933:2004, Ergonomics of the thermal environment – Analytical determination and interpretation of heat stress using calculation of the predicted heat strain.

EN ISO 8996:2004, Ergonomics of the thermal environment – Determination of metabolic rate.

EN ISO 9886:2004, Ergonomics – Evaluation of thermal strain by physiological measurements.

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

EN 27243:2004, Hot environments – Estimation of the heat stress on working man, based on the WBGT-index (wet bulb globe temperature).

Gusman A., Marucci A., Salvatori L., 2008, Control of the climate parameters inside greenhouses to defend workers health, Proceedings of Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems, Ragusa.

Malchaire J., Piette A., Kampmann B., Mehnert P., Gebhardt H., Havenith G., den Hartog E., Holmer I., Parsons K., Alfano G. and Griefahn B. 2001, Development and validation of the predicted heat strain model, Annals of Occupational Hygiene, 45 (2), 123-135.

Monarca D., Cecchini M., Panaro A., Porceddu P.R. 2004, Valutazione del rischio di stress termico per i lavoratori in serra, Proceedings of dBA incontri 2004, Modena, (in Italian).

McNeill M. B., Parsons K. C. 1999, Appropriateness of international heat stress standards for use in tropical agricultural environments, Ergonomics, 42, 779-797.

Okushima L., Sase S., Lee I.-B.,. Bailey B. J. 2000, Thermal environment and stress of workers in naturally ventilated greenhouses under mild climate, Proceedings of the V International Symposium on Protected Cultivation in Mild Winter Climates: Current Trends for Sustainable Technologies.

Yaglou C. P. 1927, Temperature, humidity and air movement in industries, Journal of Industrial Hygiene, 9, 297-309.

An Evaluation of a Small-Scale Farm Safety Extension Service

Lundqvist P., Alwall Svennefelt C.
Swedish University of Agricultural Sciences
Department of Work Science, Business Economics and Environmental Psychology
Box 88. S - 230 53 Alnarp, SWEDEN
Tel 0046 40415495, e-mail: Peter.Lundqvist@ltj.slu.se & Catharina.Alwall@ltj.slu.se

Abstract

The purpose of this study was to evaluate a small-scale farm safety extension service. This service was a 2-hour on-farm safety advice visit without charge and provided by farm safety engineers (with an option to pay for extended service). It was financed by the Federation of Swedish Farmers (LRF) and the Federation of Swedish Forestry and Agricultural Employers (SLA) during the period 2007-09.In order to make an evaluation of this program, it was started with an interview of the program leaders from both organizations. There was also an interview with one of the farm safety engineers. Based on these interviews web-based surveys was developed and tested, before being sent to all safety engineers as well as a sample of farmers (111) which had visits during this period.The results was based on answers from all 7 farm safety engineers as well as 70 (63%) of the participating farmers. The survey to the safety engineers showed that they found it hard to motivate farmers; to book up visits as well as buying extra advice services besides the free service. The farmers who had visits were over-all quite satisfied with the visit and the free-service. The main reason for accepting a visit was that they had experienced an injury themselves or that they wanted advice on child injury prevention. Nine out of ten farmers said that they had done injury prevention measures after the visit. Only 20% wanted to buy extra services, since they were satisfied with this free 2 hour service. This study has shown that on-farm safety advice service, free of charge is one way of improving the safety standard among farmers. The issue of motivating farmers is still a key issue, but the experience of an injury or the presence of children on the farm changes the impression of resistance.

Keywords: farm safety, extension, evaluation, Sweden

Introduction

Injuries in Swedish agriculture are a matter of great concern and the injury rate is higher than in most other occupations. Besides adults, a number of fatalities involve children every year. A study by Pinzke and Lundqvist (2006) showed that about 5000 injuries each year require medical care, but only 10% are reported to the official injury register (SJV, 2007).

During the 1980s and 1990s there was a occupational health service for Swedish farmers with special health centers all over the country. Since this service was abolished it has been hard for farmers to find support for their extension needs related to safety and health. The Federation of Swedish farmers (LRF) have established a national network for health & safety, but there was still a lack of preventive support for farmers.

In 2006, a new project with a small-scale farm safety extension service was initiated and financed by the Federation of Swedish Farmers (LRF) and the Federation of Swedish Forestry and Agricultural Employers (SLA) for the period 2007-09. This service was a 2-hour on-farm safety advice visit without charge and provided by farm safety engineers (with an option to pay for extended service).

Purpose and goal

The purpose of this study has been to carry out an independent evaluation of this small-scale farm safety extension service for the period 2007-09 (Alwall Svennefelt & Lundqvist, 2010). The evaluation was based on the project goals set up by the providers of this service:

> Farmers should know how and where they can access qualified extension service with a focus on work environment issues such as health and safety
>
> After the conclusion of the project the service should be established and the farm safety advisors should be able to provide extension service on their own, based on the farmers' needs without financial support from the farming organizations.

Method and material

The evaluation process was initiated by an interview of the project leaders from the farmers' organizations in order to get an in-depth view of the background, purpose and the goal of this small-scale farm safety extension service. There was also an interview with one of the farm safety advisors in order to get a closer view of their work and their experiences.

The evaluation was then based on a mail-survey sent to the advisors, and a web-based survey to farmers who had used the service. The survey by mail to the advisors involved all seven safety engineers, one female and six males (41-64 years of age).

A total of 111 web-based surveys sent to the farmers resulted in a response-rate of 63% (70 answers). The majority of the farmers (84%) were older than 50 years of age.

Results

The results are divided into two parts, the survey among the advisors and the survey to the farmers (the customer perspective), respectively.

The farm safety advisors

The result in this part is based on a mail survey including all seven farm safety advisors.

Networking and collaboration

It was concluded that the advisors had good contact with each other, but it differed in how often they used this network – from weekly contacts to a couple of times each year. Other contacts of importance for them were farm organizations, health and safety organizations as well as authorities and specialists at institutes and universities. For most of them it was important to have this network in order to handle problems, discuss solutions and methods.

The extension service

Almost all of the advisors found it difficult to start up their advisory mission due to lack of interest among farmers as well as insufficient marketing of their services. Most of them also found it hard to provide the marketing on their own. One of them said it was like "selling ice to Eskimos". They also found it hard to sell additional services besides the free two-hour service.

They described the normal 2-hour extension service as a process:

1. Booking of the farm-visit
2. Short description of the farm and the production
3. What the problem is or the needs of the farmer / farm
4. A focused discussion of the problem and the possible solutions
5. Additional services needed, such as further evaluations or administrative support (reports to insurance companies, authorities etc.).

The advisors reported that this extension work took between 10-60% of their total full-time work. They also concluded that between 0-30% of their contacts led to further contacts or missions for the same farmer. Most of them only provided the free 2-hour service. It was less often that they took part in farm walks or farm shows.

Advisors' experiences

The advisors were of the opinion that when they were engaged in this 2-hour service with the farmers it was often a creative and positive process with motivated farmers. The main problem was to reach the farmers and motivate them to accept a visit to their farm with this service. They also concluded that the farmers they had met now knew where they could find farm safety extension services in the future.

On the other hand, they did not believe that they would be able to provide this service to farmers without financial support from farming organizations. They did not believe that farmers – in most cases - would be willing to pay for a safety and health extension service with visits to individual farms.

Their final recommendations were to continue with this free service as an investment for safer and more motivated farmers, but that it then needs better support and marketing strategies provided by the farming organizations. They argued that they are safety and health experts, and not sales-people.

Farmers

Information and contacts

Most of the farmers (39%) told us that they got information about this offer during local meetings with the farming organizations. Less often they found information through the media, farm shows etc.

The main reason for inviting the advisor to the farm was a farm safety evaluation (36%), other reasons were previous injuries, the need for rehabilitation or the need for child accident prevention.

An important question was if they had taken any accident prevention measures on their farms after the visit of the safety engineer. The farmers themselves reported that 88% of them had taken preventive measures. The most common of these were technical improvements or solutions (43%), followed by improved use of personal protective equipment (PPE) (28%), followed by new routines for health and safety plans (24%).

Almost 81% told us that they had not asked for further services from the advisors. The main reason for this, according to the majority, was that they judged themselves to be able to handle the health and safety work on their own after this initial free service. 65% felt confident about handling the up-coming health and safety issues by themselves due to the positive support from the advisors. They also noted that in general the right amount of extension service would be the provision of the 2-hour service. About 17% said that they would buy further services in the future. A small minority told us that they it was for economical reasons that they would not ask for further services.

Another question was related to what kind of extension service, relating to health and safety, they would prefer. The majority answered farm visits (56%), followed by practical training (such as animal handling) (16%), group based extension service (12%), farm walks (11%), telephone service (3%) and web-based service (2%).

Most of the farmers were of the opinion that a farm with safe and healthy working conditions would benefit their economy as well; only 25% thought this was true to a lesser extent, while fewer than 2% did not agree at all.

84% told us that they now had a greater interest for health and safety issues compared to the situation before the visit of the advisor. In another question the farmers were asked if they would consider the need of a visit from an advisor in the future; 68% said that they thought so, while 32% were quite sure that they would not. To the question why not, we got answers such as:

I have already got good advice

Too expensive – have other needs which are more important

Well, might be needed after 3 years, but only if it will be without charge

The only reason would be for a follow –up

I am cutting down on my farming so it is not needed

Only if the authorities require it

Small farm – I can handle it on my own

We have a safety and health plan which we follow

Ideas for improvement of this service were also brought up such as:

Use real injuries as examples

A yearly follow-up visit

Nice to be up-dated about latest news

Important with help providing safety and health

Discussion

This study has shown that an on-farm safety advice service, free of charge, is one way of improving the safety standard among farmers. The matter of motivating farmers is still a key issue, but the experience of an injury or the presence of children on the farm changes the impression of resistance.

The evaluation of this small-scale farm safety extension service has both positive and negative parts. The number of advisors seems to have too small, not covering certain areas of the country. It also seems that the advisors had different motivation needs for their efforts to reach and motivate the farmers.

It was also quite clear that it was possible to motivate farmers to buy further services besides the free 2-hours which were sponsored by the farming organizations. Solutions might be needed both for the individuals, such as further education in marketing, communication and motivation as well as organizational support through their networks all over the country to better communicate and motivate the farming population (LAMK, 2010).

From a farmer's point of view it seems to be an attractive concept to get a free 2-hour extension service. The challenge is to form this concept so it keeps its positive concept, but also motivates the farmer to continue to use this service even when they need to pay for it.

This kind of on-farm extension service is in line with the other concept which is now provided for Swedish farmers – Säkert Bondförnuft (2010) (Common Safety Sense for Farmers).

It is, however, also important to understand that not all farmers like extension persons on their farms, which has been discussed by Thelin at al (2010).

From the answers from the farmers it is concluded that own experiences of injuries and risks for children are important motivation factors when it comes to health and safety. This has also been shown very clearly in studies by Sorensen (2009).

The evaluation study also shows that it has effect when it comes to preventive measures. Almost 90% tell us that they have carried out preventive solutions on their farms, which shows us that extension service makes a difference. Studies in New Zealand report similar results (Morgaine et al 2006). It is, however, much harder to show if there has been a positive effect on the number of actual injuries.

Relating back to the goals set up by the farm organizations it can be concluded that:

Many farmers now know how and where they can reach farm safety advisors

It is still too early to run this service for farmers without financial and organizational support from the farming organizations

A final comment is that this concept has a future importance in Swedish agriculture, but it needs further development and still, at least for a limited time, financial and organizational support.

References

Alwall Svennefelt C., Lundqvist P. 2010. Utvärdering av projektet "Regionala arbetsmiljöutvecklare 2007-09". Landskap trädgård jordbruk: rapportserie (Sveriges lantbruksuniversitet, Fakulteten för landskapsplanering, trädgårds- och jordbruksvetenskap), vol 2010:10. (In Swedish) http://pub-epsilon.slu.se:8080/1651/01/LTJ-rapport_2010-10.pdf

Lantbrukets arbetsmiljökommitté (LAMK).2010. The Swedish Committee on Working Environment in Agriculture (LAMK). http://lantbruketsarbetsmiljo.slu.se/

Morgaine, K., Langley. J.D., McGee, R.O., 2006. The FarmSafe Programme in New Zealand: Progress evaluation of year one (2003). Safety Science 44, 359-371.

Pinzke S., Lundqvist P. 2007. Occupational Accidents in Swedish Agriculture. Agricultural Engineering Research, vol 13, 159-165

Sorensen, J. 2009. Social marketing for injury prevention: changing risk perceptions and safety-related behaviors among New York farmers. Umeå University Medical Dissertations. New Series No 138. Umeå University. Umeå. http://umu.diva-portal.org/smash/record.jsf?pid=diva2:158038

Statens Jordbruksverk (SJV). 2007. Moverka olycksfall i lantbruket. Rapport från Jordbruksverket och Skogsstyrelsen. Rapport RA07:8. Jönköping. (In Swedish) http://www2.jordbruksverket.se/webdav/files/SJV/trycksaker/Pdf_rapporter/ra07_8.pdf

Säkert Bondförnuft. 2010. Säkert Bondförnuft. (In Swedish) http://sakertbondfornuft.se/

Thelin, A., Michanek, P.,Borglid, L-O. 2010. Vi har avlivat din häst. Den ligger under presenningen. Djurskyddslag för vem? Recito Förlag. (In Swedish).

Improvement of Tractor Operator Safety by Multibody-FEM Techniques: The Influence of Soil Modelling

Mangialardi L.[1], Pascuzzi S.[2], Soria L.[1]
[1]*Politecnico di Bari, DIMeG – Mechanical Design Section*
V.le Japigia 182 – 70126 Bari, ITALY
Tel. +39 080 596 2710 – 2813, Fax +39 080 596 2810 – 2777
luigi.mangialardi@poliba.it, soria@poliba.it
[2]*University of Bari – PRO.GE.SA. – Mechanics Section*
Via Amendola 165/A – 70126 Bari, ITALY
Tel. +39 080 544 2214, Fax +39 080 544 2214
simone.pascuzzi@agr.uniba.it

Abstract
Most of the serious accidents in agriculture occur in the area of tractor roll-over. In order to reduce the number of work accidents, manufacturers have mandatory to equip their tractors with ROPS and seat safety belt anchorages, according to the European Community directive 2003/37/EC.
In this field of very high interest for worker safety, we have been carrying out a research activity aimed to analyse the injuries to operators and the effectiveness of restraint systems, by using a multibody-FEA approach. In particular the Madymo code is utilised (MAthematical DYnamic MOdels, TNO Automotive Safety Solutions).
In a previous paper we analysed the roll-over dynamics of a wheeled tractor with narrow track, placed on a slope, by means of a pure multibody scenario. Both the tractor structure and the ground were indeed modelled as infinitely rigid. In this paper the behaviour of two typical type of soil have been implemented in the model (by means of a FE description), analysed and compared with that of the rigid one. The aim of the study is to analyze how the soil mechanical strength affects the results of the accident dynamics simulation, by comparing the values both of the kinematic parameters and of the operator biological traumas. A better, more realistic description of all the interesting quantities is obtained, as expected.

Keywords: roll-over, restraint systems, dummies, injuries, soil

Introduction
Most of the serious accidents in agriculture occur in the area of tractor roll-over. As it is well known, ROPS and safety belts constitute the best option to avoid fatal consequences (ISPESL 2002, Comer *et al.*, 2003, Nichol *et al.*, 2005). These roll-over protective systems, indeed, allow to absorb the impact energy of an overturning vehicle without violating the DLV (Deflection Limiting Volume) and restrict driver movements inside the aforementioned clearance zone (Myers and Pana-Cryan, 2000, Nichol, 2005).

The European Community directives and the international Standards concerning the homologation of agricultural and forestry tractors for road circulation (EC 2003, EEC 1979, EEC 1986, EEC 1987, ISO 1989, OECD 2005) have by now obliged manufacturers to provide their tractors with a ROPS and a seat belt anchorage. Agricultural tractors are then equipped with a strong frame or a cab and with a pelvic restraint system, fastened to two points belonging to the driver seat or, less frequently, to the tractor chassis (Molari and Rondelli, 2007).

In this area of high interest for worker safety, we have carried out a research activity aimed to study the injuries caused by the overturning of the tractor and the effectiveness of the operator restraint systems, by means of a multibody-FEA code, Madymo (MAthematical DYnamic MOdels, TNO Automotive Safety Solutions) (Mangialardi and Soria, 2005, Mangialardi *et al.*, 2008).

The Madymo solver is generally utilised for the analysis of road vehicle safety related problems, to study the dynamic behaviour of safety structures and devices involved in simulated crashes, even evaluating the occupants biological injuries (Ambrosio, 2001, EuroNCAP, 2004, Kleinberger *et al.*, 1998). This is possible because the code includes libraries of numerical dummies, as models of seat belts and airbags (TNO Automotive Safety Solutions, 2009) which allow to reproduce the dynamic behaviour of the real instrumented dummies usually employed in real vehicle crash tests.

In a previous paper, we analysed the overturning dynamics of a wheeled tractor with narrow track, with the purpose of comparing the operator biological traumas in the cases (i) he was restrained with a pelvic belt or (ii) not restrained at all. As a starting point, in that study the structure of the tractor and the soil were both considered infinitely rigid, leading to a pure multibody scenario (Mangialardi *et al.*, 2008).

In this paper, we have improved the simulation model, by considering real stiffness values and constitutive material model of two different type of soil: The clay- and the sand-based ones. We have compared the results coming from the tractor-soil impact simulated dynamics obtained in those two cases with that obtained in the case of rigid soil. In the study, differently from the previous one, only the case of operator restrained with a 2-point pelvic belt is considered.

A more realistic description of all the interesting kinematic quantities has been obtained, as expected. High picks on time-varying accelerations related to step variations of the linear and the angular momentum, typical of hits between rigid bodies, are no longer present.

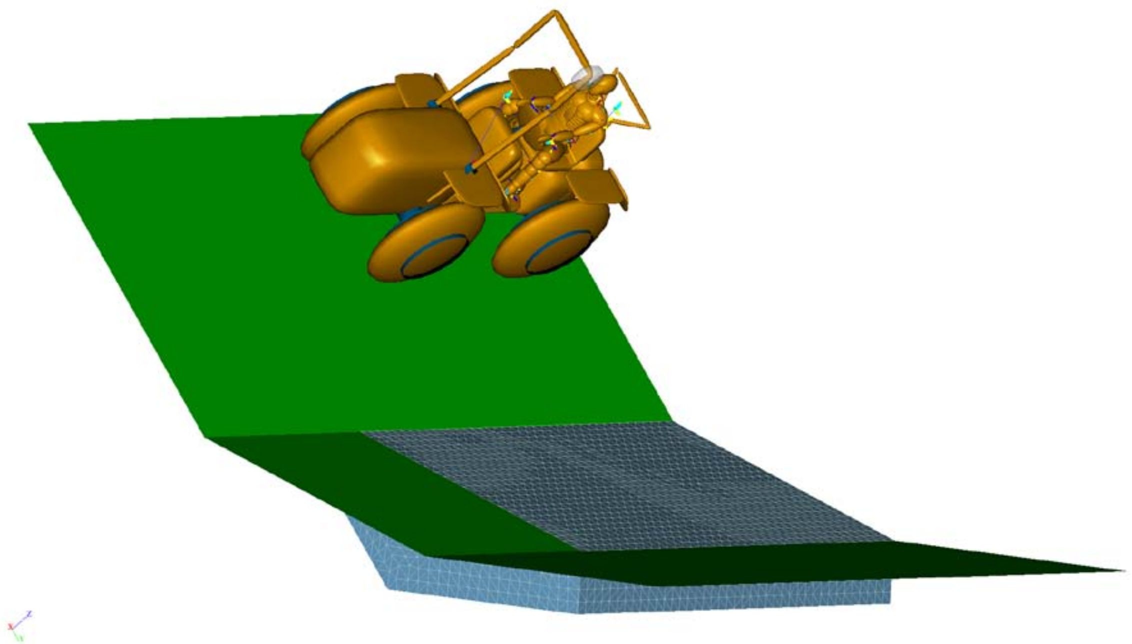


Figure 1. 3D view of the accident scenario (the initial position of the simulations is represented)

Materials and methods

The tractor

A narrow track wheeled tractor equipped with two ROPS (safety frames), selected among the ones available on the market, has been considered. The 3D multibody model, obtained moving from 2D drawings, has been reproduced with native hyper-ellipsoidal Madymo surfaces and consists of seven parts: (i) the body frame, (ii) the four wheels, (iii) the front and the rear safety ROPS. This model and the inertial frame used for the simulation are represented in Figure 1.

To each of the surfaces a body reference frame is rigidly connected and the whole spatial distribution of the mass (centre of gravity and inertia tensor) is declared with respect to this frame. The entire tractor model is then obtained by constraining the parts each other, by means of kinematic joints. The safety frames are supposed to be fixed to the body frame, by means of two brackets. Each of the four wheels is connected to the body frame by a cylindrical joint. The whole tractor model is then declared in the input scenario by means of a free joint.

When the tractor does not have any contact taking place with the ground, e.g. in a particular phase of the accident, the model has, in conclusion, 10 degrees of freedom (d.o.f.), the 6 rigid body motion d.o.f. and the 4 wheel rotations.

The soil

The tractor interacts with the soil by unilateral contacts. During the accident dynamics, every part of the tractor could actually come into contact with the soil, giving rise to the resultant number of d.o.f. of the whole scenario, in each instant of time.

A typical roll-over accident is analysed. The soil is supposed to be composed of three planes of different slope (Figure 1). At the beginning of the simulated dynamics, the tractor is positioned on the plane having the highest slope, in a way that the resultant weight force is able to make the tractor rolling over. A four node tetrahedral finite element model of the intermediate soil plane has been implemented in the accident scenario to take into account its solid behaviour. An isotropic elastic, perfectly plastic constitutive model has been utilised. The intermediate plane is actually the one which the rolling over tractor ends to hit on.

To model the dynamic behaviour of an agrarian soil subjected to time-varying mechanical forces proves to be rather difficult due to the strong variability of the parameters (texture, porosity, humidity, plasticity, etc.) and as a consequence of the physical-mechanics properties of the soil itself (Biondi, 1999, Peruzzi, 1997).

Generally, in the technical literature, a certain soil is described as a transversally isotropic medium and the theory of the plasticity is utilised (Lancellotta, 1987).

In this study we have considered two types of soil having quite different mechanical properties: (i) a sand-based soil and (ii) a clay-based soil. The parameter values utilised in the accident model, are reported in Table 1.

Table 1. Mechanical property parameters of the two considered soils

soil	mass density [kg/m^3]	Young's modulus [MPa]	Poisson's ratio	yield stress [kPa]
sand	1600	200	0.3	200
clay	1800	40	0.3	120

The dummy

The tractor operator is simulated by means of a numerical dummy chosen among the ones available in the Madymo libraries, the Hybrid III 50th percentile male dummy, which is the most frequently utilised in the crash tests and in all the NCAP programs (New Car Assessment Programs). The dummy numerical models available in the Madymo libraries are multibody systems, composed by simple geometry bodies and/or FEM models assembled with kinematics joints and restraints, which reproduce the connections present in the instrumented real dummies usually employed in the crash tests.

The evaluation of biological damages by multibody techniques: The injury parameters

An estimation of the biological traumas that occur to occupants of a vehicle involved in a crash can be obtained through the evaluation of the values of the so-called injury parameters. The injury severity can be evaluated by utilising the corresponding injury criteria, i.e. by comparing the calculated value of each parameter with a certain threshold value. This thresholds have been established with the progresses made in the field of biomechanics, by carrying out experimental test campaigns on volunteers and dead bodies (Ambrosio, 2001, EuroNCAP, 2004, Kleinberger *et al.*, 1998).

The following injury parameters and the corresponding criteria have been utilised in this paper:

The Head Injury Criterion (HIC) for the estimation of head injuries. It is evaluated by means of a suitable integral average of the head centre of mass acceleration in a time window of not more than 36 ms. The criterion threshold value is 1000 $(m/s^2)^{2.5}s$ during an impulsive frontal shock. It has to be stressed that head sudden rotations are not considered in HIC evaluation.

The Neck Injury Predictor (N_{ij}) for the estimation of neck injuries. It is evaluated by the calculation of the forces and moments acting on the occipital region. The values achieved by these quantities are put in a suitable dimensionless form by using critical values, that depend on the dummy typology and on the neck loading conditions. They do exist four types of N_{ij}, indeed, one in each of the possible cases, tension – extension (N_{TE}), tension – flexion (N_{TF}), compression – extension (N_{CE}), compression – flexion (N_{CF}). In all the cases, to not have severe damages to the neck, it has to be $N_{ij} < 1$.

The 3 ms Criterion (3ms) for the estimation of damages occurring to thorax. Thorax injuries are the most critical after head injuries. To not have severe damages, the thorax centre of mass has not to undergo an acceleration higher than 60 g for a time longer than 3 ms.

Results

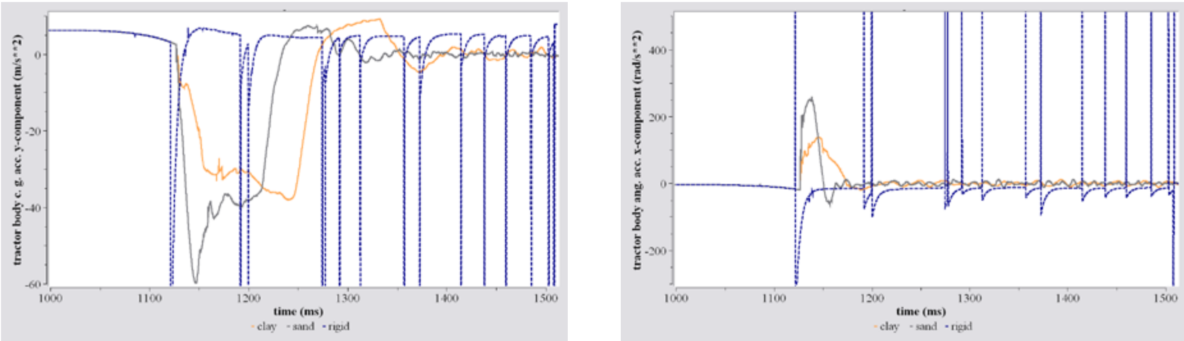
The roll-over kinematics

In Figures 2 and 3 the kinematic quantities of main interest, i.e. the longitudinal (*x*-) component of the tractor body angular velocity and acceleration and the transversal (*y*-) component of the tractor body centre of gravity velocity and acceleration are represented as functions of time in the three cases of soil considered, (i) clay, (ii) sand and (iii) rigid.

In the case of rigid soil, as expected, the tractor bounces on it with a series of following shocks, in each one of which one has a step variation of the angular velocity vector (Figure 3 b) and an extremely high peak value of the angular acceleration (Figure 2 b). This behaviour is actually far from that it is the real one. Similar consideration can be made referring to velocity and acceleration of the tractor body centre of gravity (Figure 3 a and 2 a), which in average moves down along the slope.

Both in the cases of sandy and clayey soil, instead, all the acceleration peaks reduce to realistic values and, in particular, the time interval in which one has the main first rebound of the tractor body becomes wider.

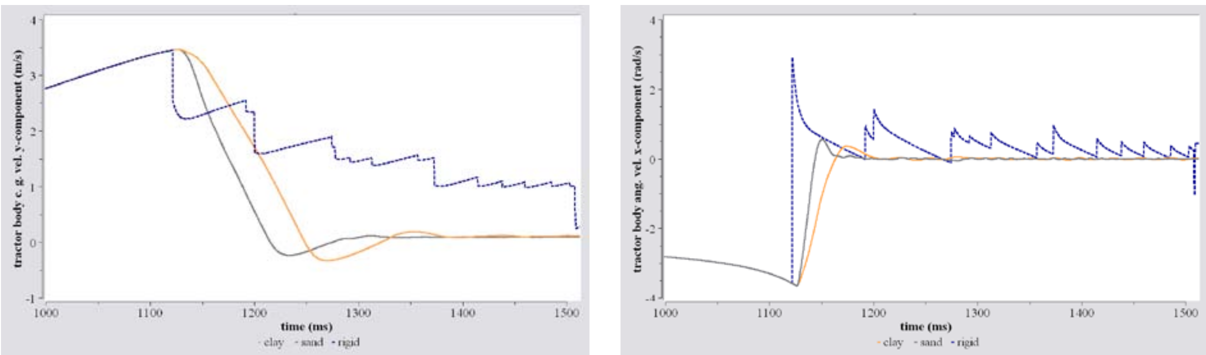
In conclusion a slower variation of the kinematic quantities is obtained with a consequent more realistic representation of the roll-over dynamics of the tractor.



(a) (b)

Figure 2. The -component of the tractor body centre of gravity acceleration (a) and the -component of the tractor body angular acceleration (b) as functions of time

In Figure 4 the final time of the simulations is represented. The soil plastic deformations related to the interaction with the tractor body and mainly with the front safety frame can be clearly seen. The algorithm utilised to detect a multibody-FEM contact is basically related to the evaluation of the virtual relative penetration between the two interacting parts. This quantity allows the evaluation of the reactive forces due to the contact between the nodes of the soil FEM mesh and the hyper-ellipsoidal surfaces of the multibody tractor.



(a) (b)

Figure 3. The -component of the tractor body centre of gravity velocity (a) and the -component of the tractor body angular velocity (b) as functions of time

The biological traumas caused to the operator

In Table 2 the values of the said injury parameters are reported in the case of operator restrained with a 2-point pelvic belt, for the two different examined type of soil.

First of all one has to notice that none of the injury parameters overcomes the corresponding threshold value and this highlights the utility of the seat safety belt, as expected.

Moreover the comparison of the injury parameter values obtained in the different simulated cases of soil points out that the operator traumas seem to increase a bit as the stiffness of the soil decreases: the injuries evaluated in the case of clayey soil are higher than the ones obtained with a sandy soil and these last ones are higher than those related to a rigid soil.

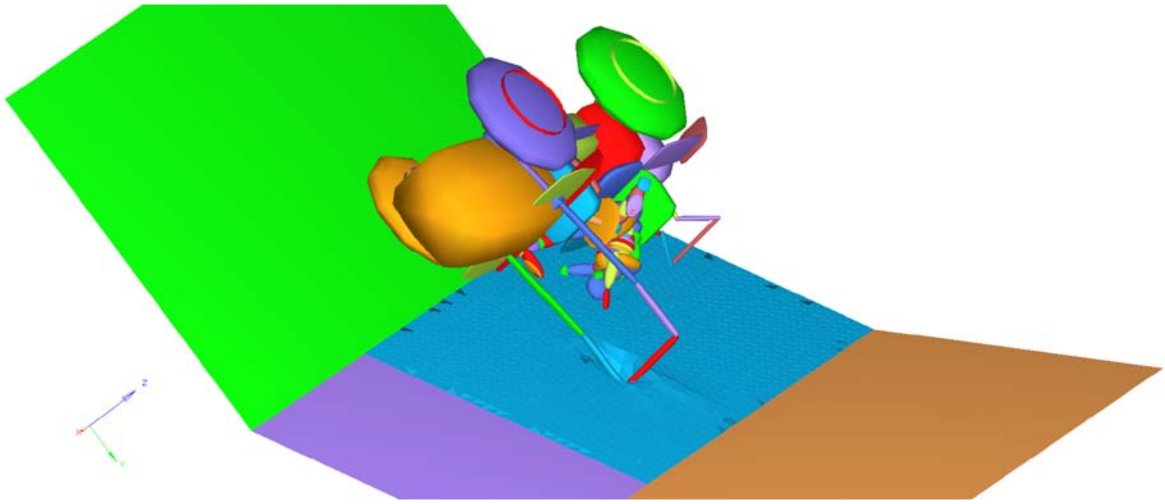


Figure 4. End of the simulation: it is possible to visualise the contacts between the dummy-tractor system and the deformable soil

This result is not surprising since the different soil mechanical strength affects the whole tractor dynamics and, in particular, the amount of penetration of the ROPS into the soil, so that also the safety volume (DLV) becomes a function of the soil deformation: it becomes smaller as the stiffness of the soil decreases. As a conclusion, the interaction between the tractor operator and the soil gets more likely as the deformation of the soil increases.

Table 2. Comparison of the main injury parameters in the case of operator restrained with a 2-point pelvic belt considering each one of the examined soils

injury parameter	injury criterion	clayey soil	sandy soil	rigid soil
HIC $[(m/s^2)^{2.5}s]$	< 1000	329.10	244.84	13.015
N_{TE}	< 1	0.27029	0.29038	0.22677
N_{TF}		0.15709	0.10052	0.054920
N_{CE}		0.45020	0.39971	0.039257
N_{CF}		0.57922	0.29627	0.0096685
3 ms $[m/s^2]$	< 60 g	138.62	105.65	133.82

Conclusions

The scenario of a typical roll-over of a tractor has been reproduced in the multibody-FEA Madymo environment (TNO Automotive Safety Solutions) and, in particular, in the simulated scenario the structure of the tractor has been considered infinitely rigid, whilst two different types of soil, a clay-based soil and a sand-based one, have been modelled as deformable by means of a FE description. The dynamic behaviour of those two kind of soils have been then compared with the one coming from a similar scenario in which, instead, an infinitely rigid ground is considered.

The obtained results show clearly how useful is the seat belt in confining the operator in the clearance zone so that all the injuries are reduced. Moreover from a kinematic point of view the deformation of the soil produce close to real acceleration and velocity values with respect to those obtained considering a rigid soil.

From a dynamic point of view, the higher are the soil plastic deformations the bigger is the penetration of the ROPS in the soil so to reduce the safety volume and to make more possible the interactions between the operator and the soil. As a consequence the injury severity seems to get a bit higher, with reducing values of the soil stiffness.

In a further, final improvement of the simulation model, the deformability of the safety ROPS will be also taken into account, that again is expected to lead to a further reduction of the safety limiting area of the operator and hence to a complete, close to real estimation of the trauma severity.

Acknowledgements

Each of the authors contributed in equal parts to this work.

References

Ambrósio, J. A. C. 2001. Crashworthiness. Energy Management and Occupant Protection, vol. 423, CISM, SpringerWien NewYork.

Biondi P. 1999. Meccanica agraria. UTET Torino.

Comer R. S., Ayers P., Wang X., Conger J. B., Troutt P. 2003. Evaluation of ASAE standard S547 for the continuous roll testing on front driven mowers. ASAE Paper No. 38005.

EC 2003. Directive 2003/37/EC of the European Parliament and of the Council of 26 May 2003 on type-approval of agricultural or forestry tractors, their trailers and interchangeable towed machinery, together with their systems, components and separate technical units and repealing Directive 74/150/EEC. European Community.

EEC 1979. Council Directive 79/622/EEC of 25 June 1979 on the approximation of the laws of the Member States relating to the roll-over protection structures of wheeled agricultural or forestry tractors (static testing). European Community.

EEC 1986. Council Directive 86/298/EEC of 26 May 1986 on rear- mounted roll-over protection structures of narrow-track wheeled agricultural and forestry tractors. European Community.

EEC 1987. Council Directive 87/402/EEC of 25 June 1987 on roll-over protection structures mounted in front of the driver's seat on narrow-track wheeled agricultural and forestry tractors European Community.

European New Car Assessment Programme (EuroNCAP) 2004. Assessment protocol and biomechanical limit (version 4.1). Tech. rep.

ISO 1989. ISO 3776, Tractor for agriculture—seat belt anchorage. International Organisation for Standardisation, Geneva.

ISPESL 2002. Requisiti di sicurezza dei trattori agricoli e forestali. [Safety requirements of agricultural and forestry tractors.]. Il sole 24 ore, 16, 1-16.

Lancellotta R. 1991. Geotecnica. Zanichelli Editore Bologna

Kleinberger M., Eppinger R., Sun E., Kuppa S., Saul R. 1998. Development of improved injury criteria for the assessment of advanced automotive restraint systems. NHTSA. Tech. rep.

Mangialardi L., Soria L. 2005. Impiego di tecniche multibody per il miglioramento della sicurezza degli operatori di carrelli a forche. Atti del XVII Congresso AIMETA di Meccanica Teorica e Applicata, Firenze, 11-15 settembre 2005.

Mangialardi L., Pascuzzi S., Soria L. 2008. Use of simulation techniques to improve tractor operator safety. Proceedings of the International Conference «Innovation Technology to Empower Safety, Health and Welfare», Ragusa – Italy, September 15-17, 2008.

Molari G., Rondelli V. 2007. Evaluation criteria for the anchorage resistance of safety belts on agricultural tractors. Biosystems engineering, 97. 163-169.

Myers M. L. 2002. Tractor risk abatement and control as a coherent strategy. Journal of Agricultural Safety and Health, 8(2), 185-198.

Nichol C. I., Sommer H. J., Murphy D. J. 2005. Simplified overturn stability monitoring of agricultural tractors. Journal of Agricultural Safety and Health, 11(1), 99-108.

OECD 2005. Standard Codes for the Official Testing of Agricultural and Forestry Tractors. Organisation for Economic Cooperation and Development, Paris.

Peruzzi A., Sartori L. 1997. Lavorazione del terreno. EDAGRICOLE - Edizioni Agricole. Bologna

TNO Automotive Safety Solutions - Delft (NL) 2009. MADYMO Manuals - Release 7.1.

ISO 26000 and Sustainability: Health and Safety at Work in a Green Agriculture

Mercadante L.[1], Saldutti E. [2]
INAIL – Italian Workers' Compensation Authority
P.le G. Pastore, 6 – 00144 Roma, ITALY
[1]*Central Prevention Directorate*
Tel 0039 0654872110, Fax 0039 0654872075, l.mercadante@inail.it.
[2]*General Medical Supervisory Office*
Tel 0039 0654872109, Fax 0039 0654872760,e.saldutti @inail.it

Abstract
The strong relationship between behaviours and ethics leads to a new model of sustainability and sustainable development, whereby environment and agriculture become fields of more and more interest and activities.
ISO 26000 is the new guidance on social responsibility, a voluntary standard elaborated under the scope of the International Organisation for Standardisation (ISO), whereby core subjects such as labour practises, consumer issues, the environment are defined relevant areas as well as the "organisational governance" i.e. "system by which an organization makes and implements decisions in pursuit of its objectives".
Properly the core subject "The environment" includes prevention of pollution, sustainable resource use, climate change mitigation and adaptation and, also, principles of environmental responsibility and environmental risk management. In such a way it is moving from the "green agriculture" approach towards the "agricultural sustainability", as the maintenance of the quantity, as well as the quality of agricultural produces over very long periods of time *without* **signs of fatigue.**
The safeguard of health and safety at work seem to be the natural link, leading to the role of public policies, educational campaigns and information activities.
In Italy recent provisional laws, soft laws and National Plans are properly focused on this, with the final aim of linking health and safety at work to well-being and ethics behaviours.

Keywords: social responsibility, sustainable development, INAIL

Introduction
ISO 26000 is the future international standard for social responsibility, which is being developed to help defining the scope and practises of socially and environmentally responsible management (1).

It would provide guidance on how to integrate social responsibility in the daily practise of all kind of organisations in the private, public and non profit sector, focusing toward sustainability and a sustainable approach as the global challenge of future generations.

At the same time, the European Commission defines Europa 2020 (2), the agenda for "A strategy for smart, sustainable and inclusive growth; the strategy puts forward three mutually reinforcing priorities:
– Smart growth for developing an economy based on knowledge and innovation.
– Sustainable growth for promoting a more resource efficient, greener and more competitive economy.

– Inclusive growth for fostering a high-employment economy delivering social and territorial cohesion.

Allocating the sustainable agricultural growth as a part of environment and environmental governance, the relationship between sustainability and environmental naturally leads to a different global approach, able to ensure a new economical and social growth model.

For this purpose many policies have to be implemented, inspired by European and international references and tailored at a national level to, according to an appropriate stakeholder engagement process.

Discussion

ISO 26000 is the guidance on Social Responsibility, theme and concept strongly debated, especially in the last decade.

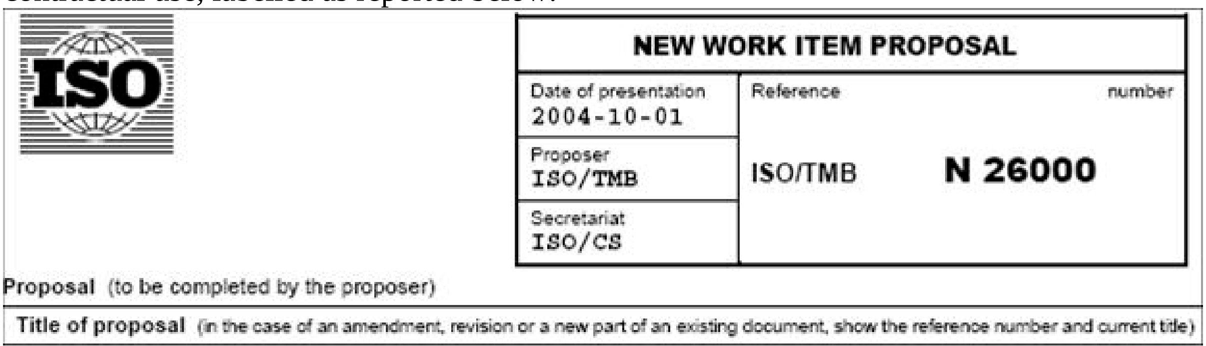
The whole document, composed by 84 pages, enriched with two annex and 175 core references, provides guidance to all types of organizations, regardless of their size or location, on:

concepts, terms and definitions related to social responsibility;
the background, trends and characteristics of social responsibility;
principles and practices relating to social responsibility;
the core subjects and issues of social responsibility;
integrating, implementing and promoting socially responsible behaviour throughout the organization and, through its policies and practices, within its sphere of influence;
identifying and engaging with stakeholders; and
communicating commitments, performance and other information related to social responsibility.

The guidance is intended to assist organizations in contributing to sustainable development and is intended to encourage them to go beyond legal compliance, recognizing that compliance with law is a fundamental duty of any organization and an essential part of their social responsibility. It is intended to promote common understanding in the field of social responsibility and to complement other instruments and initiatives for social responsibility, not to replace them.

The final aim is to assist organizations in addressing their SR and provide a practical guidance related to operationalizing SR, identifying and engaging with stakeholders, and enhancing credibility of reports and claims made about SR;

It is an International standard providing guidance, it is not a management system standard and it is not intended or appropriate for certification purposes or regulatory or contractual use, labelled as reported below.



ISO

NEW WORK ITEM PROPOSAL

Date of presentation	Reference number
2004-10-01	
Proposer ISO/TMB	ISO/TMB N 26000
Secretariat ISO/CS	

Proposal (to be completed by the proposer)

Title of proposal (in the case of an amendment, revision or a new part of an existing document, show the reference number and current title)

Figure 1. Label of ISO guidance

So, what does social responsibility really mean? The term social responsibility came into widespread use in the early 1970s although various aspects of social responsibility were the subject of action by organizations and governments as far back as the late 19th century, and in some instances even earlier. The view that social responsibility is applicable to all organizations emerged as different types of organizations, not just those in the business world recognized that they too had responsibilities for contributing to sustainable development.

Nowadays an organization's performance in relation to the society in which it operates and to its impact on the environment has become a critical part of measuring its overall performance and its ability to continue operating effectively; moreover the expectations of whole society regarding the performance of organizations continue to grow.

And how does ISO 26000 define social responsibility? It is the "responsibility of an organization for the impacts of its decisions and activities on society and the environment, through transparent and ethical behaviour that:

contributes to sustainable development, including health and the welfare of society;

takes into account the expectations of stakeholders;

is in compliance with applicable law and consistent with international norms of behaviour;

and is integrated throughout the organization and practised in its relationships".

So the starting point is knowing the extension of social responsibility; for that effect the organisation should consider the economical, social and environmental impacts of its direct and indirect activities. It also should address three relationships: between the organisation and society, between the organisation and its stakeholders, between those stakeholders and broader society.

The engagement of the organisation with people, communities and organisations that have identifiable interest in the organisation's activities is an essential element.

Owing to the difficulty of identifying all SR related topics, the guidance organizes them into seven big core subjects, each one of them including many issues. Some topics, such as health and safety, value chain and economical aspects, don't have only one core subject but are handled as crosscutting issues.

Inspiring and addressing the seven principles of SR, each organisation, together with its stakeholders, should evaluate and prioritize its actions, seeking to integrate SR throughout its decision and activities. This involves practices such as: making social responsibility integral to its policies, organizational culture, strategies and operations; building internal competency for social responsibility; undertaking internal and external communication on social responsibility; and regularly reviewing these actions and practices related to social responsibility.

A schematic overview of ISO 26000 better explains the whole process.

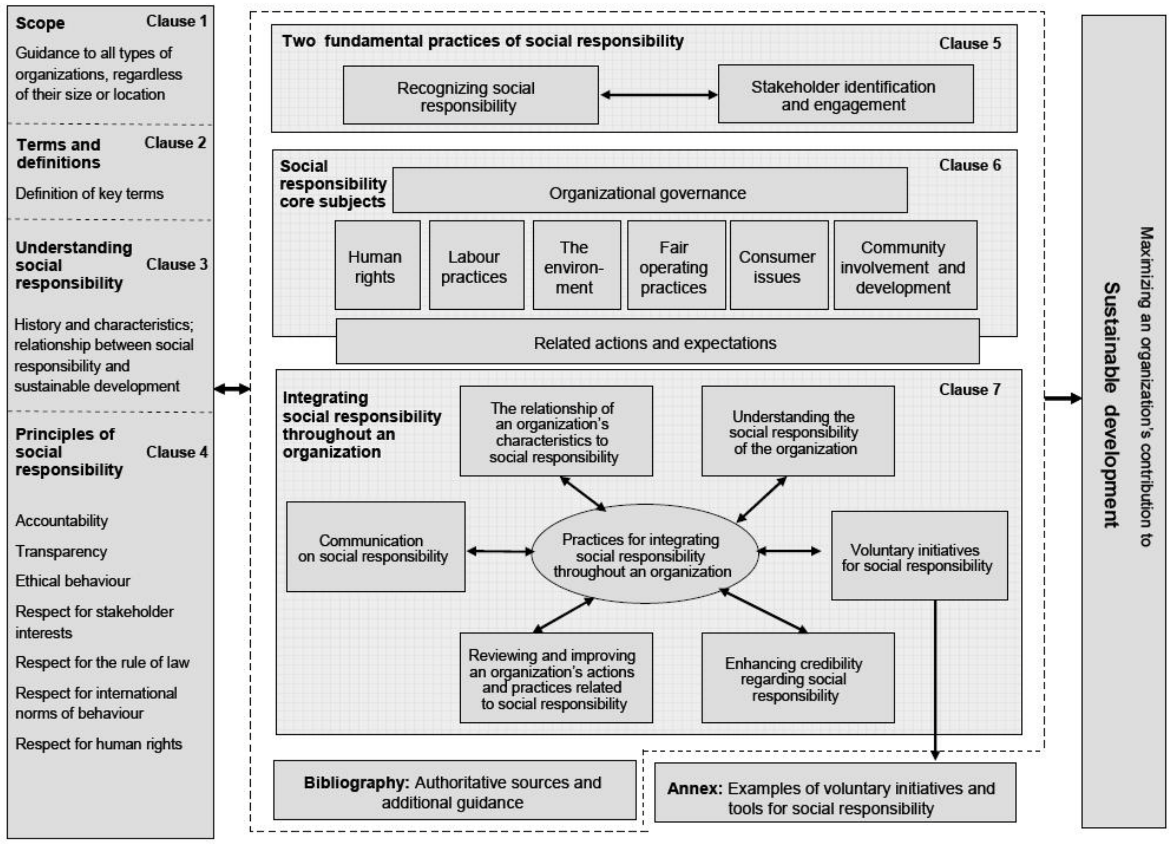


Figure 2. Schematic overview of ISO 26000

The Annex includes a list of broadly recognised voluntary initiatives and tools available to assist the integration into an organisation's activities.

The SR core subject "The environment" includes a relevant overview on Organizations and the environment and reports that "the decisions and activities of organizations invariably have an impact on the environment no matter where the organizations are located. These impacts may be associated with the organization's use of resources, the location of the activities of the organization, the generation of pollution and wastes, and the impacts of the organization's activities on natural habitats. To reduce their environmental impacts, organizations should adopt an integrated approach that takes into consideration the direct and indirect economic, social, health and environmental implications of their decisions and activities".

It is clear that agriculture, properly following a green approach is the best way to fit all these goals; in fact in the long run, all organizations' activities depend on the health of the world's ecosystems.

For this to happen, principles of sustainability must be a core part of agricultural policies, to provide incentives and enabling conditions for sustainable resource use. Such principles should also be reflected in macro policies that can potentially influence different groups of people, the resources they use and their scope for positive adaptation.

A good practise of global approach is the "Rural Development policy" of the European Union, which objectives focus on the enhancement of the social and economic cohesion, on the improvement of competitiveness in farming and forestry sectors, and on the amelioration of the environment aiming at landscape conservation and sustainable development.

Regarding the programming period 2007-2013, the European Union has adopted a so-called "multi-level" approach, including: Community Strategic Guidelines, National Strategy Plan and Rural Development Programme. The Community Strategic Guidelines (CSG)define the community strategic priorities; the National Strategy Plan (NSP) sets the strategic priorities of the Member State and the Rural Development Programme (RDP) is the operational Programme designed to implement NSP and CSG.

In Italy, according to the defined strategy, the Italian Ministry of Agricultural, Food and Forestry Policies (Mipaaf) has developed a National Strategy Plan, that is the outcome of consultations, partnerships and negotiations with the major institutional, economic and social actors. It identifies four strategic priorities in

1) improving the competitiveness of the agricultural and forestry sector;
2) improving the environment and the countryside;
3) quality of life in rural areas and diversification of the rural economy;
4) Leader approach.

For these goals a National Rural Network (NRN) (3) has been implemented; properly it is a project that gives Italy the chance to take part into the wider European Network for Rural Development project, thus joining and completing all the activities as to rural area development for the whole period 2007-2013.

The Italian project aims at supporting rural area development policies and even at fostering a greater and more efficient level of interaction and exchange of expertise between the related stakeholders, institutions and those working and living in rural areas.

One of the related key goals is to strengthen the flows of information and communication between the different levels of rural stakeholders. On the one hand, it would increase the value of Italian territory productive potentials and, on the other hand, it identifies critical points, thus improving its governance.

A "National Prevention Plan on Agriculture and Forestry", as part of the NRN strategies, has been developed, according to the existing "Patto per la tutela della salute e la prevenzione nei luoghi di lavoro" and aiming to drastically reduce occupational accidents and diseases. .

INAIL, Italian Workers' Compensation Authority, (4) as partner of the plan, strongly supports it and all related prevention activities.

Furthermore, INAIL focuses its own activity towards the agricultural sector with tailored formation and information campaigns; also involving foreign workers, largely involved into this sector and frequently affected by work accidents and occupational diseases.

Conclusion

The concurrent actions towards a sustainable development, moving both from a global approach of social responsibility and ethical behaviours and a tangible need of reducing occupational risk and enhancing prevention planning and well-being, lead to a new culture of health and safety at work, whereby environment and agriculture are to be considered relevant parts of the whole life cycle.

It really goes back to the sustainable development and ISO 26000 concepts, whereby ISO standard is a tools which supports the three dimensions of sustainable development: economic growth, environmental integrity and social equity.

References

(1) ISO/TMB WG SR N 191 Guidance on social responsibility
(2) Europa 2020 http://ec.europa.eu/eu2020/index_en.htm
(3) Rete Rurale Nazionale http://www.reterurale.it/
(4) INAIL www.inail.it

FEM Analysis of ROPS for Agricultural Self-Moving Machines

Molari G., Badodi M., Guarnieri A.
University of Bologna. DEIAGRA, Mechanics Section
Viale Fanin, 50 – Cap 40127 Bologna, ITALY.
Tel 0039 051 2096191, Fax 0039 051 2096178, mail giovanni.molari@unibo.it

Abstract

The high number of accidents due to a rolling over of agricultural machineries increases the interest of researchers and organisations for standardisation in this field. In the Fifties, standards to test rolling over protective structures (ROPS) for tractors were designed and approved, the same was not defined for agricultural self-moving machines. In the present work an analysis of different categories of agricultural self-moving machines is executed with the goal of evaluating the possibility to introduce ROPS solutions used in tractors. Three categories of agricultural self-moving machines were chosen in function of their dimensions, mass, operations performed, and their diffusion on the Italian and European market. On each machine, an evaluation of the capability to adopt a solution to protect the conducers from rolling over, like to tractors, was analysed. The ROPS design was obtained using a dedicated software to evaluate the resistance of the structures installed at the moment to protect conducers only from environmental aspects, and to design structures able to resist the load cycle imposed by the standards. The results have shown a low resistance level of the structures used at the moment on the machines chosen for the tests. The structures able to sustain the loads imposed by the standards are not too different with regards to dimensions, but an increase of the resistance of the materials or an increase of the thickness of the mountings is necessary.

Keywords: safety, standard adjustment, loading test

1. Introduction

Occupational health problems and industrial accidents are a heavy load for workers, employers and in general for the economy. The agricultural sector is one of the professional activities most affected by injuries, even though the updating of the machineries has decreased the number of fatal accidents in recent years [Eurostat, 2010]. In Italy one of the most frequent reasons of risk for the health is the rolling over of tractors and other agricultural machineries [ISPESL 2009; INAIL 2008].
With reference to tractors, firstly Sweden, in 1959, and then all the other European countries, adopted a regulation requiring Rolling Over Protective Structures (ROPS) on all new tractors. Also in 1959, the Organisation for Economic Co-operation and Development (OECD) developed a test procedure to evaluate the strength of the structures and established energy criteria [OECD, 1959]. The introduction of the ROPS in Europe sharply decreased these fatalities [Springfeldt et al., 1998], while in the United States (US), many tractors are still not equipped with a protective structure and are often associated with fatal injuries [Myers et al., 1998; Janicak, 2000].

With reference to other self-moving agricultural machineries, even if the risk of roll over is real, as reported in all the specific standards related to the safety of these machines such as EN 632 [EN, 1997] for combine harvesters, EN 706 [EN, 2010a] for grape harvesters, EN 13118 [EN, 2010b] for potatoes and EN 13140 [EN, 2010c] for vegetables harvesters, there are no similar specific standards for tractors.
The directive 2006/42/CE [CE, 2006] reports "*Where, in the case of self-propelled machinery with a ride-on driver, operator(s) or other person(s), there is a risk of rolling or tipping over, the machinery must be fitted with an appropriate protective structure, unless this increases the risk. This structure must be such that in the event of rolling or tipping over it affords the ride-on person(s) an adequate deflection-limiting volume. In order to verify that the structure complies with the requirement laid down in the second paragraph, the manufacturer or his authorised representative must, for each type of structure concerned, perform appropriate tests or have such tests performed.*", but the only a general reference like *"appropriate tests"* is reported.
In this paper two different standards, the ISO 3471 [ISO, 2008] used for earth-moving machines and the OECD CODE 4 [OECD, 2010] used for tractors were compared with the goal of evaluating the possibility of studying a standard for different self-moving machines.

2. Materials and Methods

2.1 Normative

The ISO 3471 standard and the OECD CODE 4 were compared with reference to the load sequence, the kind and amount of the loads, and the clearance zone.
Figure 1 reports the load sequence for the two standards. The OECD Code 4 foresees four different loads: one longitudinal, one vertical, one lateral and one vertical, while the ISO 3471 foresees one lateral, one vertical and one longitudinal load.

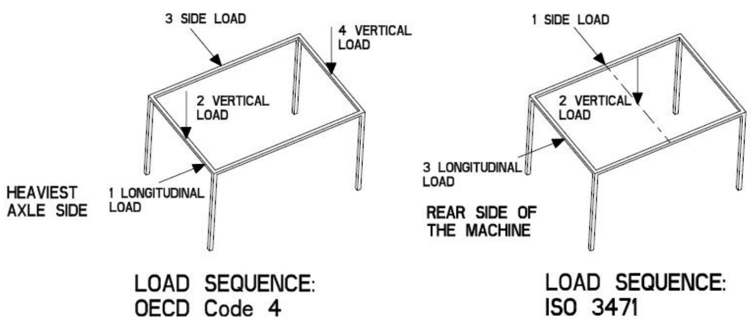


Fig. 1 – Load sequence for the OECD Code 4 and ISO 3471.

The OECD Code 4 standard foresees two vertical loads, one in the front and one in the rear part of the ROPS with respect to the ISO 3471 that foresees only one load in the centre. In the OCDE Code 4 the longitudinal load is lateral while in the ISO 3471 it is central with the consequence of a torsion of the structure in the first one that influences the following loads. The type (with energy target E [J] and with force target F [N]) and the entity of the loads are reported in Table 1.

CODE/STANDARD	OCSE CODE 4	ISO 3471
LONGITUDINAL LOAD		
700<M<4630Kg 4630<M<59500Kg M>59500Kg	E=1.4*M[J]	F=4.8*M[N] F=56000*(M/10000)^1.2[N] F=8*M[N]
VERTICAL LOAD		
700<M<4630Kg 4630<M<59500Kg M>59500Kg	F=20*M[N]	F=19.61*M[N]
SIDE LOAD		
700<M<4630Kg 4630<M<59500Kg M>59500Kg	E=1.75*M[J]	F=6*M [N] E=13000*(M/10000)^1.25[J] F=70000*(M/10000)^1.2 [N] E=13000*(M/10000)^1.25[J] F=10*M [N] E=2.03*M [J]

Table 1 – Type and entity of the loads.

The OECD Code 4 foresees for the longitudinal and lateral load a target on the energy absorbed by the ROPS. In the ISO 3471 the loads are represented by force with the exception of the lateral one that performs an energy target and a force target. Also the comparison between the values of the energy or the force shows a difference between the two standards with higher values for the OECD Code 4 in particular with a mass of the machine lower than 25000 kg.
The safety zones of the two standards are reported in Figure 2. In the ISO 3471 the safety zone was designed taking into account the position of the driver, in the OECD standard the zone refers to the position of the pelvis and the head of the driver.

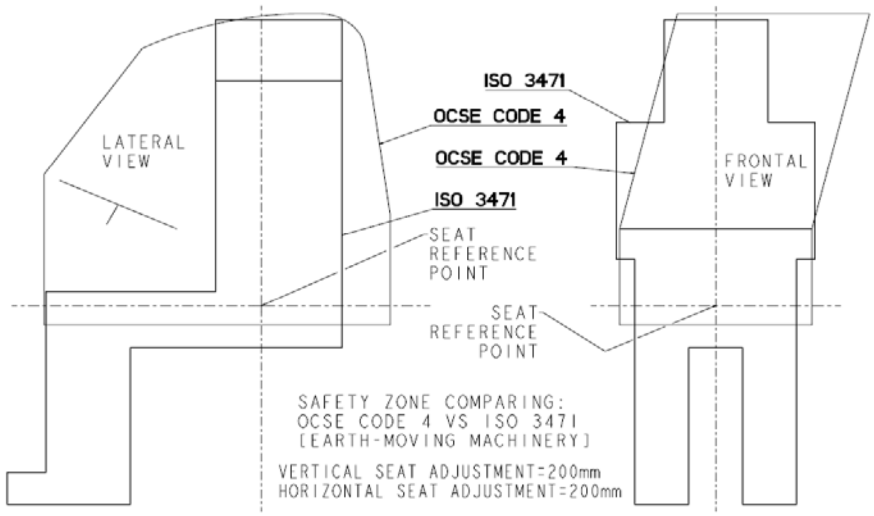


Figure 2 – Safety zone in the two standards.

The two zones are different, in particular the OECD code 4 does not consider the part related to the lower legs, moreover in the lateral view the safety zone defined by the OECD code 4 included the safety zone of the ISO and the zone related to the position of the driving wheel. In the front view the width of the two zones is equivalent but in the OECD Code 4 an inclination in the higher part is considered.
The consideration reported above for the following test takes into account only the OECD Code 4 because the safety level is higher.

2.2 Choice of the machines

For the analysis of different ROPS, four grape harvesters, four combine harvesters, two vegetable harvesters, one olive harvester and one for fruits were chosen. The information regarding the machines are reported in Table 2, in particular the dimensions of the ROPS were analysed.

Machine :	**Mass. [kg]:**	**ROPS type: n° posts**	**Original material of ROPS:**	**Sections dimensions: -Upper elements LxH, S[mm] -Posts LxH, S [mm]**
A: Grape harvester	9700	4	Fe510	Upper el.: 40x40 S=5; 20x40 S=5 Posts: 90x40 S=5; 35x30 S=5
B: Grape harvester	9300	4	Fe510	Upper el.: 40x40 S=5; 20x40 S=5 Posts: 85x40 S=5; 35x30 S=5
C: Grape harvester	9200	4	Fe420C	Upper el.: 50x40 S=5 Posts: 80x50 S=5
D: Grape harvester	3000	4	C40	Circular section diameter 20mm
E: Combine harvester	9800	4	Fe360C	Upper el.: 30x30 S=6 Posts: 60x45 S=6
F: Combine harvester	10200	4	Fe360C	Upper el.: 30x30 S=6 Posts: 60x45 S=6
G: Combine harvester	9600	4	Fe510	Upper el.: 50x40 S=5 Posts: 70x50 S=5
H: Combine harvester	9000	4	Fe420C	Upper el.: 35x45 S=5 Posts: 55x75 S=5
I: Tomatoes harvester	9300	2	Fe42	Upper el.: 35x35 S=5 Posts: 50x50 S=5
J: Fruits harvester	3400	No	-	-
K: Olives harvester	3000	4	C40	Upper el.: 25x35 full sec. Posts: 40x40 full sec.
L: Vegetables harvester	5700	4	Fe42	Upper el.: 30x45 S=5 Posts: 50x50 S=5

Table 2 – Data of the machines analysed.

2.3 FEM Test on the structures

First of all the structures installed on the machines were analysed with the goal of verifying the cabs' safety level and, consequently, the cab that allows to exceed the standard was designed and verified.
The analysis of the cabs was obtained with a dedicated software [Fabbri, 2001] for the analysis with finite elements in a not linear and elasto-plastic field.
The software permits an analysis of the structures submitted to loads fixed by the OECD codes. The structures need to be divided in a finite number of elements connected by junctions. Beam elements were used. In Figure 3 one lay-out of the ROPS is reported.

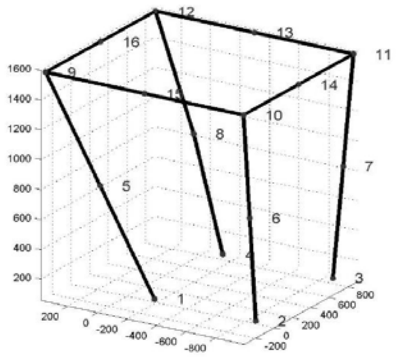


Fig. 3 - Lay-out of a ROPS of a grape harvester and input of the software .
The different loads fixed by the OECD Code 4 are reported in Table 3.

Machine	Longitudinal load [J]	1st crush test [N]	Side load [J]	2nd crush test [F]
A	13580	194000	16975	194000
B	13020	186000	16275	186000
C	12880	184000	16100	184000
D	4200	60000	5250	60000
E	13720	196000	17150	196000
F	14280	204000	17850	204000
G	13440	192000	16800	192000
H	12600	180000	15750	180000
I	13020	186000	16275	186000
J	4670	68000	5950	68000
K	4200	60000	5250	60000
L	7980	114000	9975	114000

Tab. 3 – Loads for the different structures.

3. Results

The results of the tests on the original design of the structures and the dimensions of the ROPS that are necessary to skip the test are reported in Table 4.

Machine	Test result on original design	Necessity of new design	New ROPS type: n° posts	Material	New ROPS section dimension: -Upper elements LxH, S [mm] -Posts LxH, S [mm]
A	Negative	Yes	4	same material	Upper el.: 40x40 full section Posts: 70x70 full section
B	Negative	Yes	4	same material	Upper el.: 40x40 full section Posts: 85x40 full section; 35x30 full section
C	Negative	Yes	4	Fe510	Upper el.: 80x80 full section Posts: 90x90 full section
D	Negative	Yes	4	same material	Upper el.: 40x35 full secton Posts: 40x35 full section
E	Negative	Yes	4	Fe510	Upper el.: 45x45 full section Posts: 70x70 full section
F	Negative	Yes	4	Fe510	Upper el.: 50x50 full section Posts: 75x75 full section
G	Negative	Yes	4	same material	Upper el.: 45x45 full section Posts: 70x70 full section
H	Negative	Yes	4	Fe510	Upper el.: 35x40 full section Posts: 60x70 full section
I	Negative	Yes	4	same material	Upper el.: 95x90 full section Posts: 80x80 full section
J	-	Yes	4	same material	Upper el.: 30x30 full section Posts: 45x35 full section
K	Positive	No	-	-	-
L	Negative	Yes	4	same material	Upper el.: 30x40 full section Posts: 60x60 full section

Tab. 4 – Results.

The results show that only the machine for harvesting olives has a structure that is able to skip the OECD Code 4. In the machine for harvesting fruits there are no structures, and in all the other machines the structure is not able to sustain the load imposed by the standards.
Where it was possible, the original design was maintained and only a modification of the dimensions of the components was modified. In the other cases the structures were modified.

4. Conclusion

In this paper the problem of defining a safety level for drivers of agricultural machineries in case of rolling over was analysed.
The different standards used in other machines like earth-moving machines and tractors were compared. In particular, the OECD Code 4 used for tractors was chosen for the widest safety zone and the higher loads applied to the structures. The code was also applied to different kinds of machines through a FEM software to evaluate the safety level of the structures installed at the moment on the machines and a structure able to overtake the standards was designed.
Only one structure is able to overtake the standards but in the other cases a deep revision of the structure is not necessary, an increasing of the section of the jambs is sufficient.
In conclusion it is possible to design a standard that guarantees conducers of self-moving machinery and adequate safety level. The results of this paper can be considered a first step. More tests are necessary above all to measure the rolling angle in these machines.

References

EN (1997). Standard 632. Macchine agricole, Mietitrebbiatrici e macchine per la raccolta del foraggio Sicurezza, Edition December 1997

EN (2010a) Standard 706. Macchine agricole, Potatrici per vigneto. Sicurezza Edition January 2010

EN (2010b). Standard 13118. Macchine agricole, Macchine per la raccolta delle patate. Sicurezza Edition January 2010

EN (2010c). Standard 13140. Macchine agricole, Macchine per la raccolta delle barbabietole da zucchero e da foraggio. Sicurezza, Edition March 2010

Eurostat (2010), Database health and safety at work

Fabbri A., Ward S. (2001). Validation of a Finite Element Program for the Design of Roll-over Protective Framed Structures (ROPS) for Agricultural Tractors, Biosystems Engineering n. 81 pag. 287-296.

INAIL (2008). Istituto Nazionale per l’Assicurazione Contro gli Infortuni sul Lavoro. Statistics

ISO (2008). Standard 3471 – Earth-Moving Machinery. Roll-Over Protective Structure. Laboratory Tests and Performance Requirements, Fourth Edition 2008-08-15.

Janicak C A (2000). Occupational fatalities to workers age 65 and older involving tractors in the crops production agriculture industry. Journal of Safety Research, 31(3), 143–148.

Myers J T; Snyder K A; Hard D L; Casini V J; Cianfrocco R; Fields J; Morton L (1998). Static and epidemiology of tractor fatalities - a historical perspective. Journal of Agricultural Safety and Health, 4(2), 95–108.

OECD (2010). OECD Standard Code for the Official Testing of Protective Structures, February 2010.

OECD (1959). Standard Codes for the Official Testing of Protective Structure Mounted on Agricultural Tractors. Organisation for Economic Co-operation and Development.

Springfeldt B; Thorson J; Lee B C (1998). Sweden’s thirty-year experience with tractor rollovers. Journal of Agricultural Safety and Health, 4(3), 173–180.

Task Analysis, Risk Assessment and Clinical Evaluation of Work Related Muscoloskeletal Disorders in Viticulture and Olive Culture Farming

Montomoli L.[1], Ardissone S.[2], Colombini D.[3], FantiM.[4], Ruschioni A.[5], Sartorelli P.[1]

[1]Section of Occupational Medicine, Dept of Clinical Medicine and Immunological Sciences, University of Siena, Italy+39 0577 586768 lorettamontomoli@katamail.com
[2]SPRESAL ASL 19 Asti, Italy
[3]Research Unit EPM, Ergonomic of Postures and Movements, Policlinic Foundation, Don Gnocchi Foundation, University of Milano, Italy
[4]Studio Fanti, Siena, Italy
[5]ASUR Ancona, Italy

Abstract

Introduction: in international literature the clinical data regarding results of specific epidemiologic studies on prevalence of musculoskeletal disorders in agriculture are not so numerous. This study carried out an evaluation of risk in some viticulture and olive culture farms in Italy. Methods: to obtain an exposure index in vine-growing the work organization was previously analysed and all working tasks were video recorded. Then the ergonomic analysis using OCRA check-lists and NIOSH method was performed. In Tuscany the workers were submitted to a clinical examination especially finalized to study the spine and upper limb work-related musculoskeletal disorders. Results: in vine-growing each tasks analysed showed an high risk of biomechanical overload of the upper extremities. Regarding the manual material handling in the grape-harvest, band of risk changed from yellow to green. Considering the total number of the exposed workers studied in risk assessment (no=125), only 42 of them were allowed to submit to a clinical examination by a specialist in rheumatology. The most relevant pathologies were the wrist and fingers tendinitis and the carpal tunnel syndrome. Discussion: the agricultural work certainly causes a marked risk of musculoskeletal disorders as confirmed by our study. Also considering the first results of this clinical examination it is possible to conclude that this specific working population, show a specific occupational musculoskeletal hand disease that we can perhaps call "the pruning hand".

Keywords: wine-growers, manual material handling, musculoskeletal disorders of the upper extremities, physical risk factors, farming, clinical evaluation

Introduction

Work-related musculoskeletal disorders of the upper limbs (WMSDs) and spinal disorders reported in the past by the pioneers of occupational medicine have, in the last 35 years, became extremely widespread, reaching epidemic levels, in all advanced industrialised countries [1]. Up to recent times in Italy, no particular attention was paid to these disorders even among occupational health specialists. However some occupational health professionals began to suspect that the situation was very much the same as that reported in other western countries [4].
Some biomechanical factors (frequency and repetitiveness of movements, use of force, type of posture and movements, distribution of recovery periods) are determining factors for

WMSD. There are also other risk factors (complementary factors) that by themselves do not cause these diseases but may be of importance.

In international literature the frequency of WMSDs and spinal disorders are not well investigated in farmers.

A cross sectional study conducted among 537 workers pruning grapevines in the region of Champagne emphasized a prevalence of nocturnal hand paresthesias and hand wrist pain (37 and 12% respectively). All workers completed a questionnaire about nocturnal hand paresthesias and musculoskeletal pain during a period of 12 months [2]. Risk factors associated with hand paresthesias were: female gender, being overweight, payment on a piecework basis and traditional blade sharpening method. The development of hand paresthesias, which affected a third of employees, was different from hand paresthesias observed in industrial workers since most vineyard workers recovered without medical treatment after the pruning season. In a another study [3] the same authors evaluated biomechanical strains on the hand-wrist system during grapevine pruning through surface electromyography activity of the right flexor digitorum muscle and wrist posture. In this way the authors emphasized high biomechanical strain with maximal voluntary handgrip contraction of 23,5 %. Numerous cuts required moderate or extreme ulnar deviation.

This paper reports an evaluation of risk on farms in Italy (Tuscany, Piedmont and Marches) adopting different growing systems, to point out the most dangerous activities for biomechanical overload. Limited to the Tuscany case the workers were submitted to a clinical examination especially finalized to study the spine and upper limb work-related musculoskeletal disorders. The results were inserted in a dedicated software.

Materials and Methods

Risk assessment

To obtain an exposure index in vine-growing the study was conducted in three phases: 1)analysis of work organization, 2)analysis of each working task and 3)ergonomic analysis using OCRA check-lists and NIOSH method [5].

1) To analyse the work organization farms were previously selected and relevant data (number of workers, working tasks and hours/months for each task) collected in a data base. After that the production methods and working tasks were analysed and a "list of tasks yearly distributed" was created. (see Table 1).

2) To identify working tasks characterized by repetitive movements the "yearly job description" was used. The following working tasks were identified: cut of mother vine, "tendifili: wire straining ", pruning (dry and green part), grape harvest.

3) All working tasks were videorecorded and ergonomic analysis using OCRA check-lists for repetitive movements of the upper extremities and NIOSH method for manual material handling were performed.

Table 1 Working tasks carried out in vine-growing during the year

Working tasks		February	March	April	May	June	July	August	September	October	November	December
Soil preparation (trenching)		■	■	■	■							
Preparation and maintenance of vineyard frame	■	■	■	■	■	■	■	■	■	■	■	■
Soil dressing	■	■	■	■	■					■		
Treatment with plant protection product				■	■	■	■	■				
Cut of mother vine	■											■
Vine plantation			■	■	■	■	■			■		■
Pruning (dry part)	■	■	■	■	■					■	■	■
Green pruning					■	■	■	■	■			
Grape harvest								■	■	■		

Clinical evaluation

The percentages of the pathologies were estimated on the total number of the exposed workers at the beginning of the clinical examination (No= 125) even if it was not possible to visit all the workers Only 42 of 125 exposed workers were allowed to submit to a clinical examination by a specialist in rheumatology.

The medical doctor did only clinical diagnosis (without instrumental clinical tests) deriving the information in Table 2: in the future the clinical diagnosis will be completed by means of more objective and specific instrumental tests

Results

Risk assessment

Table 3 shows that the greater part of the tasks analysed are included in red-violet band of OCRA check list, confirming that there is a high risk of biomechanical overload of the upper extremities for farmers.

Green pruning – pinching out (left hand) is included in the green band (acceptable risk) whit a value of 5 Check List OCRA. Green pruning – polling (right hand) and green pruning – stripping of leaves (left hand) are included in the yellow band (borderline risk) with a value of 9.5 and 11 respectively.

The greater part of the tasks analysed, vine plantation (left/right hand), "tirafili: wire straining" with tool (left/right hand), pruning (dry part) – Tuscany (left/right hand), pruning (dry part) – Piedmont (left hand), green pruning polling (left hand), green pruning – stripping of leaves (right hand), grape harvest – Tuscany, Piedmont, Marches (left/right hand) , are included in the red band (middle –light risk) whit a value of between 13.5 to 22. In these tasks the middle – light risk could produce a high incidence of pathologies.

Table 2 List of clinical terminology used to define the musculoskeletal disorders showed by "pruning workers"

	MALE		FEMALE	
List of main clinical musculoskeletal disorders	N.	%	N.	%
Myofascial opponens right pollicis syndrome	9	15,8%	18	20,7%
Myofascial brachioradialis syndrome	8	14,0%	14	16,1%
Carpal tunnel syndrome	2	3,5%	12	13,8%
Myofascial flexor carpi radialis syndrome- enthesitis	2	3,5%	11	12,6%
Myofascial extensor carpi radialis syndrome	6	10,5%	9	10,3%
Metacarpophalangeals synovitis (hypertrophy of Metacarpophalangeals synovitis)	7	12,3%	7	8,0%
Flexor 3 and /or 4 digitorum tenosynovitis	2	3,5%	6	6,9%
Proximal and/or distal interphalangeal arthrosis	3	5,3%	3	3,4%
Caput longum musculi bicipitis tenosynovitis	2	3,5%	0	0,0%
Acromiohumeral conflict syndrome	2	3,5%	2	2,3%
Vagina tendinum musculi flexori hypertrophy	1	1,8%	0	0,0%
Thenar eminence hypotrophy	2	3,5%	0	0,0%
Dupuytren syndrome	3	5,3%	0	0,0%
Trigger finger	1	1,8%	0	0,0%
Guyon's syndrome	0	0,0%	1	1,1%
Subacromial bursitis	1	1,8%	0	0,0%
Metacarpophalangeals arthrosis	1	1,8%	0	0,0%
Trapeziometacarpal arthrosis (rhizoarthrosis)	1	1,8%	1	1,1%
Epicondylitis	2	3,5%	0	0,0%
Abductor right pollicis Myofascial syndrome	2	3,5%	0	0,0%
De Quervain	0	0,0%	1	1,1%
M.of Duplay	0	0,0%	1	1,1%
Compression of nervus ulnaris in elbow	0	0,0%	1	1,1%
TOTAL	57		87	

Mother vine (left/right hand), manual "tirafili: wire strianing" (left/right hand), pruning (dry part) – Piedmont (right hand), pruning (dry part) – Marches (left/right hand), green pruning – pinching out (right hand) are included in the violet band (very high risk) whit a value of more than 25.5.

These results evidence the same risk, of biomechanical overload of the upper extremities, for female and male.

Regarding the manual material handling in the grape-harvest, the band of risk changed from yellow for farmers (male and female) who worked on farm tractor (I.S.C. respectively 0.82 and 0.99) to green for farmers on the land (I.S. 0.73).

Clinical evaluation

The total exposed population was composed by 125 workers: 82 male and 43 female: they operated in 4 farms in Tuscany. Only 42 of them were allowed to submit to a clinical examination by a specialist in rheumatology: 22 male and 20 female. The average age of the group is 49 (range 23 – 77) for male and 44 for female (range 27 – 59); the average working time in pruning 10 years (range 1 – 42) for male and e 5 years (range 0,5 – 15) for female.

In Table 4 the percentage of the affected workers are reported.

Table 3 Results of OCRA Check list for each of the working task analysed

Working tasks	Side	Recovery	Frequency	Force	Total of posture	Additional factors	Value of Check list
Mother vine	dx	4	9	7	9,5	2	31,5
Mother vine	sx	4	3	7	9,5	2	25,5
Vine plantation	dx	4	4,5	0	5	0	13,5
Vine plantation	sx	4	2	0	9	0	15
Manual “tirafili”	dx	4	8	11	10	2	35
Manual “tirafili”	sx	4	6	11	10	2	33
“Tirafili” with tool	dx	4	5	2	7	2	20
“Tirafili” with tool	sx	4	5	2	7	2	20
Pruning (dry part) - Tuscany	dx	4	7	2	7	2	22
Pruning (dry part) - Tuscany	sx	4	1	1	5,5	2	13,5
Pruning (dry part) - Piedmont	dx	4	7	2	13	2	28
Pruning (dry part) - Piedmont	sx	4	1	1	13	2	21
Pruning (dry part) - Marches	dx	4	7	3	17	2	33
Pruning (dry part) - Marches	sx	4	7	1	17	2	31
Green pruning - polling	dx	4	1	1	3,5	0	9,5
Green pruning - polling	sx	4	8	2	5,5	0	19,5
Green pruning – pinching out	dx	4	8	6	9	0	27
Green pruning – pinching out	sx	4	0	0	1	0	5
Green pruning – stripping of leaves	dx	4	5	2	3,5	0	14,5
Green pruning – stripping of leaves	sx	4	2	2	3	0	11
Grape harvest - Tuscany	dx	4	3	1	6	0	14
Grape harvest - Tuscany	sx	4	6	1	6	0	17
Grape harvest - Piedmont	dx	4	3	1	6	0	14
Grape harvest - Piedmont	sx	4	6	1	6	0	17
Grape harvest - Marches	dx	4	3	1	9	0	17
Grape harvest - Marches	sx	4	6	1	9	0	20

In Figures 1 the different distributions for joint of the UL-WMSDs and Figure2 the prevalence of UL-WMSDs for number of pathologies/person are reported for males and females

In the diagrams the presence of high percentages of right wrist tendinytis and Carpal tunnel syndroms is evident both in males and females.

Table 4. Percentage of workers affected by UL-WMSDs for gender

	% UL-WMSDs		
FARMS	MALE	FEMALE	TOTAL
A	25,0%	55,0%	33,8%
B	28,6%	44,4%	34,8%
C	25,0%	0,0%	18,2%
D	33,3%	45,5%	39,1%
TOTAL	**26,8%**	**46,5%**	**33,6%**

Figure 1. Distribution of the different UL-WMSDs for each joint and for gender

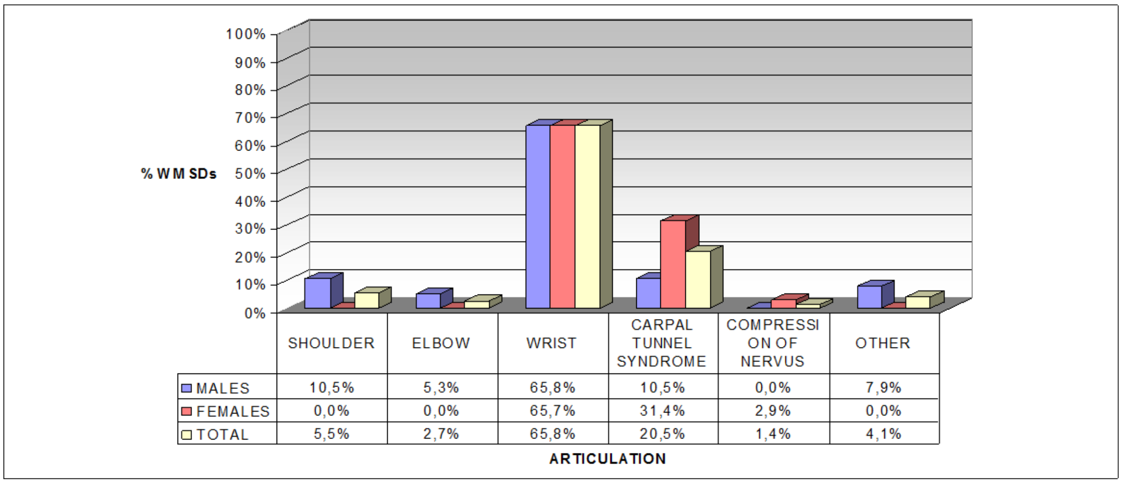
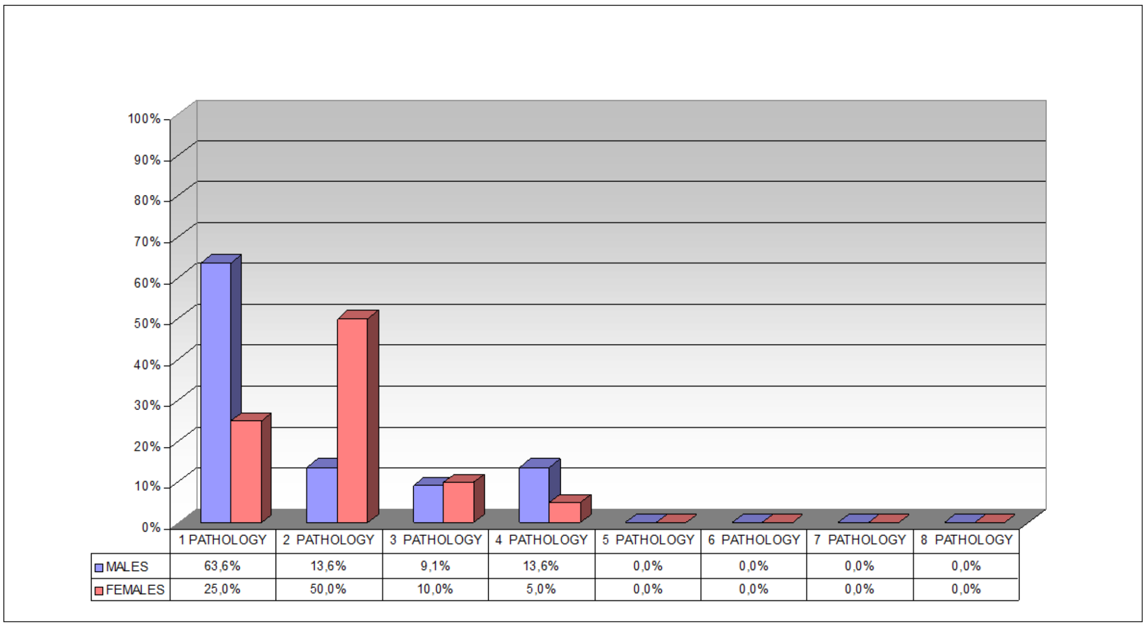


Figure 2. Prevalence of UL-WMSDs for number of pathologies/person for males and females



Discussion

In vine-growing there is a medium-high risk for repetitive movements of the upper extremities, indicating the need to begin actions to improve the work.

The same holds for the manual material handling in the grape-harvest, especially for farmers who work on farm tractor.

The results of vine growing is used to evaluate the risk of each worker based on the task and the hours worked.

The agricultural work is certainly implies a marked risk of musculoskeletal disorders as confirmed by our study. Clinical examination, even if preliminary, indicates that this specific working population, spending many months a year in pruning vine and olive, show a specific occupational musculoskeletal hand disease that we can perhaps call "the pruning hand" characterised by Myofascial opponens right pollicis, Myofascial brachioradialis syndrome, Carpal tunnel syndrome syndrome, Myofascial flexor and extensor carpi radialis syndrome.

Instrumental clinical tests will be carried in the future out to get a further confirmation of the preliminary clinical examination.

Acknowledgements

Help and collaboration of the Research Unit EPM (Ergonomic of Postures and Movements) is deeply acknowledged.

References

1. Hagberg, M., Silvestrin, B., Wells, R., Smith, M.S., Hendrich, H.W., Carayon, P., Perusse, M., (1995) Work-related musculoskeletal disorders: a reference book for prevention. In: *Taylor and Francis (Ed.), London*.

2. Roquelaure, Y., Gabignon, J.C., Delaliux, P., Ferrari, C., Mea, M., Fanello, S., Penneau-Fontbonne, D., (2001) Transient hand paresthesias in Champagne vineyard workers. *Am J Ind Med* 40(6): 639-645.

3. Roquelaure, Y., Dano, C., Dusolier, G., Fanello, S., Penneau-Fontbonne, D., (2002) Biomechanical strains on the hand-wrist system durino grapevine pruning. *Int Arch Occup Enviorn Heallth* 75: 591-595.

4. Colombini, D., Grieco, A., Occipinti, E., (1996) Occupational muscolo-skeletal disorders of the upper limbs due to mechanical overload: methods, researches, experiences, criteria for prevention. Med Lav Vol 87 n.6.

5. Colombini, D., Occhipinti, E., Fanti, M., (2005) Il metodo OCRA per l'analisi e la prevenzione del rischio da movimenti ripetuti. In: *Franco Angeli (Ed), Milano*.

First Results of a Comparative Study on Biomechanical Overload with Different Tools for Pruning Through Vocational EMG Analysis

Pigini L., Colombini D., Rabuffetti M., Ferrarin M., Occhipinti E.
EPM Research Unit, Biomedical technology department of Don C. Gnocchi Foundation.

Abstract
Starting from these first studies on hazard and damage produced by biomechanical overload of wine-growers' and olive-growers' upper limbs, musculoskeletal disorders of these areas are assumed to be also correlated with the use of inappropriate pruning equipment. The paper is aimed at facing a preliminary feasibility analysis of future studies on working tools used in agriculture in order to search those better meeting ergonomic criteria in view of obtaining "ergonomic quality brands". Second goal is using an exportable instrumentation for surface electromyographic analysis on the field during design of new models to check their accuracy ever since the beginning.

Keywords: surface elecrtromyography, force; muscular fatigue, work related muscle skeletal disorders, biomechanical overload, ergonomic redesign

Introduction and goals

The present research is aimed at identifying the parameters indicating the muscular activation levels by analysing the surface electromyographic signal recordable during a dynamic manual work. Such parameters would be able to provide more objective information essential for ergonomic design of tools and workplaces as well as for risk assessment of upper limb musculoskeletal disorders (UL-WMSDs) associated with a specific activity.

A typical problem of agricultural work is the prolonged and rapid used of scissors for pruning. This prolonged use may be the origin of a variety of musculoskeletal disorders affecting hand, wrist, elbow and shoulder. Some kinds of pruning tools were selected to assess necessary muscular activation levels.

Methods

After carefully going through the literature on acquisition and processing surface electromyographic data from an ergonomic standpoint, a new apparatus and new procedures were implemented for synchronized EMG and video acquisition, ensuring a good inter and intra subjective repeatability degree and a processing software for technical use "on the field" to calculate signal frequency and width parameters, regarding fatigue and muscular force respectively was implemented.
The developed methodology was first tested in laboratory on a group of healthy subjects, studying a "pick and place" repetitive task.
The methodology was then tested in a working environment to evaluate applicability in analysing the working gesture also under non-controlled conditions like those of a laboratory, in particular to compare the muscular effort required during the use of different types of tools for pruning.

Applicative protocol at workplace

Seven types of tools (two manual, four pneumatic and one electric scissors) were used during branch cutting olive trees of 0.4 to 1.5 cm size, by two skilled subjects: one 42 year woman and one 50 year man with 156 height and 54 weight the former and 172 cm height and 95 kg weight the latter, respectively). Selection was based on subjects with no neuro-muscularskeletal diseases.
The goal was assessing EMG data acquisition and processing method effectiveness in differentiating muscular activation levels recordable using the different tools to be able to draw conclusions on the best ergonomic tool in terms of upper limb biomechanical overload reduction during pruning stages.

Data acquisition

Each subject was submitted to test preparation experimental stage (subject preparation, execution of maximum voluntary contractions of each muscle involved in the analysis).
Then, each subject made a cutting test of 30 s duration with each pruning tool cutting branches with three different diameter sizes here below indicated as "small" (between 0.4-0.,6 cm), "medium", (between 0.6 and 0.8cm), and "large"(between 0.8 and 1.5 cm). Details of tests and tools are reported in Table 1.
Between one cutting test and another, the subject was allowed a two- minute break.

TOOL	CODE AND CHARACTERISTICS
	**E7:** Battery driven electric tool. Batteries are placed in a container (weight approx 2.5 kg) put in a sling (braces plus belt) worn by operator. During pruning stages, the battery is placed at the lumbar zone. Asymmetric beak bladed non progressive scissors (sharp blade and support counter blade). Use of this equipment was judged very light and easy with reduced fatigue at shift end. It was a bit awkward only during olive pruning on ladder.
	**M8:**Manual pruning scissors with ergonomic handles: one of the two arm has a rotating shaped handle to allow better compliance to operating requirements and hand configuration. Subjectively, this typical rotation is appreciated by some workers, while others prefer the same shaped model but fixed. Cutting blades are long and asymmetric beak shaped (sharp blade and support counter blade). They are used for cutting branches with diameter less than =.6-0.8 (small and medium size)
	**M10:**Manual pruning scissors with unshaped traditional handles and short and symmetric cutting blades (double cutting blades).
	**P1:**Pneumatic scissors with double cutting symmetric and very short blades. Pneumatic scissors are all equipped with connection cable of compressed air to a compressor
	**P4:**Asymmetric beak non progressive pneumatic scissors (sharp blade and support counter blade) Pneumatic scissors are equipped with connection cable of compressed air to compressor.
	**P5:**Progressive pneumatic scissors versus pressure degree on button with asymmetric beak blades (sharp blade and support counter blade).Pneumatic scissors are equipped with connection cable of compressed air to compressor.
	**P6:**Progressive pneumatic scissors versus pressure degree on button with asymmetric beak blades (sharp blade and support counter blade). Pneumatic scissors are equipped with connection cable of compressed air to compressor.

Table 1. The tools for pruning used for electromyographic analyses

All the collected electromyographic data were pre-processed via MRXP 1.07 Master editing software (Noraxon, USA) for synchronized view of EMG signal and video and selection of parts regarding the movement to be analyzed and then processed with a dedicated software in Matlab 6.1 environment (TheMatworks, USA) to

assess amplitude parameters (RMS-Root mean Square- 100ms; APDF- Amplitude Probability Distribution Function and Percentiles (10^{th}, 50^{th} , 90^{th}).
All the calculated values saved in a text file were then processed with Excel to extrapolate the diagrams concerning activation levels and spectral parameters.

Results

Rough data

To start presentation of obtained results, in this case as well the following figures will show the rough data obtained in pruning tests of one of the two subjects in the three cases of pruning with manual scissors, pruning with pneumatic scissors and finally pruning with electric scissors (Figures 1-2-3)

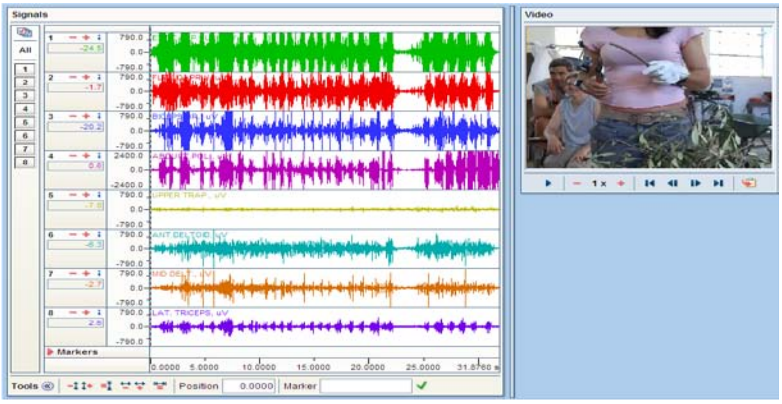


Figure.1 Rough data obtained in pruning test by one of the two subjects using manual scissors

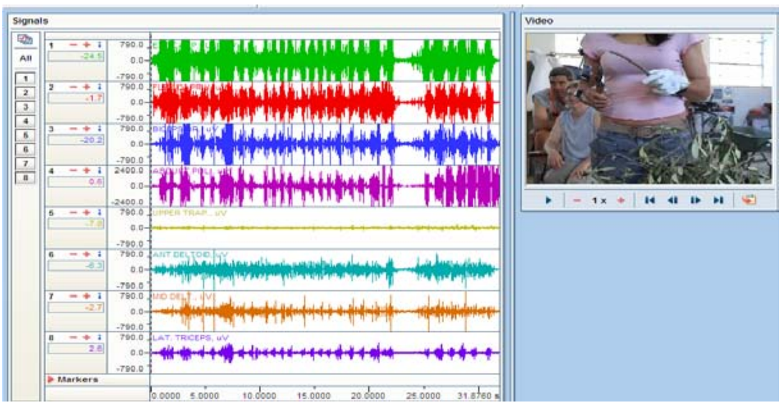


Fig. 2 Rough data obtained in pruning test by one of the subjects using pneumatic scissors

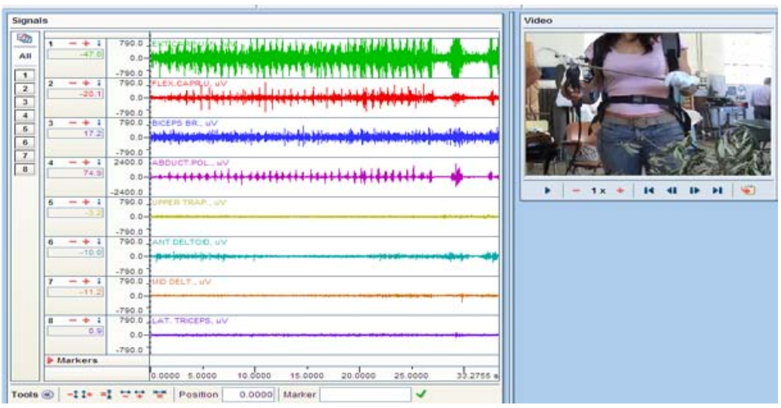


Fig. 3 Rough data obtained in pruning test by one of the subjects using electric scissors

Results of width analysis

In this case electromyography is aimed at identifying the variety of pruning tools to assess which one induces a lower muscular activation level and hence a fatigue lower level over the long period and a lower overload level for affected upper limb joints. The tables and diagrams here below report the percentile values (10°-50°-90°) obtained over the 30 second cutting per subject (TeMo: woman code and GiFo: man code). More specifically the diagrams report:

The comparison of the 3 types of scissors (manual, electric and pneumatic) through the values obtained with the two manual scissors and those obtained with the 4 pneumatic scissors by averaging cutting values of small and medium branches.

The values calculated separately for each type of instrument by averaging cutting values of small and medium branches

The values calculated separately for each type of pneumatic and electric tool over cutting values of large branches.

The activation values (%MVC) corresponding to 10th percentile of APDF (Figures 4-5) obtained by calculating the average values of pneumatic and manual scissors and those obtained with electric scissors by averaging cutting values of small and medium branches remain for male and female below MVC 5%. It is the suggested static load level but for woman's carpus extensor muscles for whom the values are 6.5% MVC for pneumatic scissors, 7 % MVC for manual scissors and 8% MVC for electric scissors.

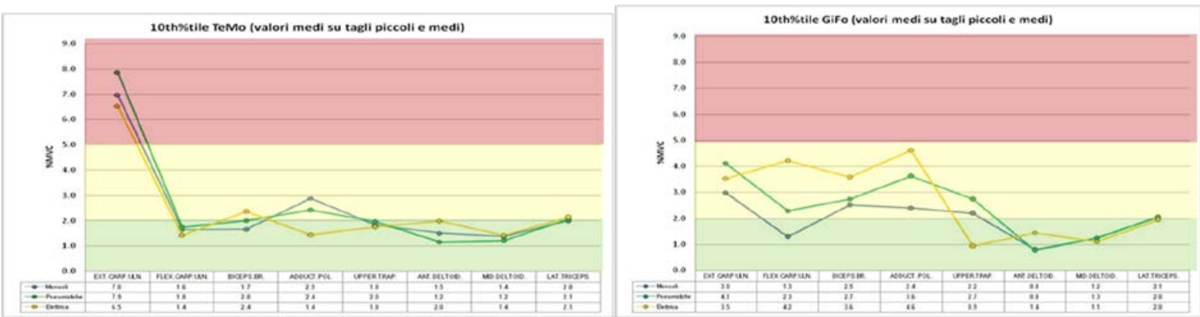
The activation values (%MVC) corresponding to 50th percentile of APDF (Figure 6-7) obtained by calculating the average values of pneumatic and manual scissors and those obtained with electric scissors by averaging the cutting values of small and medium branch remain for female and male below 14% MVC,. It is the suggested static load level limit but for female carpus extensor muscles for whom the values are 15.7%MVC for pneumatic scissors, 18% MVC for manual scissors and 14%MVC for electric scissors and for male inch abductor for whom the values are 18.1%MVC, 11.2%MVC and 16.3%MVC (values in the yellow band for pneumatic scissors and red band for manual and electric scissors). Notice the female's inch abductor who proves to work much more using manual scissors (12.9%MVC, nearly borderline with yellow band) than with the other two types of scissors (5.9%MVC for pneumatic average and 3.3 for electric). This result for male does not seem to be in agreement with female's trend for whom the highest values are still obtained for average of manual scissors (18.1%MVC) followed however by electric scissors (16.3%MVC) and finally by pneumatic average (11.2%MVC).

Activation values (%MVC) corresponding to APDF 90th percentile (Figures 8, 9) obtained by calculating the average values of pneumatic and manual scissors as well as thos obtained with electric scissors by averaging cutting values of small and medium branches remain both for male and female below MVC 70% , which is the suggested static load level limit.

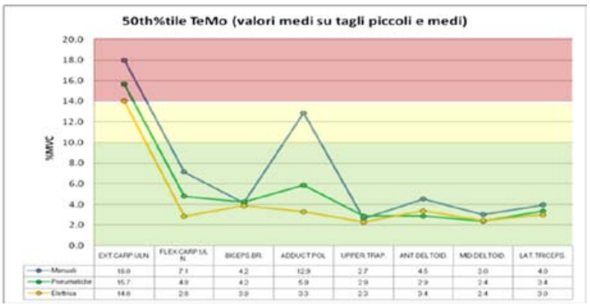
It is worh emphasizing the presence of muscular activation levels exceeding MVC 50 %: updated standars (EN 1005-5 and ISO 11228.3) actually show the presence of risk when there are inner force values equal or higher than MVC 50% for at least 10% of time.

In particular, we found for female 54.4%MVC values in carpus extensor muscles during cutting with manual scissors and values are MVC 54.4% and in male inch abductor during cutting with manual scissors for whom the values are MVC 68.4%. Both for man and female higher peak values are obtained using manual scissors for muscles more involved in movement: carpus extensor, carpus flexor, inch abductor. Lower values on the contrary might be ascribed to electric scissors in some case or to pneumatic average.

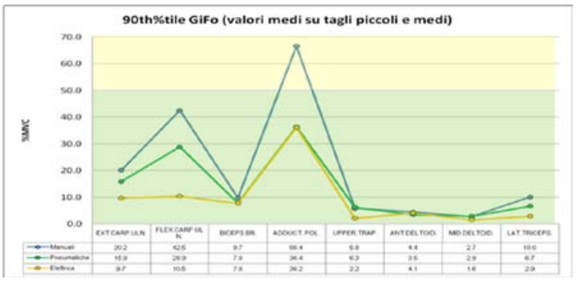
Hence, further processing is needed to distinguish the different types of pneumatic scissors.



Figures 4-5. Diagrams of MVC % 10th percentile of the two subjects (TeMo: female code and GiFo: male code) obtained by calculating the average values of pneumatic and manual scissors as compared with electric scissors by averaging small and medium cutting values. The diagram highlights the values recommended by Jonson B., 1978 through coloured bands on the background: green = area below limit (<2%MVC), yellow= border area (2-5%MVC), red= area above limit(>5%MVC).

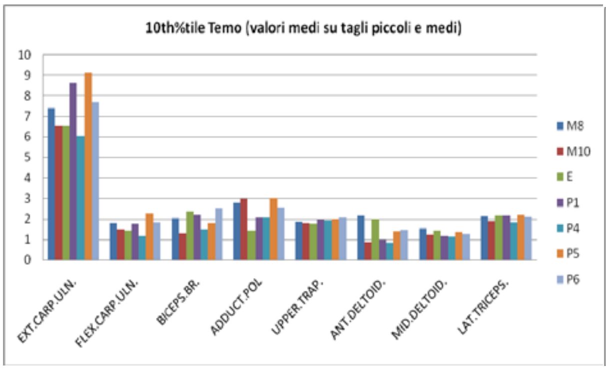


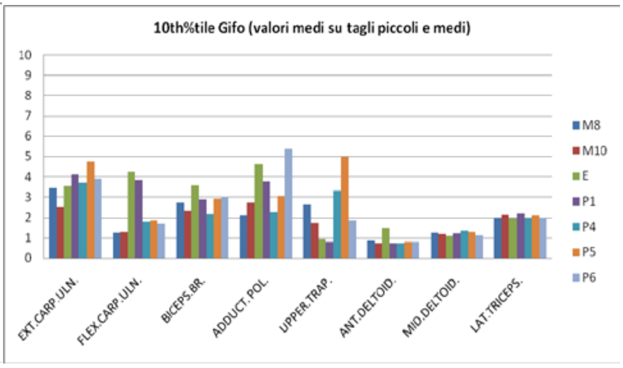
Figures 6-7. Diagrams of MVC% 50th percentile of the two subjects (TeMo: female code and GiFo: male code) obtained by calculating the average values of pneumatic and manual scissors as compared with electric scissors by averaging small and medium cutting values. The diagram highlights the values recommended by Jonson B., 1978 through coloured bands on the background: green = area below limit (<10MVC%), yellow= border area (10-14 MVC %), red= area above limit(>14MVC%).



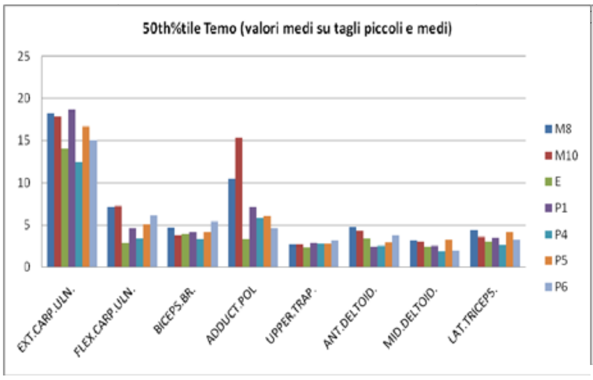
Figures 8-9. Diagrams of MVC% 90th percentile of the two subjects (TeMo: female code and GiFo: male code) obtained by calculating the average values of pneumatic and manual scissors as compared with electric scissors by averaging small and medium cutting values. The diagram highlights the values recommended by Jonson B., 1978 through coloured bands on the background: green = area below limit (<50MVC%), yellow= border area (50-70 MVC %), red= area above limit(>70 MVC%).

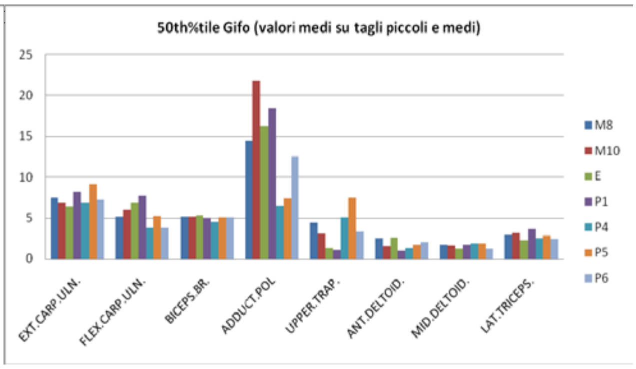
Therefore the diagrams (Figures 10 to 21) report the subsequent values of 10°- 50°- 90° percentile obtained by calculating separately the values of pneumatic, manual and electric scissors and separately also for male and female evidencing when such values fall into green, yellow or red load level bands. They show first of all a different activation level of some muscles: if for the female the most affected muscular group proves to be the forearm extensor, for the male it is the inch abductor.



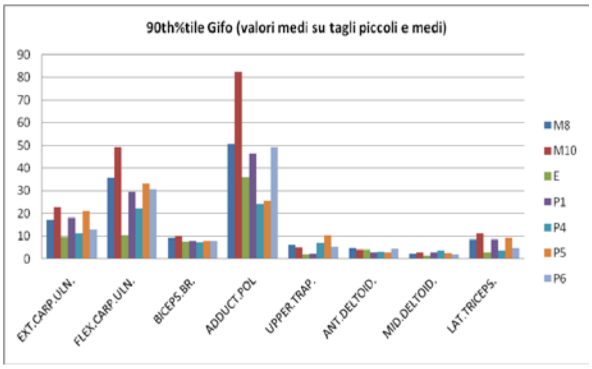


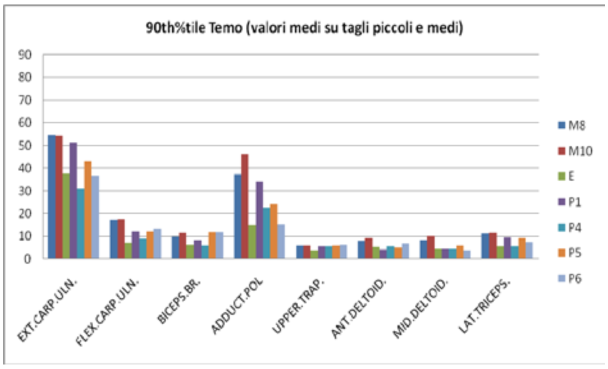
Figures 10 e 11. Diagrams of the MVC % 10th percentile of the two subjects (TeMo: female code and GiFo: male code) obtained by calculating the values separately for each type of tools used by averaging small and medium cutting values. In ordinate the coloured arrows evidence the values recommeded by Jonson B., 1978 through coloured bands in the background: green = area below limit(<2%MVC), yellow= border line (2-5MVC%), red= area above limit(>5MVC%).



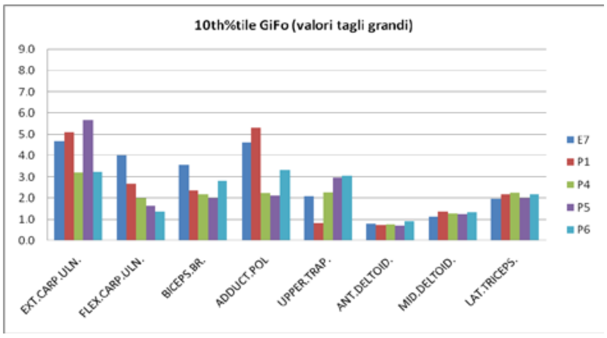


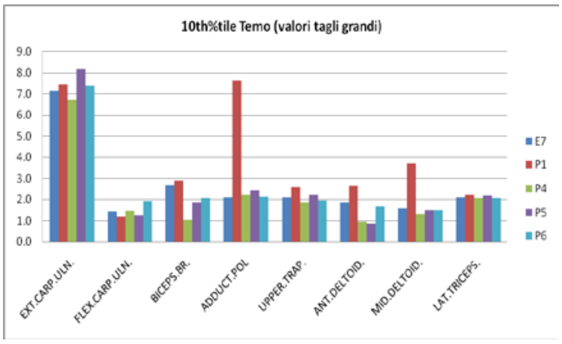
Figures 12 e 13. Diagrams of the MVC % 50th percentile of the two subjects (TeMo: female code and GiFo: male code) obtained by calculating the values separately for each type of tools used by averaging small and medium cutting values. In ordinate the coloured arrows evidence the values recommeded by Jonson B., 1978 through coloured bands in the background: green = area below limit(<10 MVC%), yellow= border line (10-14 MVC%), red= area above limit(>14MVC%).



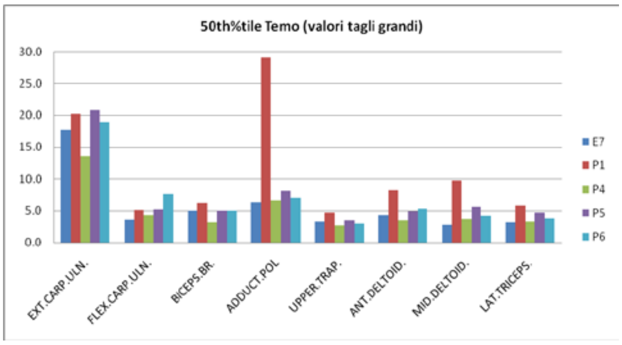


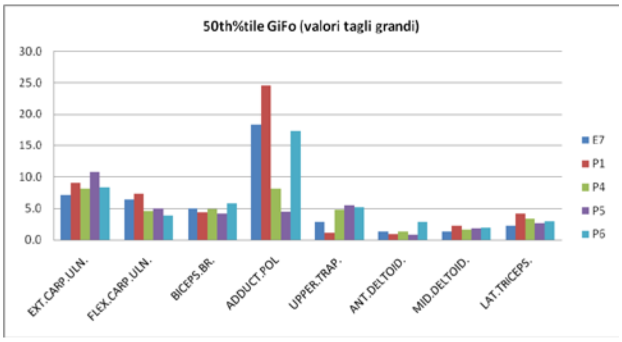
Figures 14 and 15. Diagrams of the MVC % 90th percentile of the two subjects (TeMo: female code and GiFo: male code) obtained by calculating the values separately for each type of tools used by averaging small and medium cutting values. In ordinate the coloured arrows evidence the values recommeded by Jonson B., 1978 through coloured bands in the background: green = area below limit(<50 MVC%), yellow= border line (50-70 MVC%), red= area above limit(>70 MVC%).



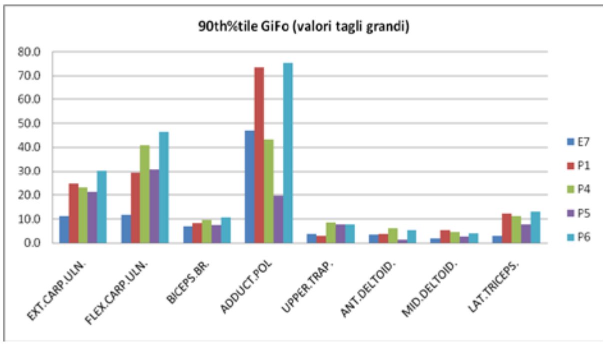


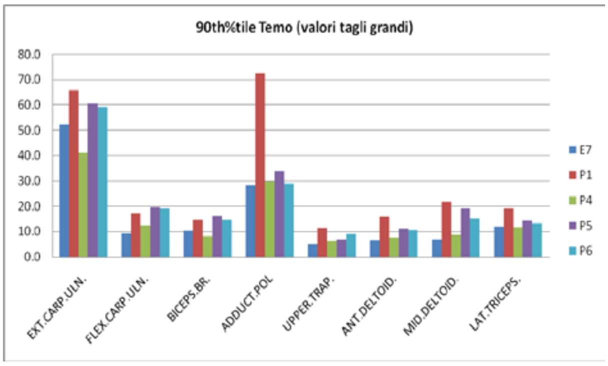
Figures 16 e 17. Diagrams of the MVC % 10th percentile of the two subjects (TeMo: female code and GiFo: male code) obtained by calculating the values separately for each type of pneumatic or electic tool used for large cutting values. In ordinate the coloured arrows evidence the values recommeded by Jonson B., 1978 through coloured bands in the background: green = area below limit(<2 MVC%), yellow= border line (2-5 MVC%), red= area above limit(>5 MVC%).





Figures 18 e 19. Diagrams of the MVC % 50th percentile of the two subjects (TeMo: female code and GiFo: male code) obtained by calculating the values separately for each type of pneumatic or electic tool used for large cutting values. In ordinate the coloured arrows evidence the values recommeded by Jonson B., 1978 through coloured bands in the background: green = area below limit(<10 MVC%), yellow= border line (10-14 MVC%), red= area above limit(>14 MVC%).





Figures 20 e 21. Diagrams of the MVC % 90th percentile of the two subjects (TeMo: female code and GiFo: male code) obtained by calculating the values separately for each type of pneumatic or electic tool used for large cutting values. In ordinate the coloured arrows evidence the values recommeded by Jonson B., 1978 through coloured bands in the background: green = area below limit(<50 MVC%), yellow= border line (50-70 MVC%), red= area above limit(>70 MVC%).

On the basis of the mere observation of the above diagrams, trends common to the two subjects are anyhow highlighted, in particular as regards manual scissors, observing over threshold values, M8, a manual tool equipped with ergonomic shaping with rotating arm and long asymmetric beak cutting blades leads to average inch abductor activation levels on the subjects of approx 30-33% less than M10, which is a manual tool as well but differing for unshaped traditional handles and short symmetric cutting blades (double cutting blades).

As regards pneumatic scissors, P4 model (asymmetric beak bladed non progressive scissors) is the only one not showing on average any critical activation level on the two subject and on mall –medium cuttings. P1 (very short symmetric cutting bladed pneumatic scissors), P5 (double cutting progressive scissors versus pressure degree on button with asymmetric beak blades) and P6 (progressive pneumatic scissors versus pressure degree on button with asymmetric beak blades show on the contrary over threshold activation levels as to carpus extensor 10° percentile.

As regards large cuttings, P4 again appears not to show special criticality whereas P1 and P5 appear to be the most critical for corpus extensor and P1 and P6 for inch abductor.

Asymmetric beak bladed non progressive electric scissors show values comparable with those of P4 and again fall into gree or yellow band for 10° and 50° and green for 90°.

Discussion of results

Company application results showed that the protocol tested in laboratory can be easily exported also to a working environment and video signal synchronized to electromyographic analysis can be a useful assessment tool also on one individual since the point is just to observe how activation levels change when changing the tool. Hence it is applicable in this case to discriminate muscular levels activation times induced by the use of different tools according to the different actions required and then able to help select the most comfortable tool with the minimum risk of disease for a single individual.

What instead could be derived from assessing average muscular activations in a subject population (heterogeneous as well as by homogeneous subgroups in anthropometric characteristics) could be objectification of a tool ergonomics as compared with another one following anthropometric characteristics.

Diagrams and tables may help the ergonomist understand which muscle is on average more stressed as to the use of different tools and hence make an objective choice protecting the individual or should the study include a significant population sample, it could lead to implementing projects to be applied on large scale. The case studied clearly shows that in pruning the crucial point is a major activity of inch abductor and carpus extensor muscles (these data are confirmed by the high incidence of tendon diseases affecting these body areas).

In short the following considerations arising from this preliminary study are:

Long asymmetric beak blades proved to be better than the short double cutting blades for manual and non manual tools

Non progressive non manual tools needing only pressing a key to have full cutting prove to be better in terms of lower activation level needed as compared with progressive tools. Note however that they may produce more injury.

Manual and non manual similar tools showed differences due to a better ergonomic design worth to be investigated by users before adoption.

As regards the significant difference observed between male and female regarding the different inch abductor and corpus extensor activation, its meaning is still to be clarified:

A preliminary assumption could be the different use of tools by the two subjects and hence the different use of musculature. The different motor strategy observed through a simple video could be quantified for example with a laboratory kinematic study of motor pattern jointly with EMG analysis or more simply by observing a significant population sample.

A second assumption could refer to MVC errors.

Therefore if the results in absolute terms of percentage load levels should be used with caution, the results regarding activation levels achieved using the different tools would in principle be valid. Actually the obtained results appear to be coherent for male and female.

These preliminary results show that by further improving research programmes on these subjects, two requirement could be met in the short term:

- *preparation of educational packages providing buyers with purchasing criteria of a good tool and users with correct instructions for use*
- *identification of project criteria for technological innovation of pruning tools in collaboration with manufacturers in view of getting an ergonomic trademark by skilled laboratories.*

Bibliography

1. ANTON D, COOK TM, ROSECRANCE JC, MERLINO LA: Method for quantitatively assessing physical risk factors during variable noncyclic work. Scand J Work Environ Healt 2003; *9*: 354-362

2. ARENDT-NIELSEN L, MILLS KR: The relationship between mean power frequency of the EMG spectrum and muscle fibre conduction velocity, Electroencephalogr. Clin Neurophysiol 1985; *60*: 130-134

3. ATTEBRANT M, WINKEL J, MATHIASSEN SE, KJELLBERG A: Shoulder-arm muscle load and performance TECNICHE DI ACQUISIZIONE ED ANALISI DEL SEGNALE ELETTROMIOGRAFICO DI SUPERFICIE 15 PIGINI E COLLABORATORI
during control operation in forestry machines. Appl Ergon
1997; *28*: 85-97

4. BARR AE, GOLDSHEYDER D, OZAKAYA N, NORDIN M: Testing apparatus and experimental procedure for position specific normalization of electromyographic measurements of distal upper extremity musculature.
Clin Biomech 2001; *16*: 576-585

5. BLANGSTED AK, SJOGAARD G, MADELEINE P, et al: Voluntary low-force contraction elicits prolonged lowfrequency fatigue and changes in surface electromyography and mechanomyography. J Electromyogr Kinesiol 2005; *15*: 138-148

6. BORG G: A category scale with ratio properties for intermodal and interindividual comparison. In Geissler HG, Petzold P (eds): *Psycophysical Judgement and the Process of Perception*. Berlin: VEB Deutscher Verlag der Wissenschaften, 1982: 25-34

7. BORG G: *Borg’s Perceived Exertion and Pain Scales*. HumanKinetic Europe, 1998

8. COLOMBINI D, OCCHIPINTI E, FANTI M: *Il metodo OCRA per l’Analisi e la prevenzione del rischio da movimenti ripetuti*. Milano: Franco Angeli editore, 2005

9. DE LUCA CJ: Myoelectrical manifestation of localized muscular fatigue in humans. Crit Rev Biomed Eng
1984; *11*: 251-279

10. EN 1005-5:2007 Safety of machinery - Human physical performance - Part 5: Risk assessment for repetitive handling at high frequency

11.HÄGG GM, LUTTMANN A, JÄGER MJ: Methodologies for evaluating electromyographic field data in ergonomics. J Electromyogr Kinesiol 2000; *10*: 301-312

12.HELMRICH K: *Productivity Processes. "Methods and experiences of measuring and improving"*. International MTM Directorate, www.mtmitalia.it

13.HUI L, NG GY, YEUNG SS, HUI-CHAN CW: Evaluation of physiological work demands and low back neuromuscular fatigue on nurses working in geriatric wards. App Ergon 2001: *32*: 479-483

14. ISO 11228-3:2007 Ergonomics - Manual handling - Part 3: Handling of low loads at high frequency

15. JOHNSON B: Kinesiology: With special reference to electromyographic kinesiology. Electroencephalogr Clin Neurophysiol Suppl 1978; *34*: 417-428

16. KENDALL FP, MCCREARY-KENDALL E, PROVANCE PG: Principi fondamentali. In Kendall FP, McCreary-Kendall E, Provance PG, eds. *I muscoli: funzioni e test*. IV Ed. Roma: Verducci editore, 1995: 1-8.

17. LARIVIÈRE C, DELISLE A, PLAMONDON A: The effect of sampling frequency on EMG measures of occupational mechanical exposure. J Electromyogr Kinesiol 2005; *15*: 200-209

18.MERLETTI R, FARINA D, RAINOLDI A: Myolectric manifestation of muscle fatigue. In Kumar S (ed): *Muscle Strenght*. CRC Press, 2004: 393-419

19.MERLETTI R, GULISASHVILI A, LO CONTE LR: Estimation of shape characteristics of surface muscle signal spectra from time domain data. IEEE Trans Biomed Eng 1995; *42*: 769-776

20.MERLETTI R, KNAFLITZ M, DE LUCA CJ: Myoelectric manifestations of fatigue in voluntary and electrically elicited contractions. J Appl Physiol 1990; *69*: 1810- 1820

21.MOORE JS, GARG A: The strain index: a proposed method to analyse jobs for risk of distal upper extremity disorders. Am Ind Hyg Assoc 1995; *56*: 443-458

22. OCCHIPINTI E, COLOMBINI D: Updating reference values and predictive models of the OCRA method in the risk assessment of work-related musculoskeletal disorders of the upper limbs. Ergonomics 2007; *50*: 1727- 1739

23. PIGINI L, RABUFFETTI M, MAZZOLENI P, FERRARIN M: Analisi sul lungo periodo dei pattern cinematici durante l'esecuzione di compiti lavorativi ripetitivi degli arti superiori. Atti del VIII congresso SIAMOC *Analisi del movimento in clinic.* Cuneo, 24-27 Ottobre 2007

24. RAINOLDI A, NAZZARO M, MERLETTI R, et al: Geometrical factors in surface EMG of the vastus medialis and lateralis muscles. J Electromyogr Kinesiol 2000; *10*: 327-336

25. SOBOTTA J, BECHER H: *Atlante di anatomia umana*. USES, 1969

26. ZSCHERNACK S, FRIESDORF W, GOEBEL M: Monitor position and muscular strain during minimal- invasive syurgery. Proceedings of the *16th IEA Congress of the International Ergonomics Association*. Maasrticht 14-14 Luglio 2006

Use of an Artificial Test Track to Declare Field WBV Tractors Data by Manufacturer

Preti C.[1], Deboli R.[1], Calvo A.[2]
[1] IMAMOTER CNR, Strada delle Cacce 73, - 10135 Turin, ITALY.
r.deboli@imamoter.cnr.it
[2] University of Turin. DEIAFA, Mechanics Section

abstract
As requested by directive 2002/44/ec the employer have to declare vibration level exposure of his employees. this is a problem never solved related to the field tractor wbv data declaration.
Also if for the italian law the employers may use manufacturers' wbv data, it must be clarified that these data are only obtained in laboratory, as requested by standards, to guarantee high repeatability and reproducibility values.
If manufacturers could use a standard wbv measurement criterion to simulate the field operations, it should be sufficient to measure vibration values with this method and then to write them in the machine instructions. in this way the employer can be reassured for the wbv data declaration, which is mandatory by law, but which is difficult to retrieve correctly because it depends on mass and geometry of the vehicle, speed of travel, pressure of the tires, type of ground, performed operational cycle.
In this article the first results of wbv values measured on a agricultural tractor travelling on the artificial test track (iso 5008) and on the grass are given.

Keywords: WBV, artificial test track

introduction

It is recognised that tractor operators are exposed at high levels of whole-body vibration (WBV) during field operations as well as during on road and offroad transportation (Bovenzi, 1994). Low-frequency vibrations consequences, produced by the agricultural vehicles, can be extremely severe and mainly depend on the soil type over that the agricultural vehicle is crossing and from its forward speed (Lines et al., 1995, Scarlett et al., 2007).

To analyze vibration transmitted at the seat of the tractor driver, many studies have been carried out both in controlled and standardized situations (Banfo G.L. et al., 1997, Deprez et al., 2005a, 2005b, Paddan and Griffin, 2002, Scarlett et al., 2007). Many of these studies have been done on the basis of the international standard ISO 2631 (1978). A specific standard has been set up for seat laboratory measurements (ISO 5007, 1980) and for measurements on normalised track (ISO 5008, 1979).

As requested by 2002/44/EC Directive, the employer must declare the employees vibration level. To evaluate the vibration risk, the employer may use information given by machine manufacturer, as reported in the machine use and maintenance booklet. In this case, however, he must consider that vibration values refer to test conducted in particular situation (laboratories) and usually these data are lower than others measurable during real machine utilisation. The vibration values as reported in the machine use and maintenance booklets are useful to satisfy the 42/2006/EC Directive requests ("Machine Directive") which establishes that manufacturers must furnish, among many other things, their machine vibration levels before commercialisation. For this reason, machines must be tested using technical standards to guide how and where test the machines. Unfortunately, a specific standard for agricultural tractors does not exist and only generic standards may be used, which do not solve the question of vibration data declaration for employers

Aim of this work is therefore to identify a test methodology which may support the agricultural tractor manufacturers to define their machine vibration level. As a consequence, the employers should receive an effective help to evaluate the vibration risks for themselves and for their operators.

materials and method

Tests have been conducted at the CNR IMAMOTER testing facilities, located at Pratofiorito (Candiolo, TO).

<u>Tested tractors</u>

Tested tractors (tab.1) were of A category (78/764/EC Directive), class I (unladen mass < 3600 kg), class II (3600 kg < unladen mass < 6500 kg), class III (unladen mass > 6500 kg).

Table 1: Main characteristics of tested tractors

Tractor	**Weight**			**Tires**			
	Front (kg)	*Rear (kg)*	*Total (kg)*	*Front*	*Pressure (atm)*	*Rear*	*Pressure (atm)*
I /A Unsuspended	1190	1550	2740	Trelleborg TM 700 270/70 R16	2	Trelleborg TM 700 420/70 R24	2
I /B Unsuspended	1230	2200	3430	Galaxy 10.00-16	2	Galaxy 18.4-34	1.6
II /C Unsuspended	1670	2410	4080	Pirelli 480/65 R24	1.2	Pirelli 600/65 R34	1.2
II /D Unsuspended	1945	2445	4390	Michelin Multibib 480/65 R24	1.6	Michelin Multibib 540/65 R38	1.6
III /E Suspended front axle & cab	2570	4045	6615	Continental 540/65 R 28	1.6	Continental 650/65 R 38	1.6

They were equipped as originally furnished by manufacturers: ballasts were not added and tires were the manufacturers ones. Concerning tires pressure, machine use and maintenance booklets were referred and lacking information were directly retrieved by tires manufacturers.

<u>Test environment</u>

To verify the proposed methodology applicability, for the moment tests were carried out on the grass and on a artificial track. Therefore, tests on a grass surface at 10 km/h speed, typical of many hay-making operations (especially cut) were conducted. Subsequently tractors passages on a smoother ISO track (ISO 5008) from 1 until 14 km/h speed were observed. Forward speed for each tractor was monitored by a Peiseler wheel. During all the tests, the same drive behaviour was maintained and the same operator (70 kg mass and 180 cm height) was involved.

For each tractor and for each forward speed, both on grass and on artificial track the acceleration values averages were calculated.

Standards

Tests have been carried out following the requests of International Standard ISO 5008 that defines the specification of instruments, measurement procedures, measurement site characteristics and frequency weighting that allow agricultural wheeled tractors and field machinery whole body vibration measurements to be made and reported with an acceptable precision. Vibration have been evaluated in accordance with currently standard (ISO 2631-1) which includes means of weighting the vibration levels at different frequencies to take account of the frequency sensitivity of the human operator to whole body vibration.

Tracks description

For the artificial track tests, vibration measurements have been carried out when the tractor was driven over a 100 m smoother track, that consists of two parallel strips suitably spaced for the wheel track of the tractor. The surface of each strip is formed of pieces of wood sited firmly in a base framework. The surface of each track strip has been defined by the ordinates of elevation, with respect to a level base, listed in tables of ISO 5008.

Instead, the grass track was a normalised one, present at the IMAMOTER experimental field site, with an homogeneous grass cover.

Instruments

For the acceleration data acquisition a three channel analyzer was used, to obtain at the same time the three axis (X, Y and Z) measurement. The used measurement system also let to execute the frequency analysis in the 0.5-80 Hz band (these range is interesting at hygienist level for the whole body vibration exposition, as reported inside the ISO 2631). A tri-axial accelerometer ICP® (Integrate Current Preamplifier) was put on the cab floor (platform), in the vibration transmission point to the seat. As the tractor seat was new of factory, in order to avoid any effect of the seat running in, the measurements of vibration were executed only on cab floor.

Instruments

For these tests, only the z-axis (cranium-caudal) analysis was performed, because this is the more solicited axis respect the others (x: back-ventral and y: lateral). Moreover to the z-axis the weighing Wk curve for the whole body, as requested by ISO 2631, was applied.

Therefore, all the acceleration values were analyzed by a 1/3 octave band spectrum analyzer.

Acquisition times were of some minutes for grass track tests, whereas for the smooth ISO track tests times were bind to the machine forward speed (from 59 seconds for the 6 km/h forward speed, until 25 seconds for the 14 km/h forward speed).

At least three repetitions for each velocity were executed.

results

A first analysis of the acquired data on the grass track reveals that, in many cases, the main frequencies interest the frequency lying between 2 and 6.3 Hz.

Therefore the equivalent acceleration averages of the passages over the grass track and over the artificial track, for each speed, have been compared. Independently from the tractor class, the artificial track speed which generates more similar values (both as equivalent acceleration value and spectral distribution) to the same obtained over the grass track is 4.5 km/h, as reported in the graphs of figures 1, 2, 3 and 4.

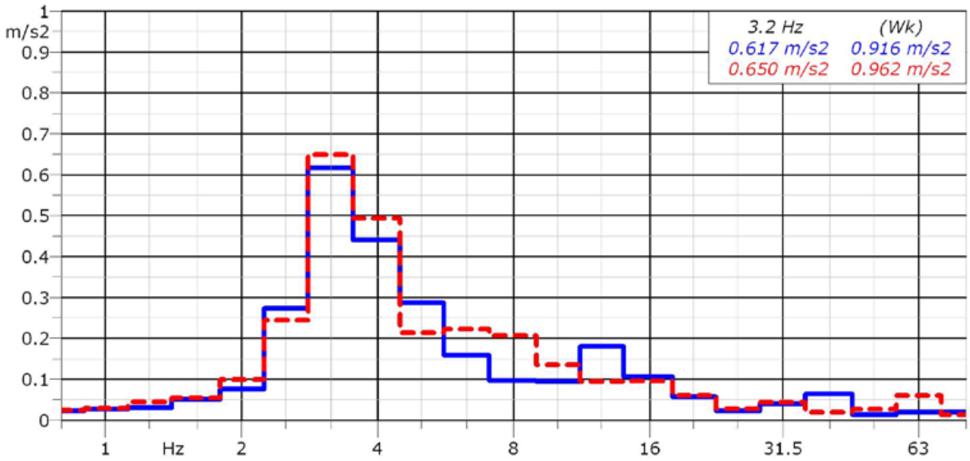


Figure 1. Acceleration value averages for frequency band of tractor A (class I, mass 2870 kg) on grass (10 km/h, blue line) and on smooth track (4,5 km/h, red dot line)

From the figure 1 graph it is evident that solicitation distributions over the tractor cab floor generated by grass path mainly occur in the frequency field from 2.5 to 5 Hz. Some resonances are observable at higher frequencies, but they are less representative than the global value.

An interesting result is obtained crossing the smooth track at 4.5 km/h: the energy distribution transmitted to the cab floor of the tractor is quite similar to the one obtained from the grass track passages at 10 km/h. As reported in the values of the graph in figure 1, acceleration values, frequency weighted (Wk), over the vertical direction z, are quite the same and differ only of a 5% (0.916 and 0.962 m/s2).

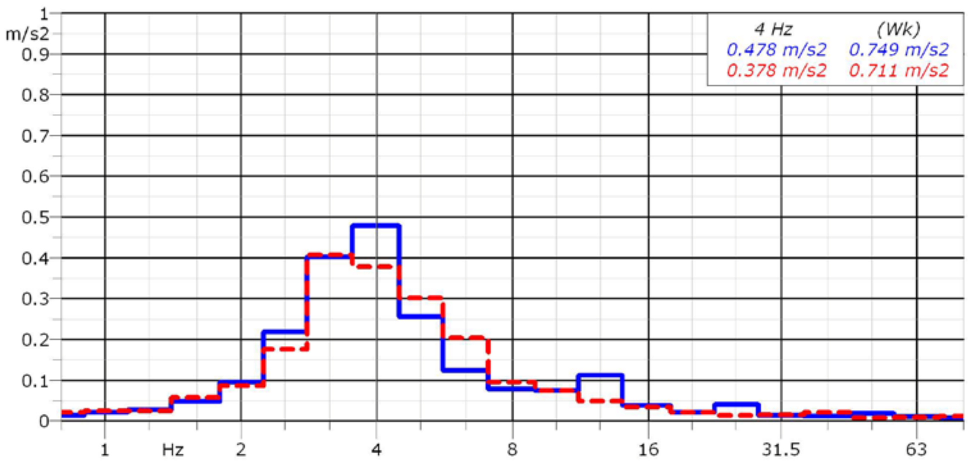


Figure 2. Acceleration value averages for frequency band of tractor B (class I, mass 3430 kg) on grass (10 km/h, blue line) and on smooth track (4,5 km/h, red dot line)

Also in the case represented by the figure 2 graph, the most relevant spectrum distribution is always included in 2.5 – 5 Hz interval, but with the average peak of the grass cross shifted to 4 Hz. Likewise at the previous case, the frequency weighted acceleration values are similar (0.749 and 0.711 m/s^2).

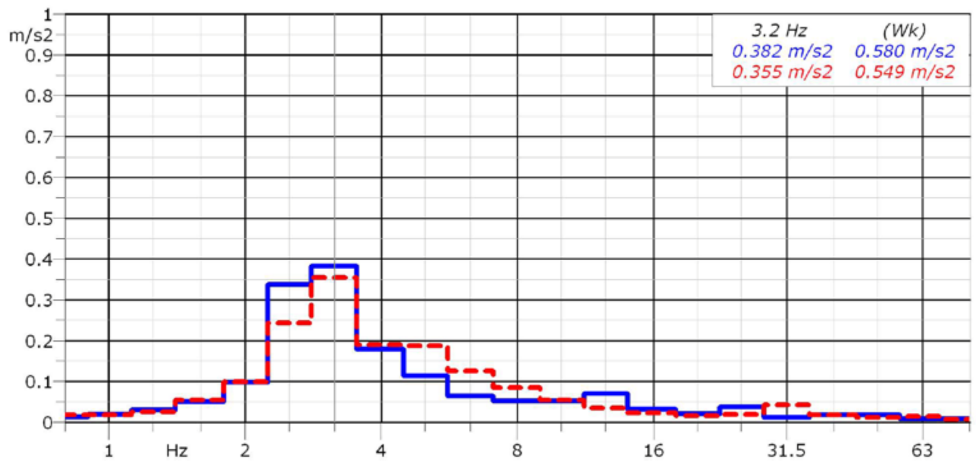


Figure 3. Acceleration value averages for frequency band of tractor C (class II, mass 4080 kg) on grass (10 km/h, blue line) and on smooth track (4,5 km/h, red dot line)

It is evident, observing the graph in figure 3, that for the class II tractor C the cross on grass track produces an highest relevance of frequency distribution shifted to lowest frequencies with respect to 4 Hz with a dominance in the range 2.5-3.2 Hz. Frequency values are equally well represented in the case of passage on artificial track. Also acceleration equivalent values are very similar (0.580 and 0.549 m/s^2).

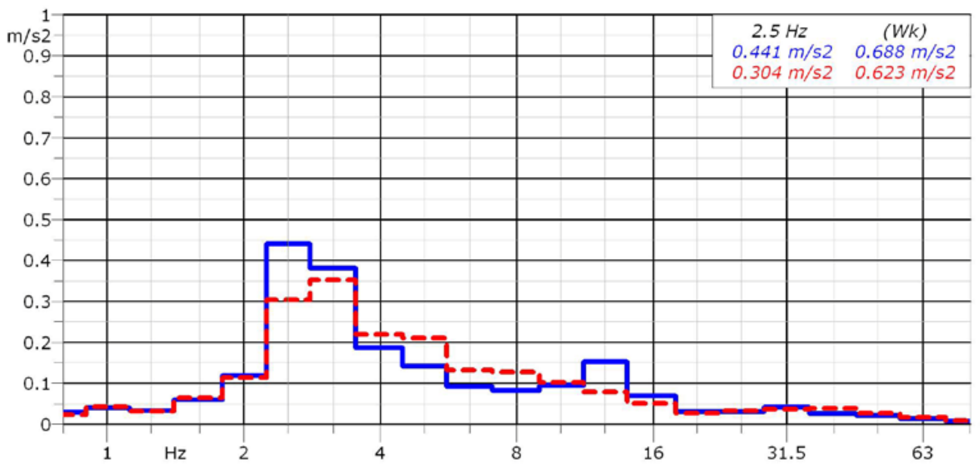


Figure 4. Acceleration value averages for frequency band of tractor D (class II, mass 4390 kg) on grass (10 km/h, blue line) and on smooth track (4,5 km/h, red dot line)

Analyzing the second tractor of class II, there is a frequency distribution centered on frequencies between 2.5 and 4 Hz (figure 4). The passage on the smooth track shows a spectral distribution similar to the graph of figure 3, with a reversal of the levels at frequencies of 2.5 and 3.2 Hz (blue line).

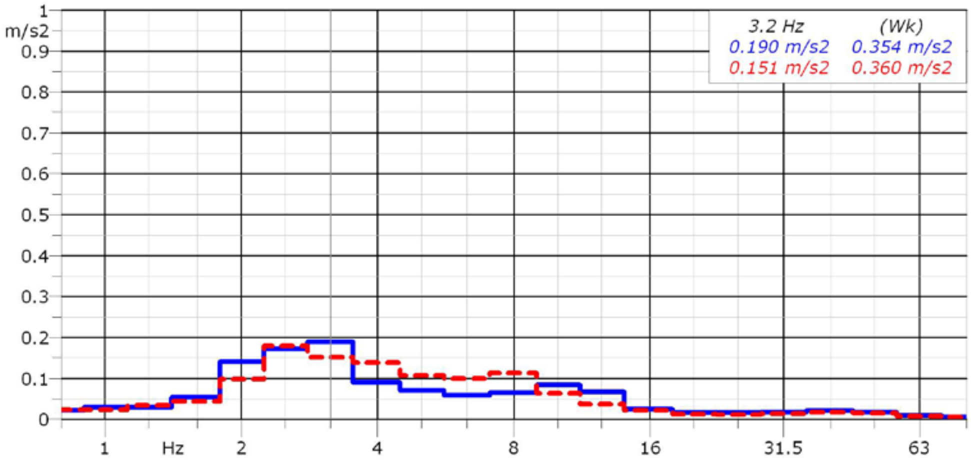


Figure 5. Acceleration value averages for frequency band of tractor E (class III, mass 6150 kg) on grass (10 km/h, blue line) and on smooth track (4,5 km/h, red dot line)

When the tractor mass augments, it emerges (case of graph in figure 4) a most significant frequency concentration toward lowest frequencies, between 2 and 3.2 Hz. The comparison between the spectrum generated by the crosses on grass and the same obtained from the passages on the smooth track let to appreciate a slightly different distribution compared with the previous graphs, also in the frequency range 4-8 Hz. Also in this case measured acceleration values are similar (0.354 and 0.360 m/s^2).

Comparing the graphs of the 4 figures, we can see how the tractor mass increment contributes in a significant way to the realization of a spectrum with lowest acceleration values, more uniformly distributed in the frequency field from 2 to 4 Hz.

The average RMS acceleration values for the 5 measured tractors on the 2 tracks with their percentage difference are referred in table 2.

Table 2 - Acceleration mean values on tractor cab floor

	Grass track Aweq (m/s^2)	Smooth ISO track Aweq (m/s^2)	Mean value difference (%)
Tractor A (class I)	0.916	0.962	5%
Tractor B (class I)	0.749	0.711	5%
Tractor C (class II)	0.580	0.549	5%
Tractor D (class II)	0.688	0.623	9%
Tractor E (class III)	0.354	0.360	2%

In conclusion, average RMS acceleration values obtained from grass and ISO track crosses are very similar for each tractor, with highest differences for the tractor D. Moreover, as it was foreseeable, higher masses lead to lowest acceleration values.

conclusions

Measurement and comparison of vibration levels obtained in each test were not aims of this work: on the contrary, the purpose was to begin to study a simplified methodology for the tractor manufacturers' vibration levels declaration. Also considering the difficulties met attempting to simplify a complex problem like this, the first results obtained in this work with a first comparison of 5 different tractors running on grass and smooth ISO track are hopeful. Average RMS acceleration recorded are not only similar in all the situations, but even 1/3 frequencies band are overlapping with negligible differences, considering the tire reaction over different roughness surfaces (Deboli et al., 2008).

For example, to declare vibration values of a tractor that must work for hay-making operations, a manufacturer should simply let the tractor travel on a smooth ISO track at the forward speed of 4.5 km/h to obtain a reliable data.

references

Banfo G.L., R. Deboli, G. Miccoli. 1997. Vibration active control device application to earth-moving machines seats. Proceedings of 7th European ISTVS. Ferrara, October 8-10, 1997, 462-469

Bovenzi M. 1994. Low-back disorders in agricultural tractor drivers exposed to whole-body vibration and postural stress. Applied Ergonomics, 25(4), 231-241

Deboli R., A. Calvo A, C. Preti, G. Paletto. 2008. Whole body vibration (WBV) transmitted to the operator by tractors equipped with radial tires. Proceedings of the International Conference: Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems. September 15-17, Ragusa (Italy), CD

Deprez K., D. Moshou. H. Ramon. 2005a. Comfort improvement of a non-linear suspension using global optimization and in situ measurements. Journal of Sound and Vibration, 284, 1003–1014

Deprez K., D. Moshou, J. Anthonis, J.D. Baerdemaeker, H. Ramon. 2005b. Improvement of vibrational comfort by passive and semi-active cabin suspensions. Computers and Electronics in Agriculture, 49, 431–440

EEC 2002/44. Council Directive on the Minimum Health and Safety Requirements Regarding the Exposure of Workers to the Risks Arising from Physical Agents (Vibration) (2002/44/EC). Journal of the European Communities No. OJ L 177, 6th July, 13pp

ISO 2631. 1978. Guide for the evaluation of human exposure to whole-body vibration. International Organisation for Standardisation, Geneva, Switzerland

ISO 5007. 1980. Agricultural wheeled tractors. Operator seat. Measurement of transmitted vibration. International Organisation for Standardisation, Geneva, Switzerland

ISO 5008. 1979. Agricultural wheeled tractors and field machinery. Measurement of whole-body vibration of the operator. International Organisation for Standardisation, Geneva, Switzerland

Lines J.A., M. Stiles, R.T. Whyte. 1995. Whole body vibration during tractor driving. Journal Low Freq Noise Vib, 14(2), 87–104

Paddan G.S., M.J. Griffin. 2002. Effect of Seating on Exposures to Whole-Body Vibration in Vehicles. Journal of Sound and Vibration, 253(1), 215-241

Scarlett A.J., J.S. Price, R.M. Stayner. 2007. Whole-body vibration: Evaluation of emission and exposure levels arising from agricultural tractors. Journal of Terramechanics, 44, 65–73

Topic 3
"Safety in field and in greenhouses"

Poster Presentation

Risk Assessment of Hand-Arm Vibration in Different Types of Portable Shakers for Olives Harvesting

Aiello G.[2], Catania P.[1], La Scalia G.[2], Piraino S.[1], Salvia M.[1], Vallone M.[1]
[1]*University of Palermo. Department of Engineer and Agricultural Forestry Technologies, Viale delle Scienze ed.4 - 90128 Palermo, Italy*
Tel 0039 917028147, Fax 0039 91484035, m.vallone@unipa.it
[2]*University of Palermo. Department of Management, Production and Mechanical Engineering. Viale delle Scienze - 90128 Palermo, Italy*
Tel 0039 91 23861827, Fax 0039 917099973, *aiello@dtpm.unipa.it*

Abstract

The aim of this study was to assess the level of exposure to hand-arm vibration of the operators using portable shakers. Some of the models commonly used were evaluated and correlated with the work capacity evaluated by field tests. Three different models of portable shaker with hook were compared. The tests were carried out in year 2009 both in laboratory and in the field. The field tests aimed to determine the work capacity of the three shakers; the laboratory tests were carried out according to ISO 5349-2 to assess the level of exposure to hand-arm vibration of the operators.
The results obtained from the laboratory tests allow to draw interesting comments on the evaluation of human exposure to hand-arm transmitted vibration highlighting how in some cases, the daily limit of 5 m/s^2 under the Decree 81/2008 was exceeded.

Keywords: harvest, olive, shaker, vibrations

Introduction

In olive growing the mechanization of harvest 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. The work capacity is from two to three time higher than the manual harvest; these shakers can be used also in farms whose orchards are little suitable for the mechanization because of steep slopes, training system not allowing the machines to pass, soils having high moisture content.
However, the use of such equipment may involve risk of exposure to hand-transmitted vibration.
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.
Excessive and daily exposure to hand-arm vibration can disturb the circulatory system and neurological and locomotor apparatus of the upper limbs. The combination of vascular, neurological and musculo-skeletal periphery disorders caused by exposure to hand-arm vibration is commonly referred to as "hand-arm vibration syndrome". In exposed workers, vascular and neurological disorders may occur in parallel or independently of each other. Osteoarticular and vascular lesions of the upper limbs caused by hand-arm vibration are also considered as occupational diseases for compensation in many countries.

Workers exposed to hand-arm vibration may present episodes of paleness in the fingers. These episodes are usually triggered by exposure to cold; it is a vascular disorder due to a temporary arrest of blood circulation in the fingers (Raynaud's phenomenon).
Other effects resulting from exposure to hand-arm vibration are neurological, such as tingling and numbness in fingers and hands. Persisting exposure, these symptoms tend to worsen and can interfere with the ability to work and activities of daily living. Clinical examination may show a reduction in tactile and thermal sensitivity and a decrease in manual dexterity, as well as entrapment neuropathies of nerves like carpal tunnel syndrome (CTS) due to compression of the median nerve in the passage along an anatomical tunnel in the wrist.
With reference to muscle disorders, workers with prolonged exposure to hand-arm vibration can suffer muscle weakness, pain in hands and arms and a decrease in muscle strength. It was also found that the vibration exposure is associated with a reduction in grip strength on the tool handle.
The Decree 81/2008 defines the limit of daily exposure to a standardized reference period of 8 hours, at 5 m/s^2.
The aim of this study was to assess the level of exposure to hand-arm vibration of the operators using portable shakers. Some of the models commonly used were evaluated and correlated with the work capacity evaluated by field tests.

Materials and methods

Three different models of portable shaker with hook were compared. They consist of a bar having an hook at the end which transmits the vibrations induced by the machine to the branch.

Table 1. Characteristics of the investigated portable shakers

	A	**B**	**C**
	Vibrotek TK 650	**Cifarelli SC 800**	**Valgarden S57S**
Engine	Vip 52 2004	Cifarelli C5	Valgarden
Engine displacement [cm^3]	52	52	56.5
Strokes [n]	2	2	2
Cooling	air	air	air
Tank capacity [l]	1.7	1.7	0.9
Total weight (filled up) [kg]	17.2	18.0	13.3
Length except the bar [mm]	730	1050	400
Bar length/total length ratio	0.73	0.66	-
Length of the bar [mm]	2000	2000	1600
Stroke of the bar [mm]	60.0	60.2	40.1
Hook width [mm]	40.4	40.5	30.2

Two types of shakers were examined (table 1); two of them, Vibrotek TK650 and Cifarelli SC800, respectively named "A" and "B", are provided with an internal combustion engine, with connecting rod-crank system giving the oscillations, that is mounted at the end of the bar near the handle. These machines are generally called "on line shakers". In the other shaker, Valgarden S57S, named "C" the engine is carried on the back of the worker through a frame acting as support; the engine is connected to the vibrating bar through a flexible tube 1.4 m long. This kind of machines is generally called "knapsack shaker".
The tests were carried out in year 2009 both in laboratory and in the field. The field tests aimed to determine the work capacity of the three shakers; the laboratory tests were carried out according to ISO 5349-2 to assess the level of exposure to hand-arm vibration of the operators.
Vibration monitoring presents unique demands on wireless devices, networks and associated components. At present, the one best-suited for condition monitoring applications is 802.11 b/g (often referred to as Wi-Fi).
The measuring chain contains: the digital xyz axis capacitive accelerometer, I2C converter for convert I2C to UART and XBee module for wireless transmission (ZigBee).

Figure 1. Wireless data collection system

We select Freescale MMA7455 triaxial accelerometer as the measurement device, shown in Fig.1 (left). This accelerometer has four different measurement ranges (±1.5*g*, ±2.0*g*, ±4.0*g*, and ±6.0*g*) that can be dynamically set by two input pins. Each range provides different measurement sensitivity. The accelerometer has low power consumption with 2.2V~3.6V and 500μA at the normal condition. It can also be set to a low current inactive mode (*i.e.*, sleep mode) of only 3μA operation current through a SLEEP pin, which further conserves power. The accelerometer continuously records accelerations in all three axes.
The measured data are fed into a microcontroller and sampled via an ADC. We select the Silicon Labs C8051F353 microcontroller with a built-in 24/16 bit ADC in our design. The microcontroller does simple processing on the data and set the working mode of the accelerometer accordingly. Processed data are fed into an IEEE 802.15.4 wireless transceiver and sent to the data logger unit. For our design, the XBee® 802.15.4 radio modem from MaxStream is chosen as the wireless transceiver, as shown in Fig.1 (right). It can operate under transparent mode with a simple connection with a microcontroller. With a chip antenna, it operates up to 30 meters indoor. The transmission range can be further increased to 90 meters by using a whip antenna. The XBee module has a low maximum transmit power of 1mW and a high receiver sensitivity of -92dBm. The front-end of the data logger unit is a wireless XBee transceiver. Upon receiving the measurement data from the wireless interface, the XBee transceiver forwards the data directly to the microcontroller for processing. We choose C8051F344 from Silicon Labs as the microcontroller in the data logger unit. It has convenient USB interface with a flash memory stick or directly to a PC. The processed data then serve as the basis for the calculations and software development involved in the characterization of movements.

Also, there is an initial calibration step in this sketch which assumes the MMA7455 is sitting flat with the z axis pointing up. There are calibration registers in the MMA7455 which need to be set using an interactive procedure so that the x and y axis will initially read zero and the z axis will read 1g. This has to be done each time the chip gets power since the registers are volatile. The 0g offset can be customer calibrated using assigned 0g registers and g-Select which allows for command selection for 3 acceleration ranges (2g/4g/8g).
Field tests were carried out in a farm located in Sciacca, province of Agrigento, Sicily; the variety of the olives was Cerasuola, that is typically suitable to oil production. The plot was 200 m above the sea level, with medium slope and the soil had a middle texture; the trees were about 50 years old, the distance between the rows 7 m x 7 m and the plants "free globe" shaped. The pruning is performed every two years. The mean circumference of the trunk, at the height of 0.5 m from the ground level, was 0.8 m; the mean diameter of the canopy was 5.5 m and the trees 3.8 m tall on average. The free trunk was 1 m tall and the ramification 1.2 m from the ground level.
The harvest was performed by five workers, four of them assigned to the nets and the other to the shaker.
The field tests were repeated three times; the data were statistically analyzed and the mean compared with Duncan's multiple comparison procedure ($p = 0.05$).
Laboratory tests were performed at the maximum engine regime, that is not a standard operative condition but allows to compare the different machines on equal terms on the basis of their intrinsic and design characteristics.
The tests were performed in two ways: keeping the shaker in a horizontal position and maintaining it at an angle of 45 ° to the horizontal, respectively indicated as A_0, B_0, C_0 and A_{45}, B_{45}, C_{45}. The measurement time was 40 s.
The accelerometers position, in compliance with the terms established by UNI EN ISO 5349-1:2004, was determined considering the position of the effective handle of the machine by the operator. Therefore, accelerometers were fixed near the right and left handle of each machine. The fixing was made in a way to ensure the rigid connection to the vibrating surface, using metal clamps.
To quantify vibration exposure, measurements must be taken under representative conditions. Guidelines for measuring and evaluating human exposure and details of different analysis methods for the hand-arm transmitted vibrations are 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 root-mean square frequency-weighted acceleration expressed in m/s². In addition, it is strongly recommended that for additional purposes frequency spectra should be obtained.
Acceleration values from one-third-octave band analysis can be used to obtain the frequency-weighted acceleration a_{hw}. It shall be obtained using:

$$a_{hw} = \left[\sum_{j=1}^{n} (W_j \cdot a_{wj})^2 \right]^{\frac{1}{2}}$$

where a_{wj} is the acceleration measured in the one-third octave band in m/s², and W_j is the weighting factor for the one-third-octave band.
In accordance with mentioned ISO standards, the three directions of an orthogonal co-ordinate system, in which the vibration accelerations should be measured, were as follows: Z-axis directed along the second metacarpus bone of the hand; X-axis perpendicular to the Z-axis (both these axes are normal to the longitudinal axis of the grip); Y-axis parallel to the

longitudinal axis of the grip. The inclination of the metacarpus bone when the hand grasped the grip was at 45º to the vertical. 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. The evaluation of vibration exposure in accordance with ISO 5349 is based on a quantity that combines all three axes.
The frequency weighted accelerations along the axes and the total acceleration were evaluated both for right and left handle. The values a_{hwx}, a_{hwy} and a_{hwz} were obtained according to the previsions contained in UNI EN ISO 5349-1:2004, as arithmetical average of the ones measured on the same axis (x, y and z) during the three repetitions of each test; the total equivalent accelerations a_{hv} were calculated vector adding the mean a_{hw} values of the three axes:

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

where a_{hwx}, a_{hwy} and 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. The daily vibration exposure shall be expressed in terms of the 8-hour energy-equivalent acceleration or frequency-weighted vibration total value.
The equivalent vibration total value related to 8 work hours A(8), considering a time of real exposure to vibration (T) of 4 hours, was determined as:

$$A(8) = a_{hv}\sqrt{\frac{T}{T_0}}$$

where:
T is the total daily exposure to vibration a_{hv};
T_0 is the reference period of 8 hours (28,800 s).
For each working condition, three independent measurements were carried out. Based on these values, the arithmetic mean value of the acceleration values from one-third-octave band analysis and the frequency-weighted acceleration were calculated. Statistical analysis was performed on the measurement data using Statgraphics Centurion by Statpoint inc., USA.

Results

Table 2 shows the values of the work capacity and the results of Duncan's multiple comparison procedure among the means. The values of work capacity show a large variability so that there are statistically significant differences among all the means. It can be noted that the knapsack shakers gave work capacity lower of about 50% than the on line shakers.

Table 2. Results of Duncan's multiple comparison procedure among the means for work capacity

Machine	Work capacity [kg/h]	
	mean	st.dev.
A	220.45 a	0.58
B	346.42 b	2.47
C	124.52 c	0.60

Note: Different letters in the column denote a statistically significant difference at the 95.0% confidence level.

Table 2 shows statistically significant differences among the values of work capacity of the three machines at 95% confidence level.
The shaker having the highest harvest productivity is B with 346.42 kg/h, while the lowest value was obtained by the knapsack shaker C.
In table 3 the values of the frequency weighted accelerations along the axes (a_{hwx}, a_{hwy} and a_{hwz}) and the total acceleration a_{hv} are shown (mean values).

Table 3. Frequency weighted accelerations values along the axes (a_{hwx}, a_{hwy} and a_{hwz}) and total acceleration $_{hv}$

Test	Left handle				Right handle			
	hwx [m/s^2]	hwy [m/s^2]	hwz [m/s^2]	hv [m/s^2]	hwx [m/s^2]	hwy [m/s^2]	hwz [m/s^2]	hv [m/s^2]
A_0	4.58	2.97	4.84	7.33	4.34	5.36	4.56	8.28
B_0	5.75	5.17	5.35	9.40	5.12	5.48	3.51	8.29
C_0	6.99	6.61	6.63	11.68	7.25	7.05	7.12	12.37
A_{45}	3.46	3.64	2.67	5.81	3.57	3.91	2.86	6.04
B_{45}	5.54	5.41	4.80	9.11	5.44	5.07	2.57	7.88
C_{45}	6.74	6.56	6.42	11.39	6.65	6.97	6.55	11.65

In table 4 the equivalent vibration total value exposures related to 8 work hours A(8) are reported.

Table 4. Equivalent vibration total value exposure related to 8 work hours A(8) and results of Duncan's multiple comparison procedure among the means

Test	A(8) dx [m/s^2]		A(8) sx [m/s^2]	
	mean	st.dev.	mean	st.dev.
A_0	5.85 a	0.48	5.18 a	0.22
B_0	5.86 a	0.40	6.65 a	0.13
C_0	8.75 b	0.32	8.26 b	0.11
A_{45}	4.27 a	1.30	4.11 a	1.28
B_{45}	5.57 a	0.24	6.44 a	0.03
C_{45}	8.24 b	0.38	8.05 b	0.24

Note: Different letters in the column denote a statistically significant difference at the 95.0% confidence level.

As regards the A(8) values obtained in the tests, table 4 shows that the highest values were obtained for all machines in the horizontal test, both in the right in the left handle.
From table 4 it comes that the highest A(8) values, higher than 5 m/s^2 which is the daily exposure limit value according to Decree 81/2008, have been obtained in machine C where

the two handles are placed on the vibrating rod. On the contrary, the lowest values were obtained in machine A, in which neither of two handles is placed on the vibrating rod. The A(8) values of the two machines, in fact, show statistically significant differences at 95% confidence level. The data on machine B are intermediate compared to machines A and C as only one handle is placed on the vibrating rod.
In machines A and C the A(8) values obtained in the right and left handles are similar.
In machine B, however, the values of daily exposure to vibration are higher in the left handle, placed on the vibrating rod, with respect to the right, both in the test performed in a horizontal position (12%) than in the test performed at 45° angle (14 %).
The machine B (Cifarelli), who provided the highest work capacity equal to 346 kg/h, recorded A(8) values lower than machine C (Valgarden) with work capacity of 124 kg/h, about 20% in the left handle and about 33% in right handle, in the test performed at 45 °.
The A(8) lowest values, 4.11 m/s^2 obtained in the left handle and 4.27 m/s^2 in the right one, in the test performed at 45° angle, were recorded by machine A (Vibrotek) whose work capacity was equal to 220.45 kg/h.

Conclusions

Interesting results were obtained from the first laboratory tests carried out by the authors, whose objective was risk assessment of hand-arm vibration to the operator using portable shakers to perform olives harvesting.
The more efficient machine both in terms of operator's health and in terms of work productivity appears to be the B machine (Cifarelli). This shaker, in fact, provided, among all, the highest value of work capacity compared with a daily exposure to vibration just higher than machine A with lower labor productivity by 33%.
The results appear to be slightly different from those recorded by other authors as the tests differ in the type of machines used (Monarca et al. 2003) and in the test mode (Pascuzzi et al. 2009).

References

Law Decree 81, 9 April 2008 of the Italian Republic

Monarca D., Cecchini M., Colantoni A. 2007. Study for the reduction of vibration levels on an "Olive electrical harvester". Proceedings of XXXII CIOSTA-CIGR Section V Conference "Advances in labour and machinery management for a profitable agriculture and forestry". Nitra, Slovakia, 17-19 September.

Monarca D., Cecchini M., Colantoni A., Bedini R. 2003. Indagine sul rischio da vibrazioni al sistema mano-braccio nell'uso degli agevolatori meccanici nella raccolta delle olive. Atti del Convegno Nazionale AIIA 2007: Tecnologie innovative nelle filiere: orticola, vitivinicola e olivicolo-olearia, Vol. I, 60-63, Pisa e Volterra, 5-7 settembre.

Pascuzzi S., Santoro F., Panaro V.N. 2009. Investigation of workers' exposure to vibrations produced by portable shakers. Agricultural Engineering International: the CIGR Ejournal. Manuscript MES 1127. Vol.XI. September 2009.

UNI EN ISO 5349-1:2004. Misurazione e valutazione dell'esposizione dell'uomo alle vibrazioni trasmesse alla mano. Parte 1: Requisiti generali.

UNI EN ISO 5349-2:2004. Misurazione e valutazione dell'esposizione dell'uomo alle vibrazioni trasmesse alla mano. Parte 2: Guida pratica per la misurazione al posto di lavoro.

Work Safety and Risk Prevention in Mechanical Harvesting of Olives

Almeida A.
Escola Superior Agrária de Bragança - Centro de Investigação de Montanha
Apartado 1172 – 5301-855 Bragança - PORTUGAL
E-mail: acfa@ipb.pt

Abstract

The Northeast of Portugal is a mountainous region with an important olive production. Slopes difficult mechanical harvesting, being necessary to adopt strategies to face the problem. Special trajectories to move the harvesting equipment inside olive orchards are necessary when slopes increase the risk of accidents. These solutions are necessary for a safe work, but can jeopardize the equipment performance. Some of the solutions adopted are described, and consequences evaluated.

Keywords: mechanical harvesting; olives, slopes

Introduction

In Portugal one of the most interesting zones for olive production is located in the Northeast of the country (Trás-os-Montes region).

The olive oil has excellent quality and assumes a high economic and social importance.

The mechanization of harvesting is adopted by significant number of olive producers.

The region is mountainous. The majority of olives orchards are placed in soils with significant slopes, sometimes superior to 15%.

This factor increases dramatically the risk of accidents with the equipment for mechanical harvesting, jeopardizing the work safety.

The objective is to reveal some solutions adopted for a safe work and evaluate the consequences in work rates.

Field tests carried out to compare three different systems to mechanize olive harvesting: System I, System II and System III. In all of them a trunk shaker detaches olives. The difference is in the collecting procedure. In System I olives are collected by canvas placed under the trees and moved by labourers. In System II a mechanical rolling canvas was used to collect olives. In System III olives detached are collected on an inverted umbrella.

System III revealed to be the most advantageous when not enough labourers are available for System I.

All of the systems need special attention when working in slopes, with emphasis on System III.

In slopes superior to 15% alternative trajectories are necessary for a safe work, with consequences in work rates.

Material and methods

Olive orchards

Field trials carried out in seven traditional olive orchards (sites) over three years. Traditional olive orchards vary from 100 to 150 trees per hectare. Three of the olive orchards are in Trás-os-Montes region and four are in Alentejo region. A total of 1768 trees were used in the field trials.

In Alentejo olive orchards are placed in flat areas. Olive orchards in sloping areas are in Trás-os-Montes.

In Trás-os-Montes there are three main cultivars: Cobrançosa, Verdeal and Madural, whereas in Alentejo, Galega is the main cultivar.

Harvesting systems

The mechanical harvesting systems studied are based on a trunk shaker mounted on the front loader of a 60kW four wheel drive tractor. Three different systems were used to collect olives detached.

The experimental design was a randomized complete block with three treatments (system I, II and III) and three replications.

In system I (Fig 1) the olives detached are collected on a 10m 10m canvas placed under the canopy projection, and moved by four labourers. In a parallel row, a second group was placing another canvas under the next tree to be shacked (Fig 2). A second tractor and trailer was standing by to collect the olives when canvas became too heavy, as well as to provide transport to the processing unit.

Figure 1 - System I

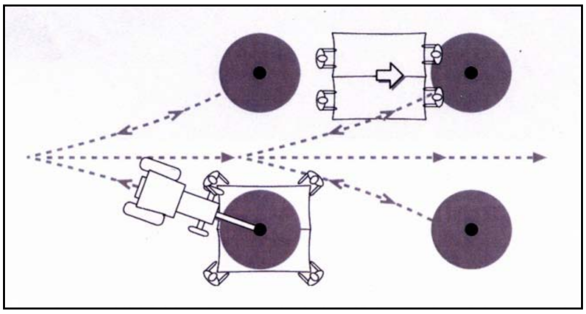


Figure 2 - System I: equipment trajectory

In system II (Fig 3) the olives detached are collected on a rolling canvas catching frame mounted on a second tractor. Two labourers are necessary to support the canvas movement. The canvas is made by two 4m 8m separate parts, laid down on either side of the tree.

Figure 3 - System II

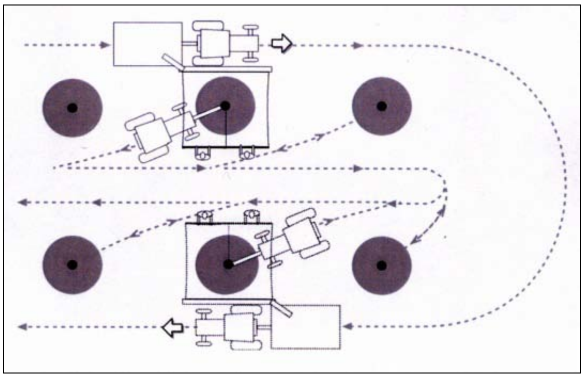


Figure 4 - System II: equipment trajectory in light slopes or flat soils

In system III (Fig 5) the olives detached are collected by a 9 m diameter inverted umbrella linked to the tractor front-end-loader under the trunk shaker frame. The inverted umbrella can store temporarily 200/250 kg of olives in a collecting tray. Under the collecting tray a lead may be hydraulically open to allow discharge of the olives.

Figure 2 (System I), Figure 4 (System II) and Figure 6 (Systems III) show the equipment work progression in olive orchards placed in flat soils.

Figure 5 - System III

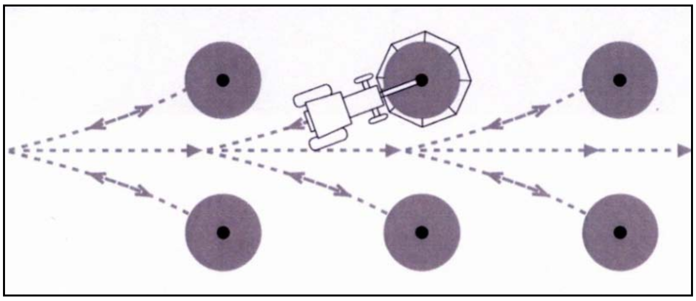


Figure 6 - System III equipment trajectory in light slopes or flat soils

In olive orchards placed in slopes between 15% to 25% alternative trajectories are needed.

With System II, the rolling canvas catching frame is mounted on the left side of the tractor. In consequence, 62% of the total weight (4455kg) is on that side of the tractor. To ensure a safe work the equipment follows the contour lines, with the rolling canvas always in the higher operation zone (Fig 7). To maintain this work methodology, when harvesting finish in one tree line, to change to the next, the equipment must go backwards for the beginning of the next line, instead of simply 180º turning.

With System III, to guaranty a safe work, the equipment must move through trajectories perpendicular to contour lines (Fig 8). In this system, 70% of the total weight is on the front side of the tractor.

With System I work in slopes did not require different trajectories, but more time to move between trees. It is necessary a lower velocity.

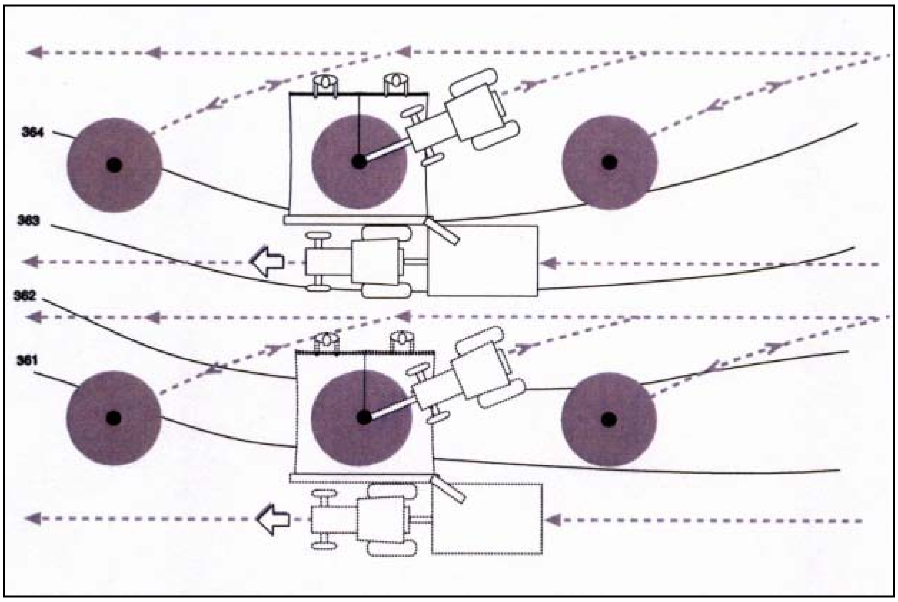


Figure 7 - System II equipment trajectory in slopes.

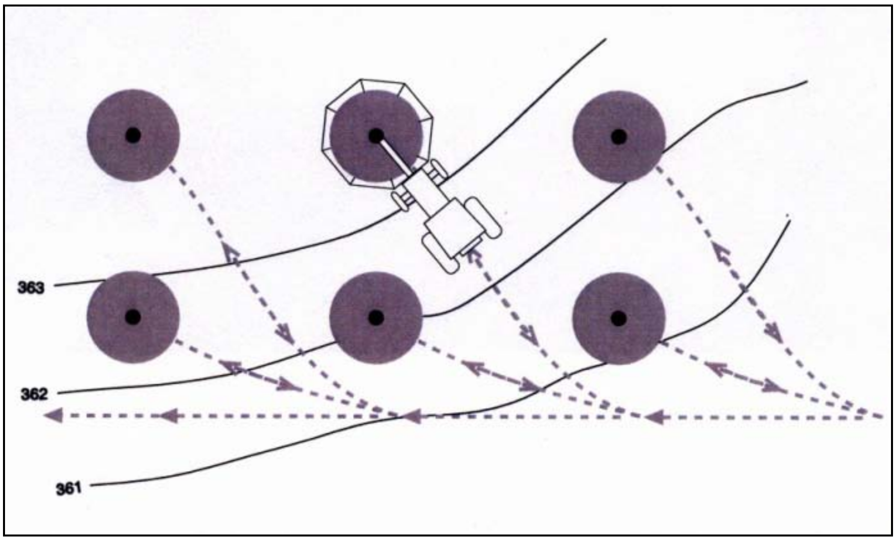


Figure 8 - System III equipment trajectory in slopes.

Results

Tables 1 and 2 show the work rates results, per system and site.

Table 1 – Olive orchards in flat areas: work rates (trees/hour)

Olive Orchards	System I	System II	System III
Site 1	57	43	36
Site 2	80	51	47
Site 3	39	47	34
Site 4	80	64	42
Average	**64**	**51,25**	**39,75**
SD	19,88	9,11	5,91

Table 2 – Olive orchards in slopes (15% to 25%): work rates (trees/hour)

Olive Orchards	System I	System II	System III
Site 5	36	35	33
Site 6	46	42	36
Site 7	41	38	26
Average	**41**	**38,33**	**31,67**
SD	5	3,51	5,13

Conclusions

Work rates in slopes are lower than in olive orchards in flat areas. In these field trials, in average, System I work rate have a reduction of 36%; System II work rate have a reduction of 26%; System III work rate have a reduction of 20%.

This fact, increase harvesting costs.

We used different olive orchards to collect data (in slopes and in flat areas), so we cannot know degree of responsibility of slopes in the work rates decrease, but we assume that slope has an important role in this effect.

Knowing that, olive growers can adopt the alternative trajectories to guaranty a safe work, if the olive oil quality pays the more expensive harvesting in these situations.

References

Almeida, A.; Peça, J. 2007. Performance of three mechanical harvesting systems for olives in Portugal. Proceedings of 35th International Symposium - Actual Tasks on Agricultural Engineering. Agricultural Engineering Department, Faculty of Agriculture, University of Zagreb, pp 461-466, Opatija, Croatia.

Michelakis, N. 2002. Olive Orchard Management: Advances and Problems. Proceedings 4th International Symposium on Olive Growing, Acta Horticulturae Nº 586 pp 239-245, ISHS, Valenzano, Italy.

Safety Aspects Regarding Spraying Pesticides in Protected Environments

Balloni S., Camillieri D., Caruso L., Schillaci G.
University of Catania. DIA, Mechanics Section
Via Santa Sofia, 100 – 95123 Catania, ITALY.
Tel. +39 095 7147512, Fax +39 095 7147600, giampaolo.schillaci@unict.it

Abstract
This work deals with the procedure and equipment for the distribution of pesticides. The research was carried out in a greenhouse nursery. The aim of the work was to identify the critical points underlying the risk to the health and safety of the operators and to the environment. The investigation was not limited to the spraying stage but was extended to the operators' entire working day. The investigation focussed on the operators and included the preliminary and conclusive stages of their day, starting with their arrival at the nursery and ending with their departure through the gate. The multiple observations carried out at the same time required the presence of the research group. The observations were based on the break down of the work into component phases and the timing of each of these. Also the input as resources used and output as chemical waste were considered. The breakdown was carried out following the CIOSTA – AIIA and Methodology of Organisational Congruence (MOC) indications. The identification of the critical points was made on the basis of the
81/08) (Single Safety test, law 81/08), the Global Gap protocol in effect (version 3.0-2_sep07 and version 3.0-3_feb09) specific to market gardens, the ENAMA protocol for the functional testing of the spraying machines and the European regulation in effect since 12 December 2009, and, more in general, by consulting the current regulations. The stages of the work were identified; the resources, tasks, responsibilities, actions and equipment were identified and assessed; and finally, together with the risk factors, also the critical points for correct management of the materials, machines and chemical waste were found. The results represent the basis for a plan of action aiming at risk reduction and prevention in greenhouse nursery.

Keywords: greenhouse, health, safety, work organisation, Global Gap protocol, ENAMA protocol

1. Introduction

The market garden and nursery plants section in protected environments in the south- east of the Sicilian Region, comprising the provinces of Ragusa and Syracuse, covers about 7500 hectares per 13200 ULA. It is thought that at least 15.20 % of the total work involves spraying pesticides.

Workers are at risk of intoxication when spraying pesticides in greenhouses; therefore, a monitoring system has been set up by the institutions concerned with preventive medicine (S.Pre.S.A.L.).

Despite the lack of statistics about this, experience has led us to believe that there is a risk of intoxication in other phases of the operation besides spraying. For this reason, the treatment methods and the equipment used for the pesticide spraying have been monitored, and the entire working day of the operators has been examined. The objective of the investigation is to identify all the phases of risk, besides the actual spraying phase, and to lay down the foundations for a method to assess the risk of intoxication of the workers.

2. Materials and Methods

The research took place in a company growing nursery plants and vegetables with a SAU of about 5 hectares with crops in a protected environment. The greenhouses are made of steel with a semi-circular domed covering, a span of 9 m, highest point 5.45 m and height at the eaves of 3.75 m. The structural characteristics comply with the EN European regulations (UNI EN 13031-1:2004). The greenhouses have a PE plastic film roofing that lasts two years and is 0.15 mm thick, and a further anti-aphid net to protect the crops from disease vectors.
The 3 greenhouses examined here, (A, B e C), 4.500 m^2, 3.500 m^2 and 2.200 m^2, form a layout of a central longitudinal corridor and 4 transversal corridors that mark out the areas with beds that support the polystyrene trays.
The work of the pesticide spraying operators was surveyed and broken down into component phases that were described and timed using the methodology CIOSTA – AIGR (today AIIA), and following the methodological procedure suggested by the Method of Organisational Congruencies MOC. All the important points were reported, with the standardized surface of 1000 m^2 considered as reference module.
The assessment of the critical points for the safety aspects of the workers was carried out using the contents of the single text on safety (D.Lgs. 81/08), of the GlobalGap protocol currently in force (version 3.0-2_Sept07 and version 3.0-3_Feb09) specifically for fruit and vegetables.
The equipment for the pesticide spraying which the workers use when carrying out monitoring work was tested following the indications of the protocol ENAMA for the functional testing of spraying machines (reference procedure for the activation of the service for the functional control of spraying machines and the periodical testing of this activity, headed by the Technical Work Group for the national planning of control activities of spraying machines Rev. December 2009) and referring to recently approved European regulations (Directive 2009/128/CE of the European Parliament and Council of 21 October 2009 that sets down a framework for community action regarding the sustainable use of pesticides – Directive 2006/42/CE of the European Council and Parliament of 17 May 2006 concerning machines, in force since 29.12.2009), and more in general referring to current regulations.

3 Results and discussions

3.1. The work phases

The protection of the crops is entrusted to 3 teams, each with two workers. The spraying work usually takes place 3 times a week, rotating all the preparations. A monitoring system of the environmental conditions, the most sensitive plants and the vectors present in the cultivation area may suggest extra interventions. The work was broken down into 8 phases. (Table 1).

Table 1 – Pesticide spraying in greenhouses – 8 phases [greenhouse 1000 m^2]

	Phase	Place	Average duration Min	Description of operation
1	Dressing	Changing room	15	The workers collect the protective clothing and put it on
2	Preparation of the mixture	Pesticide warehouse	15	One or more workers prepare the mixture to distribute among all the teams in charge of the treatments
3	Transfer from warehouse to greenhouse	Paths in the company	5	The workers go to the greenhouse on foot, carrying the mixture in containers
4	Preparation of spraying machine	Greenhouse	10-15	The machine is programmed for the treatment, the appropriate regulations are made, the mixture is poured into the tank and the water tank is filled.
5	Pesticide spraying	Greenhouse	5 (1000 m^2)	One worker traverses the nozzle while the other sees to the necessary operations of assistance, like handling the tube, keeping a distance of about 8 metres from his colleague
6	Washing the equipment	Tap next to the greenhouse	7	The workers rinse out the spray pistol and the containers
7	Transfer from the greenhouse to the warehouse	Paths in the company	4	The workers return on foot to the warehouse and put the equipment in its place (spray gun and containers)
8	Undressing	Dressing room and tap in front of the warehouse	15	The workers take off the protective clothing, clean it and keep it or dispose of it. The workers get washed

The entire duration of the work cycle, referring to a greenhouse surface area of 1000 m^2, is 76 minutes, with a higher incidence of the sub-phases of dressing of the workers (19%), preparation of the mixture (19%), setting up the sprayer (13,1%) and undressing (19%). The spraying phase comprises 6.5% of the entire work cycle. Also, the relatively important duration of the transfers should be highlighted, especially the one from the warehouse to the greenhouse with the containers full of the mixture, and finally the duration of the operation of managing the equipment after carrying out the treatments.

3.2 The critical points

We identified the following critical points (CCP) for all 8 phases of pesticide spraying:

Table. 2 **– Critical points of "dressing"**

Critical points noted	GlobalGap	Regulation of reference
'Danger' signs on the entry doors to the warehouse. .	**AF 3.3.2 - mm**	Legislative decree 81/08 Title V – Attachments from XXIV a XXXII
Procedures in case of accidents	**AF 3.3.1 - mm**	Legislative decree 81/08 Title I – Section VI D.M. n. 388 del 15 July 2003 Legislative decree 81/08 Title IX Legislative decree 81/08 attachment IV
Ventilation of changing room	**-**	Legislative decree 81/08 attachment IV – paragraph 2 – point 2.1.8.1
Access to changing room Tap inside.	-	Legislative decree 81/08 attachment IV – paragraph 1 – point 1.13.2.2 – 1.13.3.1
Devices for individual protection.	**AF 3.4.1 - MM** **AF 3.4.2 – MM**	Legislative decree 81/08 attachment IV – paragraph 1 – points 1.12.4 and 1.12.5 ISPESL – Operative lines for clearing and maintenance of DPI (March 2008)
Procedures for putting on and taking off DPI	-	Procedures and advice given by producers of pesticides
Footwear used in course of treatments	**AF 3.4.1 - MM** **AF 3.4.2 – MM**	Legislative decree 81/08 Title III – Chap II Legislative decree 81/08 Title IX Legislative decree 475/92 EN 344 - EN 345 – EN 347

The analysis of the CCP in the "dressing" and "undressing" phases indicates the need for a different management of the protective clothing, and also the need to restructure the changing room, providing it with a separate access from the warehouse and posters describing what to do in case of accidents.

Table. 3 **– Critical points in "storage, preparation and transport of mixture" phases**

Critical points noted	GlobalGap	Regulation of reference
Various pesticides in the warehouse	**CB 8.7.8 - mm**	Regulations for carrying out D.P.R. 290/01;
Arrangement of pesticides on the shelves	**CB 8.7.17 – mm**	Regulations for carrying out the D.P.R. 290/01;
Inert materials (sand) in the warehouse	**CB 8.7.12 - mm**	Legislative decree 81/08 attachment IV – paragraph 2 – point 2.1.12
Registration of files documentation of treatments.	**CB 8.2.5 – mm** **CB 8.2.6 – mm** **CB 8.2.7 - mm** **CB 8.2.9 - mm**:	D.P.R. 23 April 2001, n. 290: Memorandum 30 October 2002; Legislative decree n. 65 of 14/3/2004
Annual balance setting	**CB 8.7.11 – mm**	UNI CEI EN ISO/IEC 17025 (requirements of chemical laboratories)
Tools for the preparation of the mixtures	**CB 8.7.11 – mm** **CB 8.9.6 - MM**	Legislative decree 81/08 attachment IV – paragraph 2 – point 2.1.3
Disposal of mixture and water	**CB 8.9.7 – mm**	Legislative decree 5 February 1997 n. 22 and s.m.i. "carrying out of directives 91/156/cee on waste, 91/689/cee on dangerous waste and 94/62/ce on packaging and waste produced by packaging". Legislative decree 22 May 1999, n. 209 "carrying out of directive 96/59/ce Concerning discharge of polychlorinated biphenyl and polychlorinated triphenyl"
Bench for preparing the mixtures		Legislative decree 81/08 attachment IV – paragraph 2– points 2.1.5 e 2.1.8.1; UNI EN 14175 (chemical hoods and extractors required)
Containers for transport.		Legislative decree 81/08 attachment IV – paragraph 3 – Point 3.10

The analysis of the CCP in the phases of "storing, preparation and transport of the mixture" shows that the operations of preparing the mixture need to be revised, avoiding the use of unprofessional equipment and studying different solutions for transporting the mixture.

Table 4 **– Critical points of the phases of "preparation of sprayer" and "spraying"**

Critical points noted	**GlobalGap**	**Regulations of reference**
Periodical control of sprayers	**CB 8.4.1 – mm** **CB 8.4.2 – R**	EN 13790-2: 2003
EC branding, identification plate, instruction manual, safety pictogram		Directive 2006/42/CE Legislative decree 17/2010
Protection sheath for pressure tubes. Leaks from the tank Manometer always visible. Tank hermetic cover Control system of the level of mixture. Tank for washing hands	**CB 8.4.1 – mm**	UNI EN ISO 4254-1:2006; UNI EN 982: 2009; UNI EN 907:1998; ISO 11684:1995; ISO 5681:1992 point 3.9.5; ISO 5681:1992 point 3.9.5; attachment A of law EN 12761-1:2003;
Washing after each treatment.	**CB 8.4.1 – mm** **CB 8.5.2 - R**	Dir. 1600/2002/CE Dir. 2000/60/CE Dir. 2006/42/CE
Posters warning of danger at the entry to the greenhouse being treated.	**AF 3.3.2 - mm**	Legislative decree 81/08 Title V –Attachments from XXIV to XXXII
Return times	**CB 8.8.2 – MM** **CB 8.8.3 – mm**	Directive CEE 91/414 received in the GU 76 on 3/10/91

The analysis shows that the question raised by the up-dating of equipment in the light of current regulations needs to be radically tackled. The analysis also shows that some features of the sprayers need to conform to the current regulations, especially to avoid problems of pollution from punctiform sources. As regards the return times, the company itself fixes a suitable interval (the research has shown that there are no satisfying indications regarding this). A thorough revision of the necessary precautions and actions for the spraying is advisable.

Table. 5 **– Critical points of the "washing and handling of equipment"**

Critical points highlighted	GlobalGap	Reference to regulations
Residual mixture in tank	**CB 8.5.1 – mm**	Dir 1600/2002/CE Dir 2000/60/CE Dir 2006/42/CE
Water container for washing	**CB 8.5.2 – R**	
Devices for washing the containers or alternative procedures	**CB 8.9.6 – MM**	
Disposal of liquid for rinsing the containers and water after washing. Partial disposal of containers	**CB 8.9.1 – mm** **CB 8.9.7 – mm**	Legislative decree 5 February 1997 n. 22 and s.m.i. "carrying out directive 91/156/cee on waste, 91/689/cee on dangerous waste and 94/62/ce on packaging and waste from packaging". Legislative decree 22 May 1999, n. 209 "carrying out directive 96/59/ce Concerning disposal of polychlorinated biphenyl and polychlorinated triphenyl
Opening devices of drums for stored material, accessibility, sign indicating area of stock pile	**CB 8.9.2 –** **CB 8.9.5 -** **CB 8.9.8 – mm**	Regulation EN 840:2004 UNI 10571:1995 DIN 30740

The analysis shows that the residuals must be reduced to a minimum through precise calculations of the quantity of the pesticide used; the equipment used must be in good condition and subject to periodical control. Also the procedures for the disposal of residuals should be revised.
A revision of the procedures of the necessary movements to be made during dressing and undressing is advisable.

Conclusions and recommendations

The studies on the organization of the work show the areas of risk and the times of exposure; the epidemiological ones could provide information about the number of accidents that happen in each phase. With the results of the research carried out on the quantity of pesticides that contaminate the workers, one could reach a valid algorithm for determining the risks of acute and/or chronic intoxication of those who carry out pesticide spraying and concentrate precautions in the critical areas.
The breakdown of the work into phases through the MOC - CIOSTA methodology has enabled us to highlight the risks of each sub-phase and not only that of the spraying, seen by workers as risky. The CCP test of the 8 sub phases and the research of regulation references indicate the following recommendations:

1. handle the protective clothing in a appropriate way;
2. structure adequately the changing room;
3. revise the operations for preparing the mixture;
4. study adequate solutions for transporting the mixture.

Although the procedures used for the spraying are carried out with the required precautions, they should be examined, as should the dressing and undressing operations. The question posed by the up-dating of equipment in the light of current regulations needs to be tackled radically. Inspections, meetings of work groups, meetings with the operators and with company managers are necessary to discuss the work and plan the change of some procedures and up-dating of some equipment.

Bibliography

Legislative decree n. 81 9 April 2008. *Testo Unico in materia di tutela della salute e della sicurezza nei luoghi di lavoro*.

Lepore M. 2007. *La normativa essenziale di sicurezza e salute sul luogo di lavoro*. XIV edizione. EPC Libri.

Maggi B. 1990. *Razionalità e Benessere. Studio interdisciplinare dell'organizzazione*. ETAS Libri, Milano.

Mattheuws G.A., Hislop E.C. 2004. *Application Technology for Crop Protection. Edited*. International Pesticide Application Research Centre Imperial College at Silwood Park, UK and Institute of Arabe Crops Research Long Ashton Research Station, UK.

Schillaci G., Balloni S., Camillieri D., Conti A., Caruso L. 2009. *Punti critici e prevenzione nel rischio ambientale e nella sicurezza degli operatori in relazione alle operazioni di distribuzione degli agrofarmaci in serra*. Atti del IX Convegno Nazionale dell'Associazione Italiana di Ingegneria Agraria, Ischia Porto, 12-16 settembre.

Schillaci G., Blandini G. 2006. *Moderni criteri per la sicurezza delle macchine e degli impianti agroalimentari*. Atti su CD-rom delle Giornate di Studio dal titolo "Innovazione de1le macchine e degli impianti nel settore agro-alimentare per un'agricoltura multifunzionale nel rispetto dell'ambiente". Anacapri (NA), 5-6 giugno.

Sitography

www.globalgap.org

Risks at Work in the Disinfestation of Rural Land Deriving From the Use of Fumigants Instead of Methyl Bromide

Bongiovanni L., Conticello M., Miceli G., Ravalli P., Scibilia B.
Provincial Health Company Ragusa Department of Prevention, S.Pre.SAL Prevention and Safety Workplaces Zona Industriale I^ fase – 97100 Ragusa, ITALY.
Phone: 0039 0932234910, Fax 0039 0932234914, medicina.lavoro@asp.rg.it

Keywords: Land fumigation, chemical risk

AIMS

In ASP territory in Ragusa the land sterilisation working process based on the use of Methyl bromide, sustained by the local intensive cultivation of vegetables and flowers in protected structures, was very developed up to a few years ago and represented a significant working reality besides also being rather technologically advanced. Local firms, specialised in the process, had reached a high level of experience on the field so much so that they received intervention requests from all over the country. At times of greater expansion, in the 1990s, there were some ten undertakings which were quite active within the sector, with a workforce all in all exceeding 300 employees, mainly seasonal workers qualifying as disinfestation workers. The total amount of methyl bromide used annually by these undertakings exceeded 3,500,000 kg. (3,750,000 in 2002, SPreSAL Archive).
Crisis struck the sector after the use of Methyl bromide was limited. For environmental reasons this gas was actually included in the Montreal Protocol in the list of greenhouse gases contributing to the destruction of the ozone layer. Meanwhile, after an initial limitation of use with a relative quota of availability, the use in Italy of Methyl Bromide was prohibited as from the 1.01.2005, but for limited dispensations relating also to some specific uses in the agricultural sector. Following which, the hard times to find on the market sufficient product quantities for processing have led undertakings within the sector to search for alternative solutions relating to land sterilisation. Since 2010, the use of Methyl Bromide in Italy has been totally prohibited.
Of the new methods introduced to practise land sterilisation, the one based on chloropicrin is of major interest insofar as relating to safety problems at workplaces. This method, actually, for the purposes of work risks and the workers' safety, could be assimilated with the method base on CH3Br. Chloropicrin too, like methyl bromide, is a toxic gas whose use is regulated by Roy. Dec. no. 147 dated 09.01.1927, and as such it is only allowed to be used by well-trained workers authorised in terms of the above mentioned royal decree; besides, since Chloropicrin and its formulations are also medical devices, their use and purchase is subordinate to the authorisation (licence) provided for in art. 25 of DPR 290/01.
The abandonment of fumigation on the basis of methyl bromide has upset the work sector. Not all undertakings within the sector were able to take up the prohibition of methyl bromide with a fast conversion to an equally effective alternative technology. The most unfavourable factor for the sector has been the introduction of non exclusive land sterilisation technologies, based on substances not requiring any specific authorisations, consequently in the direct availability of any agricultural holding wanting to adopt it. Only chloropicrin, being classified

as a toxic gas like CH3 Br, actually provides exclusive use by specialised firms possessing proper authorisation.

METHODS

The Prevention and Safety at Workplaces Service of the ASP Prevention Department, has launched a study aimed at recovering full awareness of the sector and to check: the work risks having to do with the adopted technologies, any possible effects on the health of workers who have already been exposed, the validity and effectiveness of the protective measures put into effect. All this in the light of the obligations and safeguard and prevention compliance provisions envisaged by Leg. Dec. 81/08 and subsequent amendments.
On the 30th May 2010 there have been identified and surveyed six functioning and operating firms within the sector, which have been contacted for the in-depth examination required for the study such as a description of the work cycle, the amount of substance used, the equipment used, the workforce, the recording of any accidents or pathologies linked to work risks. Besides, for five of them a further on site inquiry was made to effect a direct check of the technology and procedures used in land sterilisation.
Chloropicrin is an oily, colourless or faintly yellow liquid, denser than water and little miscible with it, with a freezing temperature of – 69.2 °C, a boiling point of +112°C, at which temperature it decomposes releasing phosgene and nitrosyl chloride. At ambient temperature it evaporates swiftly liberating fumes which are highly toxic to breathe. Its presence at low doses is noticed by feeling burning eyes and sensing an acute smell. It is irritable to the eyes, skin and respiratory mucosa, and harmful if ingested. The toxic action is mainly seen on the respiratory tracts, in fact if chloropicrin fumes are inhaled, these could cause serious harmful effects developing symptoms such as vomit, cough, serious breathlessness, pulmonary oedema. In its liquid state the product, if it comes into contact with the skin and the mucosa, causes serious burns owing to its strong irritating action. The limit value of exposure allowed is of 0.67 mg/mc (0.1 ppm) TWA.

RESULTS

From a study which has been undertaken it results that the actual firms working in the sector are six, that the workforce involved amounts to about 45 persons (mostly seasonal workers), that the amount of chloropicrin used during the past three years is on the increase, that accidents during the past three years have never been related to chemical poisoning.
Chloropicrin consumption declared in Ragusa Province

2007	2008	2009
230,316.5 Kg.	285,533.7 Kg.	315,930.7 Kg.

Given that the land sterilisation of greenhouses could be achieved with different techniques based both on purely physical action (e.g. solarisation), and on chemical action (e.g. fumigation), we will focus on the description of fumigation with chloropicrin. The process consists in impregnating the land to be treated with a mixture of water and chloropicrin, where the effective amount of dissolved substance generally falls between 15% and 20%.

Impregnation occurs by means of a "machine" pumping into the ground, using the greenhouse's drip irrigation system, while the previously prepared solution obtains its water from a reserve made available by the firm owning the land. The chloropicrin is added to the water through a measure dispenser connected with a tank inside the "machine". Having set the solution with the required chloropicrin dose, the machine will start the treatment sending the solution to the tubes and sprinklers circuit positioned on the ground and connected to it. The impregnation takes place when the solution is dispersed into the surface strata of the ground where the sprinklers are to be found. The land to be treated, with all its network of sprinklers, is prepared beforehand, when it is all tightly covered and sealed with a black polythene sheet in such a way that both chloropicrin dispersion and the passage of light are reduced to a minimum. Between the ground and the polythene cover an air chamber is formed where chloropicrin fumes coagulate. The action's effectiveness depends on the duration and persistence of chloropicrin in the ground.

Chloropicrin's sterilising action usually persists for some four or five days up to its inactivation owing to degradation and halving of the concentration. Chloropicrin which has been distributed into the ground, generally only impregnates the surface strata in that it tends rapidly to rise again by natural evaporation, and this evaporation process is even faster if the ground is saturated with water. Exposure to light accelerates the degradation process for photolysis. Before re-entering treated land a safety period of seven days should be applied. Once this period has passed one could safely pass on to reclaim the land by removing the plastic sheets. For safety reasons, such an operation should be performed by workers from the same firm making the treatment, yet this is rarely the case since the undertaking prefer leaving the fabric as mulch.

All firms operating within the sector are local firms and used specialised labour. The approximate number of workers in the sector is of between 45 and 50 persons. The method could be considered tested having been in use now for at least five years. There have not been any accidents reported, neither from a check done with official accident data supplied by INAIL (the National Institute of Insurance against Accidents at Work) nor from an active review of the accident records of individual undertakings which have been contacted in the course of the present study. Actual available data of environmental monitoring relating to the presence of fumes show that in conditions of use with respect to hygiene and safety standards at work, the values for the presence of chloropicrin fumes in work areas, forming the subject of measurements, have never exceeded the permitted maximum levels (0.1 ppm), as per data supplied by a firm. There are no environmental monitoring measurements to this very day made by public bodies appointed to surveil safety at work and living places.

ARGUMENT

The technique of land sterilisation with chloropicrin, which has now been used for at least five years on the territory dedicated to greenhouse growing within the Hyblean area, has only partly substituted the important role undertaken by the preceding method based on methyl bromide. Actually, it has not had the same effect which the sector had with methyl bromide. The current sector is only a residue of what it once was. For the purpose of safeguarding the health and safety of the sector's workers, the method is not exempt from risks; workers, even if health epidemiological data on its use during these years do not give rise to any particular criticality, should be considered as being fully exposed to chemical risk as provided for in Leg. Dec. 81/08. The potential health effects can be prevented with a timely application of the protection and prevention measures regulated by Title IX Chapter I of Leg. Dec. 81/08. In particular, it seems evident that the most effective prevention measures to be adopted are: strict respect for all preparatory measures aimed at segregating the toxic gas and later, during the treatment itself, to keep the absolute no entry prohibition to treated areas for at least seven days or up to the time when one is certain, after proper measurements have been taken, that chloropicrin fume concentration levels dispersed into the air are below those permitted (0.1 ppm).

Assessment of the "Strain" Parameter in the Calculation of the Biomechanical Risk Index as Regards the Upper Limbs in Vineyard Manual Pruning

Schillaci G.[1], Bonsignore R.[1], Camillieri D.[1], Romano E.[2]
[1]*University of Catania. DIA, Mechanics Section*
Via Santa Sofia, 100 – 95123 Catania, ITALY.
Tel. +39 095 7147512, Fax +39 095 7147600, giampaolo.schillaci@unict.it
[2]*Agriculture Research Council – Agricultural Engineering Research Unit (CRA-ING); Laboratory of Treviglio, via Milano 43, 24047 Treviglio BG, ITALY.*

Abstracts

Vine pruning provokes strain (, 2009, ., 2008). Moreover the need to develop force repetitively and with a high frequency has been noted in the literature as a risk factor in causing pathologies in the tendon and muscle structure.
The force is usually estimated on the Borg CR10 scale, which is used to assess the subjective perception of the effort in relation to the force itself.
The aim of the research was to assign numerical values (derived from cutting trials using sensorised secateurs) to the effort necessary to carry out pruning and to verify whether the results obtained are comparable with the workers' subjective perception of the effort. As regards the subjective assessment of force used, a questionnaire on perception of effort made was given to a sample of pruning operators at the end of the experiment. The judgements were then converted into a score on the Borg CR10 scale and subsequently the average force score was calculated. The numerical values of the force were derived from cutting trials using sensorised secateurs carried out on various vine cultivars (., 2010) and processed with software R for statistical elaboration. They were also compared with the maximum force capacity limit values provided by the international standard EN 1005-3. The calculation simulations of exposure taking into account the objective values of the force were carried out with the software "midaOCRAmulticompiti". The replies to the questionnaire were very homogeneous as regards the operators' perception of the strain involved for the various vine cultivars.The force values derived were compared with the corresponding limit value of maximum force capacity (EN 1005-3). From the numerical values of the force and respective duration the weighted average force value (%) and weighted Borg score were calculated. From the comparison of the operators' assessment of the strain with the respective weighted scores, it appears that the latter are lower, that is to say that the values to be attributed to the strain in the Ocra Index may be lower.

Keywords: OCRA, WMSDs, force, dynamometric shears

Introduction

Vine pruning provokes strain (*Montomoli et. al.*, 2008, *Schillaci et al.,* 2009, 2010,). The need to develop force repetitively is recorded in the literature as a risk factor in causing pathologies in the tendon and muscle structure (Silverstein et al. 1986; 1987).
The force developed during the movement is defined as the biomechanical effort required to carry out a specific action or sequence of actions. It can be dynamic (applied directly by the operator for the execution of the action), or static (holding work tools or keeping single segments of the arms in a determinate position) (*Colombini et al*., 2005).

For the assessment of the risk involved in repetitive movements of the upper limbs with the OCRA Index (*Colombini e Occhipinti*, 1996; 2005), the force is usually estimated by means of the Borg CR10 scale, which is used to evaluate the subjective perception of the strain in relation to the entity of the strain itself.
The aim of this work was to attribute numerical values – derived from cutting trials with sensorised secateurs - to the strain necessary to carry out pruning and to assess whether the results obtained are comparable with the workers' perception of the effort. This would make it possible to establish whether it might be convenient to substitute measured values, weighted on the Borg scale, for subjective opinions.

Materials e methods

The evaluation of the forces focussed on the cutting of shoots of 5 cultivars that are widespread in eastern Sicily: Chardonnay, Merlot, Nerello cappuccio, Nerello mascalese e Nero d'Avola.
Besides field observations, for the subjective assessment of the force used, a questionnaire about the perception of the strain involved in making the cuts was administered to twenty pruning operators at the end of the observation period. The operators gave verbal rather than numerical answers (for example slight, moderate, etc) for each cultivar considered.

The verbal replies were then converted into a score on the Borg CR10 scale and the average score relative to the force was calculated.
The numerical values for the force were obtained from cutting trials carried out with traditional secateurs, which had had five sensors applied to their handles. Thanks to the sensors, the forces exercised by the hand and the duration of this strain could be ascertained (*Schillaci et al*., 2009, 2010).
The values obtained were compared with the limit value of maximum force capacity provided by the EN 1005-3 international standard (*Colombini et al.*, op cit). Regulation EN 1005-3, *Recommended force limits for machinery operation,* describes a method for calculating maximum force capacity limits (F_L), which can be carried out during the use of mechanical equipment, taking into consideration the various types of action and the characteristics of the target population. This value is obtained by starting with the values calculated for various activities carried out by the target population and then multiplying by a series of coefficients (*mv, mf, md*), which take into account the speed, frequency and duration of the activity.
The calculation of risk simulations using the force values measured were carried out with the software "midaOCRAmulticompiti" (Colombini e Occhipinti, 2005).
Values refer to the average of the distribution of forces among five regions of the hand.
Limits to the present work include the fact that the values for the force exercised by the hand were derived from laboratory and not field trials and that these trials involved staff not used to carrying out the work.

Results

From the observations and the questionnaire, very homogeneous answers were obtained regarding the operators' perception of the strain involved in pruning the various vine cultivars and it was possible to derive a single assessment for each cultivars and the corresponding value on the Borg CR10 scale (Tab.1).

Tab.1 – Strain assessments

Cultivar	**Assessment of strain**	**Borg value**
Nerello cappuccio	moderate	3.5
Nero d'Avola	Slight-moderate	2.5
Chardonnay	slight	2
Merlot	slight	2
Nerello mascalese	slight	2

The table below (Tab. 2) shows the mean force values and mean strain duration values obtained from the cutting trials using sensorised shears.

Tab. 2 – Force and duration values

	Force [N]				**Duration [s]**			
	Min	Max	**Mean**	St. Dev.	Min	Max	**Mean**	St. Dev.
Nerello cappuccio	9.00	37.50	**23.25**	14.25	0.45	1.90	**1.20**	0.75
Nero d'Avola	7.00	23.00	**15.00**	8.00	0.40	1.10	**0.75**	0.35
Chardonnay	7.50	20.00	**13.75**	6.25	0.20	1.20	**0.70**	0.50
Merlot	3.50	23.00	**13.25**	9.75	0.25	0.70	**0.47**	0.22
Nerello mascalese	4.00	20.50	**12.25**	8.25	0.17	0.62	**0.40**	0.22

The maximum capacity of force (F_L) for a task characterised by the thumb opposing the other fingers of the hand (typical when secateurs are gripped), and by rapid high frequency movements for the entire work shift was found to be 30 N. The value was obtained with the formula:

$$F_L = F_b \times mv \times mf \times md$$

where F_b = 250 N, *mv* = 0.8, *mf* = 0.3, *md* = 0.5 (EN 1005-3).
With reference to the same regulation, the simple movement of the limb holding the secateurs was assigned a value equal to 5% of the F_L, as it was not considered an action requiring force. Table 3 shows the percentage level of the derived values with respect to the limit value of maximum force capacity of 30 N.

Tab. 3 – Level with respect to F_L (%)

	Min	Max	Mean
Nerello cappuccio	30	125	78
Nero d'Avola	23	77	50
Chardonnay	25	67	46
Merlot	12	77	44
Nerello mascalese	13	68	41

As regards the weighted force value with respect to the corresponding F_L limit value and the weighted mean score using the Borg CR10 scale, table 4 shows, as an example, the calculations relative to the cultivar Nero d'Avola, considering the average time necessary to prune a plant to be 24 seconds (*Schillaci et al*., 2009) and using the mean force value.

Tab. 4 – Calculation of the weighted mean strain value and the force capacity required - F_L (%).

		A	**B1**	**B2**	**A x B1**	**A x B2**
	Sub-division of 24-second time cycle	Sub-division of % force level in time	% level with respect to FL	Borg scale score	Weighted force value (% FL)	Weighted Borg score
Mean Force	cuts = 7.5 s	31	50[1]	5.00[2]	15.63	1.56
	Limb movements = 16.5 s	69	5[3]	0.50[4]	3.44	0.34
	TOT = 24 s	**WEIGHTED MEAN SCORE**			19.06	**1.91**

[1] B1 = (mean force value x 100/ F_L) = 15 N x 100/30 N = 50
[2] B2 = B1/10 = 50/10 = 5
[3] B1 = 5% of F_L
[4] B2 = B1/10 = 5/10 = 0.5

The graph below (*Fig. 1*) shows the weighted Borg scores, relative to the mean strains for the 5 cultivars under consideration.

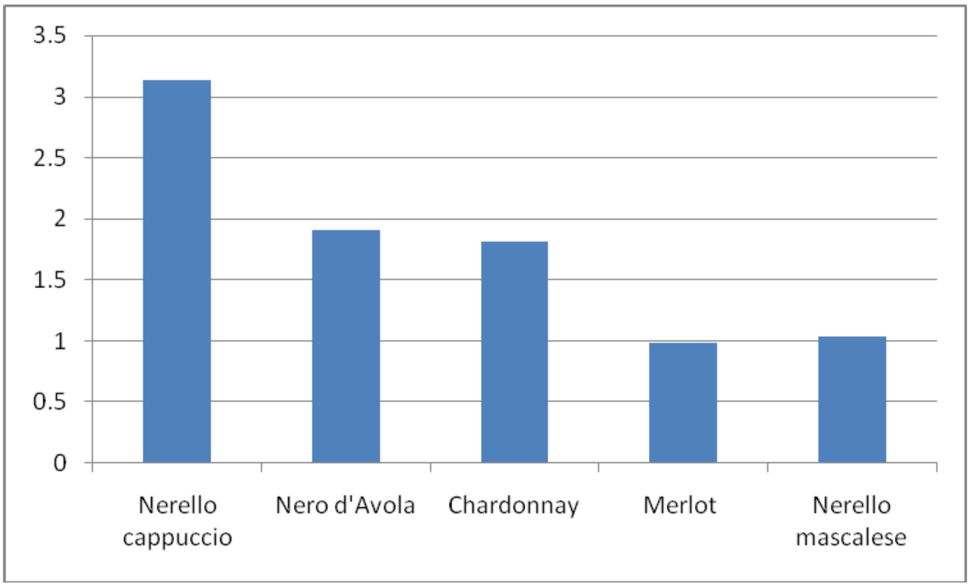


Fig. 1- weighted Borg scores for the 5 cultivars

From the calculations it can be seen that the weighted Borg scores and those derived from the workers' assessments have similar trends.
The values of this scale were compared with the workers' assessments.

Tab. 5 – Comparison of workers' assessments and the weighted scores

Cultivar	Operators' assessment Borg value	Weighted Borg score	Assessment
Nerello cappuccio	moderate 3.5	**3.13**	**moderate**
Nero d'Avola	Slight-moderate 2.5	**1.91**	**slight**
Chardonnay	slight 2	**1.82**	**slight**
Merlot	slight 2	**0.99**	**very slight**
Nerello mascalese	slight 2	**1.04**	**very slight**

From the comparisons it can be seen that the weighted assessments are lower than the subjective ones, that is to say that the cut in itself seems to be less onerous than reported by the operators in the questionnaire. This can be explained by the fact that the operator tends to over-estimate the muscular strain because he confuses it with the general tiredness he feels while carrying out the work. This tiredness depends both on a series of factors that characterise the work itself (not only the force required, but also the work environment, equipment, work rhythms and times, etc) and on the work context (organisation, motivation, personal relationships in the work place, etc.).
Figure 2 (below) presents the Ocra Indices relative to the 5 cultivars calculated with the strain values obtained from the operators' assessments (Ocra Index A) and the strain values derived from cutting trials using sensorised secateurs (Ocra Index B).

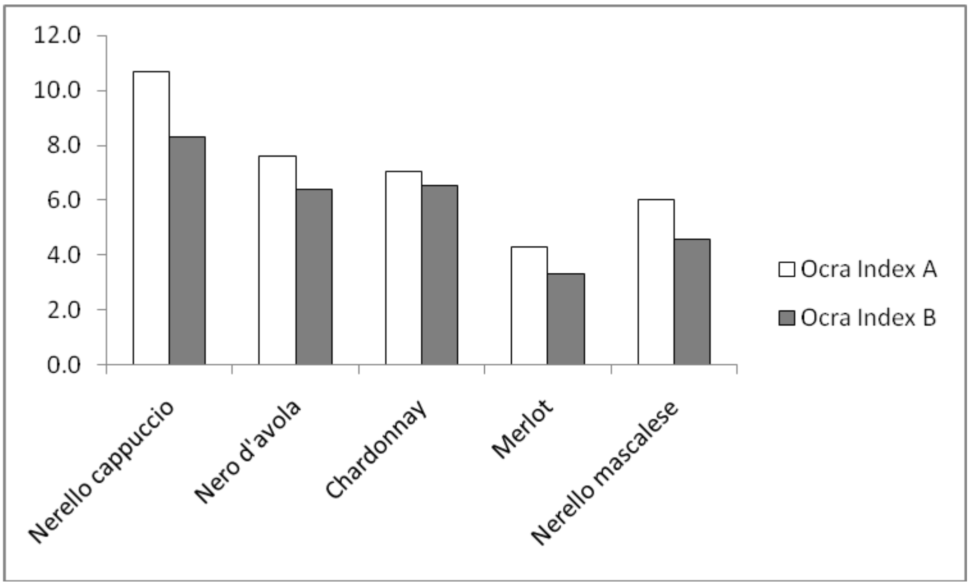


Fig. 2 – Results of Ocra Index Simulations

Ocra index B is, on average, 18.4% lower; the smallest drop (7.1%) occurred in the case of Chardonnay; the most significant difference (23.5%) was found for Merlot and Nerello mascalese – here the drop in the index coincides with a reduction of risk from medium to low. As regards Nerello cappuccio the index difference is 22.3%, taking the risk from high to medium.

The most representative bracket is the medium red one, where there is a medium exposure risk. Given the risk in this bracket, a percentage of pathological cases (number of subjects suffering from 1 or more diagnosed UL-WMSDs per 100 workers at risk) between 10.76 and 21.51% could be expected (*Colombini et al.*, op cit).

Conclusions and prospects

The values measured in the cutting trials carried out with sensorised secateurs were converted into weighted Borg scores relative to the average strains for 5 cultivars with the procedures and limits required by the method. It can be confirmed that Nerello Cappuccio requires the use of the greatest force, followed by Chardonnay, Nerello mascalese and Merlot, indicating reasonable correspondence between the methods.

From the comparison of the operators' assessment of the strain with the respective weighted scores, it appears that the latter are lower, that is to say that the values to be attributed to the strain in the Ocra Index may be lower.

In fact, simulating the calculation of exposure to risk with respect to the strain values obtained from the assessments of the operators (Ocra Index A) and the strain values derived from the cutting trials (Ocra Index B), the latter was found on average to be 18.4% lower.

To establish whether the subjective assessments should be substituted by the measured values weighted on the Borg scale, a further study on the number of cases actually diagnosed and the percentage of pathological cases estimated should be carried out as this would give more information about the strain and in particular establish whether there are significant differences between the number of diagnosed cases of upper limb disorders and the number foreseen by the Ocra model calculated with both subjective and measured strain values.

Bibliography

Colombini D., Occhipinti E., Fanti M. 2005. *Il metodo OCRA per l'analisi e la prevenzione del rischio da movimenti ripetuti.* Collana Salute e lavoro, Franco Angeli Editore.

Montomoli L., Colombini D., Fanti M., Ruschioni A., Ardissone S., Sarrini D., Coppola G., Sartorelli P. 2008. *Risultati degli studi e dell'analisi del rischio clinico da sovraccarico biomeccanico degli arti superiori in viticoltura e olivicoltura.* Seminario EPM, giugno 2008.

Schillaci G., Balloni S., Rapisarda V., Romano E., Bonsignore R., Camillieri D. 2009. *Valutazione del rischio da esposizione a movimenti ripetitivi degli arti superiori nella potatura manuale del vigneto*. Atti del IX Convegno Nazionale dell'Associazione Italiana di Ingegneria Agraria, Ischia Porto, 12-16 settembre.

Schillaci G., Balloni S., Bonsignore R., Camillieri D., Romano E. 2010. *Forze misurate e sforzi percepiti nel taglio dei sarmenti di vite*. III Convegno Nazionale di Viticoltura - CONAVI 2010, 5-9 luglio, IASMA, San Michele all'Adige (TN).

Schillaci G., Balloni S., Bonsignore R., Camillieri D., Romano E. 2010. *Hand forces during manual vine branches cutting.* CD-Rom Proc. Third Int. Cong. on Mountain Viticulture, Castiglione di Sicilia (Italy), May 12/14.

Schillaci G., Balloni S., Caruso L., Camillieri D. 2010. *Risk due to repetitive movements in manual vineyard pruning*. CD-Rom Proc. Third Int. Cong. on Mountain Viticulture, Castiglione di Sicilia (Italy), May 12/14.

Silverstein B, Fine L, Armstrong T. *Hand wrist cumulative trauma disorders in industry*. Brit J Indus Med 43:779-784, 1986.

Silverstein T, Fine L, Armstrong T. *Occupational factors and carpal tunnel syndrome*. Am J Ind Med 11:343-358, 1987.

Wood Dust Production and VOC (Volatile Organic Compound) Emissions During Mechanical Pre-pruning in Vineyards

Bonsignore R.[1], Romano E.[2], Caruso L.[1], Schillaci G.[1]
[1]*University of Catania. DIA, Mechanics Section*
Via Santa Sofia, 100 – 95123 Catania, ITALY.
Tel 0039 0957147518, Fax 0039 0957147600, giampaolo.schillaci@unict.it
[2] *Agriculture Research Council – Agricultural Engineering Research Unit (CRA-ING); Laboratory of Treviglio, via Milano 43, 24047 Treviglio BG, ITALY.*

ABSTRACT
During trials regarding the mechanization of vine pre-pruning, production of wood dust that could obstruct tractor filters was noticed. It was hence decided to investigate the production of chemical airborne pollutants during mechanical pre-pruning of vines, with the aim of assessing operators' exposure to wood dust and VOCs ( ). Experiments were carried out in 4 different vineyards during mechanical pre-pruning using pre-pruning machinery with rotating components.
The dust was collected with active filter sampling, using an IOM sampler. The VOC emissions were recorded with a portable measuring device based on photo-ionisation technology. The data was processed with R software for variability distribution and to investigate the influence of the independent variables considered. The results show that the values found for wood dust were below the limits established by Italian regulations (5 mg/m^3). However, the daily exposure of 1.55 mg/m^3 that was found indicates the importance of risk assessment. The exposure to VOCs found leads to the conclusion that during mechanical pre-pruning quantities of airborne pollutants are released that could put the operator at risk if he/she is not suitably protected.

Keywords: wood dust, VOC, airborne pollutants, operator's health, vineyard pre-pruning

1. Introduction

During trials regarding the mechanization of pre-pruning, the production of wood dust that could obstruct tractor filters was noticed. The aim of this work was both to measure the concentration of wood dust and VOC (Volatile Organic Compound) emissions from the machines and to assess the exposure risk of the operator during pre-pruning.
The literature available and the methods used for sampling do not consider the agricultural sector but refer to industrial environments and, in just a few cases, to the forestry sector. Given the scarcity of information another aim of this research was to assess the measuring procedures adopted.
D. Lgs (Legislative decree) 66 of 25 February 2000, which modified article VII of *D.Lgs 626/94 "Protezione da agenti cancerogeni e mutageni*", ("Protection from carcinogenic and mutagenic agents"), subsequently absorbed into the Consolidating Act (Legislative decree 81/2008), added hard wood dust to the category of carcinogens affecting the nasal and paranasal sinuses, in accordance with the International Agency Cancer Research (I.A.R.C.) classification.
In Italy the maximum value for exposure to wood dust per workday (TLV-TWA) is 5 mg/m^3 for "hard wood" or without distinction if the hard wood is mixed with other wood dust (Legislative decree) 81/2008 - Title IX).

Hard wood dust sampling strategy meets the requirements of the regulations set out in Legislative decree 81/2008, technical regulations (UNI EN 481/94, UNI EN 689/97, UNI EN 482/98), methods (NIOSH 0500-0600 Methods) and guide lines (Arcuri *et al., 2001)*.
The research on occupational exposure to wood dust in Europe (WOODEX) indicates that in forestry sites there are low levels of exposure (0,12 mg/m^3 of inhalable fraction) because of the characteristics of the work (outdoors), the intermittency of exposure (use of chain saw) and the low inhalability of the dust produced by the saw (FIOH-INRS, 2005).
The variables affecting the concentrations present in the air are: the number of sources emitting the agents (tractors, operators, wood from pruning), the production speed in relation to the production capacity, the type and position of the source and the dispersal of the agents due to air movements **(**Aikten RJ et al, 1999; Marconi A. 2002, Campopiano A. et al, 2008). The variables connected with individual actions and behaviour are: closeness of the person to the sources and duration of the task (UNI EN 689/97).
As far as operator exposure to VOCs is concerned, the regulations in force are not specific and do not provide evaluation criteria and nor do they indicate the maximum concentrations that should be respected in the work place. The only research body expressing an opinion is OSHA, which gives a concentration of 0,5 ppm as a limit; while as regards petrol the Italian regulations in force (*T.U. D. Lgs 81/2008 allegato XLIII* [Consolidating Act Legislative decree 81/2008 attachment XLIII]) establishes an occupational exposure limit of 1 ppm, in contrast with the ACGHI limit of 0,5 ppm.

2. Methodology

The experiments to find and assess the risks from exposure to dust and VOCs during vineyard pre-pruning were carried out in four lots cultivated with vines (A,B) situated in south-east Sicily in the Pachino area and (C,D) in a vineyard in the Castiglione di Sicilia area on the north face of Mt Etna (CT). For each vineyard note was made of the type of plantation, the cultivation techniques adopted and the way the machines were used (Tab. 1). The physical characteristics of the soil were determined with granulometric analysis and the humidity was determined with gravimetric analysis. During the trials the air temperature, relative humidity and wind speed were recorded

Tab. 1 – Characteristics of the 4 vineyards

Vineyard	Variety	Year of planting	Spacing of vines (m)	Density (plants/ha)	Row Length (m)	Headland width (m)	Pruning type
A	Nero d'Avola	2001	2,1x0,9	5.000	216	4	Spurred cordon
B	Inzolia	2004	2,1x0,9	5.000	221	3	
C	Nerello mascalese	2006	2,2x1,0	4.545	190	5	
D	Merlot	2004	2,2x0,8	5.000	200	5	

2.1 Mechanical pre-pruning

Although mechanical pre-pruning does not eliminate manual work, it reduces the pruning time, particularly because of the efficient removal of the cut shoots, and for this reason it is a widespread practice in mechanised vine cultivation. The study focussed on two pruning machines with rotating cutting devices (Tab 2) installed on a tractor.

Tab.2 - Caratteristiche prepotatrici

Vineyard	Pre-pruning machine model (blades)	year	mass (kg)	Tractor
A	Pm (9)	2003	550	FIAT DT 7286, 4 RM, 55 kW
B				
C	Pe (9)	2004	605	FIAT DT 7286, 4 RM, 55 kW
D				

The pre-pruning machines (fig.1) used in the trials are straddling machines with a double stack of 9 blades (discs) joined to an inverted U-shaped carrying framework. Height and width regulation, as well as the opening of the two columns are controlled by oleodynamic cylinders commanded by electrovalves. The "P_e" machine is towed by a 55 kW double traction tractor – not a recent model. The pre-pruning machine "P_m" is used by a company that carries out work for third parties. It is the same make as the other machine but the rotating speed of the discs has been increased with respect to the factory version. The machine is towed by a double traction tractor, again with a power of 55 kW.

2.2 The measuring instruments

The dusts were measured by active filter sampling. As regards equipment the IOM (Institute of Occupational Medicine) sampler was chosen and as regards the filtering element, a fibreglass membrane with a diameter of 25mm and a porosity of 1 µm was used. The sampler was connected to a portable pump with an APEX Casella battery (*Fig. 2*), and there was electronic control of flow and automatic compensation for pressure variations, in compliance with regulation UNI –EN 1232. The sampling flow during the trials was regulated to 2 L/min.
The VOCs were detected using a portable measurer - *MiniRAE 3000* (*Fig. 2*), with a functioning principle based on photo-ionisation techniques – Detector PID. The values measured were visualised and elaborated with the specific *ProRAE Studio* software, which made it possible to draw up graphs of the VOC concentration against time and to save the data for further analysis (*Blandini G. et al*, 2009). The data was processed with software R for variability distribution and to investigate the influence of the independent variables considered.

2.3 Method

In each vineyard sampling was performed by placing the instruments in two pockets of the work jacket worn by the operator and carefully attaching the air and filter carrier samplers near the respiratory zone (*Fig. 3*).
In order to quantify the VOCs Isobutylene was used to calibrate the equipment.
Analysis of the wood dust deposited on the filter was carried out by gravimetric measurement using a Mettler Toledo XP56 analytical balance with 0.001mg sensitivity.
Before each weighing the filters were conditioned in a climatic room (dryer) for at least 24 hours.
The calculation of the airbourne dust in the air sample taken was obtained by dividing the difference between the weight before and after sampling by the volume of air sucked in during sampling, following the method contained in the HSE-MDHS 14/3 indications.
The calculation of occupational exposure both as regards dusts and VOCs was carried out over a reference period of 8 hours (weighted mean over 8 hours, TWA):

C exp,g= C tc * Te/T0 (C esp,g= daily exposure over 8 hours, C tc= polluting agent concentration durino sampling time, Te= t exposure = 6.40 hours, T0 = 8 hours)

Fig. 1 Pre-pruning machine working

Fig. 2 – Apex Casella, sampler IOM, MiniRAE 3000

Fig. 3 Placing of instruments on operator

3. Results and discussion

3.1 Soil characteristics

The mean relative humidity of the soil was found to be 19% in vineyards A and B and 24.8% in vineyards C and D. From the granulometric analysis it was found that the soil in A and B was of a medium consistency and made up of 16.9% clay, 26.3% lime and 56.8% sand. In C and D the soil was of medium consistency tending towards sandy with a composition of 6% clay, 26.2% lime and 67.8% sand. At the time of the trials the soil was not found to be particularly dry or dusty.

3.2 Wood dust

Table 3 shows the results of the analyses. The dust exposure values are much lower than the limit exposure value of 5 mg/m^3 (inhalable fraction) established by Legislative Decree 81/2008. The low values (between 0.57 and 1.55 mg/m^3,) are due to the characteristics of the work environment (open air), the intermittency of the exposure (suspended during the manoeuvres at the end of rows, to the work time (6 h 40' – less than 8 hours) and to the type of cut made by the pre-pruning machine – removal of portions of shoot and with the production of wood shavings and a limited amount of fine dust.
On site B a greater daily exposure to dust was found (1.55 mg/m^3). This site was characterised by the high work capacity of the machine, the average wind speed of 3,7 m/s and its direction - orthogonal with respect to the forward movement of the machine (Tab. 4).

Tab. 3 – Analysis results

Vineyard	**Dust concentration (mg/m^3)**	**C exp,g = daily exposure (mg/m^3)**
A	0.85	0.68
B	1.94	1.55
C	0.71	0.57
D	0.72	0.57
Mean	1.05	0.84
Standard deviation	0.59	0.47
Geometric mean	0.96	0.76
Q Dev	1.05	0.68

Tab. 4 – Work conditions

Vineyard	Soil humidity (%)	Mean relative humidity of air (%)	Mean external temp (°C)	Mean wind spead (m/s)	Pump aspiration duration (h)	Quantity of air aspirated (litri)	Actual time pre-pruning machine in field (h)	Speed of pre-pruning machine progress (km/h)	Cr (ha/h)
A	19,0	38,7	13,6	1,8	3,20	400	2,40	6,60	1.18
B	19,1	49,0	16,4	3,7	3,28	418	3,18	6,20	1.06
C	24,8	71,9	10,5	1,5	3,01	364	2,50	2,31	0.39
D	24,8	41,0	9,7	1,3	2,12	265	2,10	2,90	0.40

In the experimental conditions dictated by the use of the IOM sampler, as already pointed out by other authors (Biondi et al. 2002), there is the problem that large particles extraneous to the inhalable fraction to be sampled are captured. In these cases the problem was resolved by manually removing the small wood shavings before weighing the sample.

The data obtained was analysed for possible correlations between the factors observed. From the data elaboration it emerged that the duration of the trial did not affect the dust concentration and that neither did the pump aspiration duration or the relative air humidity percentage. The results show similar trends to those for aspired air and speed of progress of the machine. The soil humidity is inversely proportional to the concentration but not significantly so. The factors with marked correlation are the hours of the pre-pruning machine use in the field (93%), the external temperature (88%) and the wind speed (99%).

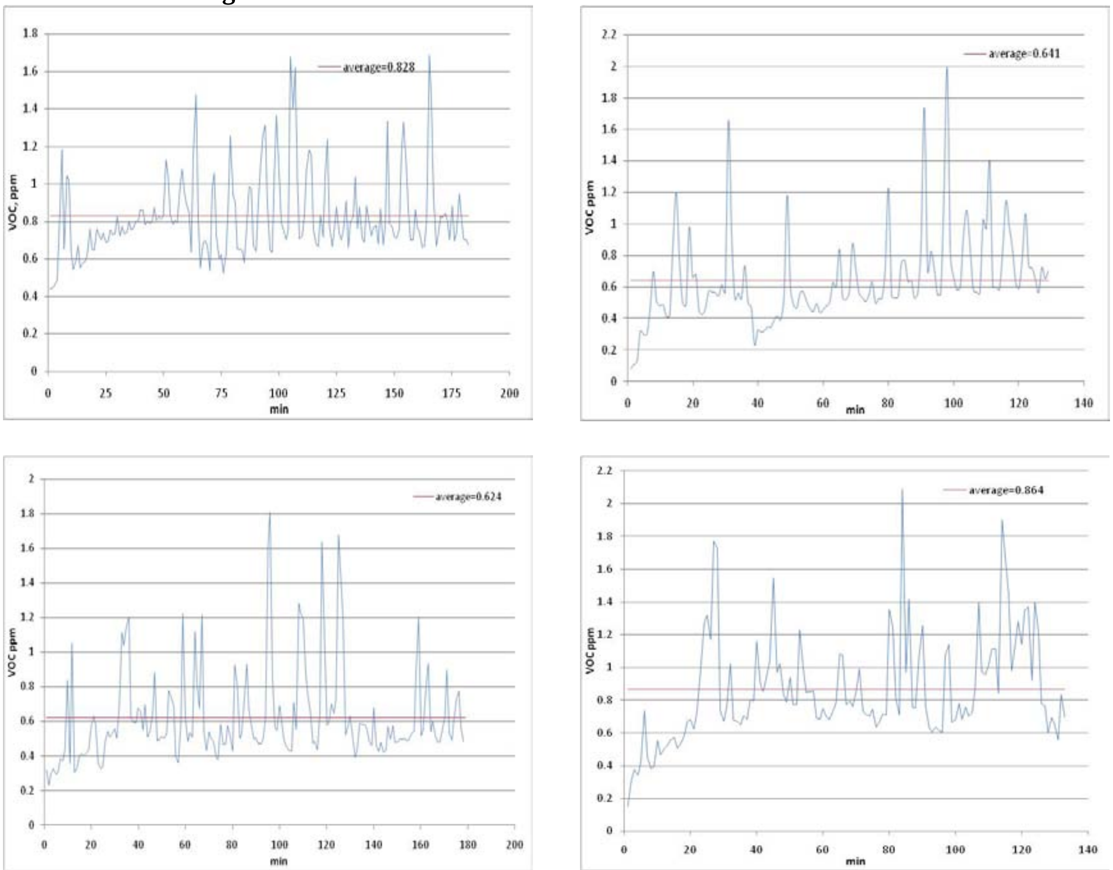
3.3 Volatile organic compound VOCs

If the exposure values found in this preliminary evaluation are compared with the limit value for benzene, it would seem that pre-pruning represents an immoderate chemical risk for the operator and that consequently further periodic tests should be organised.
The graphs in figure 4 shows the maximum concentration values found in the four trial conditions plotted against time. It is possible to see that there are concentration peaks corresponding to the turns at the end of the rows. These are probably due to the wind direction, which was often orthogonal with respect to the advance of the machine.

Tab. 5 – Analysis results

Vineyard	**VOC (ppm)** MIN PID	PID AVG	MAX PID
A	0,68	0,73	0,83
B	0,41	0,49	0,65
C	0,40	0,48	0,66
D	0,63	0,72	0,90

Fig. 4 Instantaneous Max PID concentration trends in the 4 trial conditions



Elaboration of the data obtained revealed an inverse correlation (-80%) between the VOCs and the air humidity, which could indicate that when the air is dry there is a greater quantity of volatile compounds.

It emerged that the VOCs were influenced in a statistically significant way by the trial vineyard conditions. On the other hand, the time of sampling and trial repetition had no influence on the final result. This indicates a high repeatability of the trial as regards both time and previous results.

From the variance breakdown carried out with R software there would appear to be a first order interaction between the VINEYARD factor and the TIME factor indicating that the final result is certainly influenced by the VINEYARD factor but not by the TIME factor, but that in some vineyards the time influenced the response value.

The Tukey test was applied to the mean obtained from the elaborated data (Tab. 6).

In general the VOC values were influenced by the conditions prevailing on the day the vineyards were studied. The correlations seem to show that the vineyard factor to have most influenced the final result was the low humidity present on the day of the trial

Tab. 6 – Tukey test on vineyard means.

1 0.67763 a	Vineyard A
2 0.40670 c	Vineyard B
3 0.51562 b	Vineyards C, D
DMS	0.06474

4. Conclusions

As concern dust production, the bibliography available and methodology adopted in the past do not consider the agricultural sector but refer to industrial environments and, in just a few cases, the forestry sector. This work represents the first results regarding exposure to wood dust and VOC emissions during mechanical pre-pruning, a widespread operation in mechanised vineyards. In order to monitor the production of dust in the open field it is necessary to refer to what is rigidly foreseen for closed environments (sawmills, artisan workshops). It can be said that as regards the wood dust, the mean values found were far below the limits established by the current regulations in Italy (5 mg/m^3). However, machine P_m with higher speedy blades presents more dust than the other one. In fact, in case B, the daily exposure values were found to be 1,55 mg/m^3. Although this is well under the limit mentioned above, the EU Scientific Committee for Occupational Exposure Limits (SCOEL) claims that exposure to wood dust above a 0,5 mg/m^3 of total dust (equal to 1-1,5 mg/m^3 inhalable fraction) can have an effect on the lungs and should, therefore, be avoided in order to protect workers (*Martinotti*, 2008). Also the situation regarding VOCs seems worrying, in that preliminary analyses of the exposure would seem to indicate that during mechanical pre-pruning airbourne pollutants are produced in a quantity that places the operator at risk if he is not adequately protected. Analysis of the results showed the influence of environmental factors, particularly that of the air humidity. Also aspects connected to the production of exhaust fumes and the correctness of the tractor - pre-pruning machine relationship are linked to VOC emissions and this should be studied further. Given these considerations, the investigation should be extended, focussing on the influence of air currents (intensity, constancy and direction) and on the main climatic considerations that can be found in an open environment.

5.**Bibliography**

ARCURI C., BIANCHI A., BOSI A., CACCHI F., CERVINO D., DI STEFANO S., FERRI F., GOVONI C., GUGLIELMIN A., PASSERA G., POLETTI R., VENERI L. 2001. *Problemi applicativi ed interpretativi del titolo VII del D. Lgs. 626/94 per le polveri di legno duro.* In Govoni C., Ferrari D. - Rischio Prevenzione e protezione da agenti cancerogeni e mutageni. Modena. 171-212.

BIONDI P., MONARCA D., CECCHINI M. 2002. *La valutazione del rischio da esposizione a polveri di legno duro: indagine sperimentale e metodologica*. Proc. Convegno nazionale AIIA Alghero-Sassari, 11-15 settembre, 377-390.

BLANDINI G., CERRUTO E., MANETTO G. 2009. *Rischi da polvere e da VOC per gli addetti alle operazioni colturali negli agrumeti.* Atti su CD-rom del IX Convegno Nazionale AIIA, 12-16 settembre, Ischia Porto (NA).

Decreto legislativo 9 aprile 2008 n. 81. Attuazione dell'articolo 1 della legge 3 agosto 2007, n. 123, in materia di tutela della salute e della sicurezza nei luoghi di lavoro – Titolo IX, Allegato XLII –XLIII. Suppl. ord. n.108, G.U. n. 101 del 30 aprile 2008.

FIOH, INRS. 2005. *Exposure measurements of wood dust in the European Union.* WOODEX report UE. 1-201.

IARC. 1995. Monographs on the evaluation of carcinogenic risks to humans:*Wood dust and Formaldehyde.* Lyon (France), 9-215.

SCHILLACI G., BALLONI S., CAMILLIERI D., CONTI A., TIRRÒ G., CARUSO L. 2009. *Determinazione di residui sospesi in aria dopo trattamenti in serra con agrofarmaci.* Atti su CD rom del IX Convegno Nazionale AIIA 12-16 settembre, Ischia Porto (NA).

SCHILLACI G., CARUSO L., CAMILLIERI D., BONSIGNORE R. 2009. *Macchine e tecniche di potatura invernale nella vite allevata a cordone speronato.* Atti su CD rom del IX Convegno Nazionale AIIA 12-16 settembre, Ischia Porto (NA).

SCHILLACI G., CARUSO L., BONSIGNORE R., CAMILLIERI D., EMMA G., TIRRÒ G., RAPISARDA V. - 2010. *Produzione di polveri di legno e emissione di VOC durante la prepotatura delle viti.* Third International Congress on Mountain Viticulture CERVIM, Castiglione di Sicilia (Italy), May 12/14.SCOEL. 2003.

Recommendation from Scientific Committee on Occupational Exposure Limits for Wood dust. SCOEL/SUM/102 final.

UNI CEN, 1994. Norma UNI EN 481 *"Atmosfera nell'ambiente di lavoro. Definizione delle frazioni granulometriche per la misurazione delle particelle aerodisperse".* Ed. Ottobre 1994.

UNI ISO, 1998. Norma UNI ISO 7708 *Qualità dell'aria. Definizioni delle frazioni granulometriche per il campionamento relativo agli effetti sanitari.* Ed. settembre 1998.

Development of a Towed Multi-Function Row Straddling Machine for the Cultivation of Goblet Vineyards

Bonsignore R.[1], Romano E.[2], Manetto G.[1], Caruso L.[1], Schillaci G.[1]
[1]*University of Catania. DIA, Mechanics Section*
Via Santa Sofia, 100 – 95123 Catania, ITALY.
Tel 0039 0957147518, Fax 0039 0957147600, giampaolo.schillaci@unict.it
[2]*Agriculture Research Council – Agricultural Engineering Research Unit (CRA-ING); Laboratory of Treviglio, via Milano 43, 24047 Treviglio BG, ITALY.*

Abstract

To guarantee the mechanisation of a goblet vineyard, a handmade pre-prototype of a multi-function row straddle machine towed by a common vineyard tractor was built. Trials carried out in vineyards gave encouraging results (Schillaci et al., 2008, 2009, 2010). Currently a project is under way for the improvement of the pre-prototype as an innovative machine (ENAMA, 2009) with collaboration between the constructing company FA.MA (MN), the DIA in Catania and the CRA-ING in Treviglio (BG). The pre-prototype has been redesigned to increase the number of tools applicable to the frame and the quality of operations carried out, respecting both the safety of the workers and quality of the product. The final aim is to guarantee mechanisation of goblet at a contained cost. The frame has been redesigned to optimise size, weight, sections and attachment devices for the accessory equipment which it will carry and/or activate. The newly adopted technical solutions were chosen taking into account the form of the goblet vines (expanded foliage, short trunk, vegetation near the soil), the availability of reliable but simple tools, stability, safety and flexibility of their use. The modifications were identified also by means of field trials carried out with the first version of the pre-prototype. After the redesigning phase, trials were carried out to study the performance of the mechanisms. The multi-function frame works on both sides of the row, so with only one passage the machine is able to complete the operation on the row. The modifications made to the original prototype allowed for a reduction in the attachment and detachment times of the tools to the frame. Furthermore, they increased the number of applicable tools as vine shoot tipping, leaf stripper and a sprayer equipped with a liquid recovery system thereby significantly reducing the amount of the product lost in the air or on the ground. Finally, to guarantee better performance in the field, it is now possible to regulate the working position of the tools and their height from the ground. Further results are expected when the work will be completed.

Keywords: vine cultivation, ENAMA, vine mechanisation, pruning, spraying

1. Introduction

In Italy each region is said to have its own forms of viticulture; however, all the machines that have appeared on the market over the years have been designed for VSP trellised vines (Spezia et al, 2008), which has led to a reduction in the number of cultivation systems, and a generalized leveling of viticulture towards single models (Fregoni M., 2005).
The need has arisen for technological solutions aimed also at the cultivation of the goblet vine to satisfy the needs of the growing number of firms who have chosen to privilege this form of cultivation for the benefits that, thanks to current techniques regarding both planting and

agronomic management, can be seen in terms of quality of the product (Fregoni, 2005) and environmental sustainability (Schillaci *et al* 2009).

The greatest obstacles to the mechanized cultivation of the goblet are the voluminous form (three dimensional, expanded), the foliage that is close to the ground and the distance between the rows that is reduced and/or irregular. In order to resolve some of these inconveniences, some vineyard managers have adopted a two-dimensional wall form, growing two branches parallel to the row and resting them on a wire held up by short poles. In this case, it is possible to adopt expensive self-propelled row-straddling machines equipped with specially built operating machinery. Others have kept the three dimensional form and increased the distance between the rows; the distance between plants on each row has been reduced (to keep a high load of fruit buds per hectare despite the widening between the rows) and the height of the plants has been raised (for the same agronomical reason), though keeping the relationship height/distance to <1 to avoid the reciprocal shadowing of the rows. In this case, it is possible to carry out cultivation operations by using common vine tractors equipped with tools that can easily be found on the market. However, given the height of the plant a row-straddling tool-carrier frame may be used, which can operate at the same time on both sides of the row. Tests carried out on a handmade pre-prototype of a multifunction tool-carrier, equipped in a basic way with easily found tools, have guaranteed an efficient mechanization in goblet vineyards (Schillaci *et al*., 2008), particularly concerning treatments for weed-killing and anti-fungal protection (Botrytis), tilling the soil and pruning.

Through a project of development of innovative machinery (ENAMA, 2009) and the collaboration between the building company FA.MA (MN), the DIA of Catania and the CRA-ING of Treviglio (BG), the handmade pre-prototype has been redesigned and perfected, and a towed, row-straddling tool-carrier has been created which satisfies the requirements of the rational cultivation of goblet vines. This work refers to the implementation of the machines to make their use more efficient and economical, increasing the number of utensils that can be applied to the main structure, which has been redesigned to guarantee safety and speed in assembling the numerous tools required.

2. Materials and Methods

2.1. The Pre-prototype

The project idea arose from the need to perfect a pre-prototype built by an artisan and subject of the first positive tests in a vineyard in eastern Sicily consisting of goblet vines with inter-row spaces at least 1.8 m wide (Balloni *et al* 2008).

The machine consists of a steel frame, supported by wheels with tyres (see figs. 1 and 2); it is rectangular, (1,60 m x 0,95 m), with a carriage of 2.20 m, ground clearance 1.4 m and support headframe situated at a height of 1.80 (Schillaci, 2009). It holds utensils to carry out some cultivating operations including common trimmers for pruning that can be found commercially. All the equipment is assembled on the main frame by rudimental clamping systems. For antibotrytical treatments, carried out during the setting of the fruit, a distribution apparatus fitted with a 300-litre tank is mounted on the frame; the initial tests have shown good efficiency, given the machine can proceed to a speed of about 4.6 km an hour.[1] Regarding the mechanical pruning, it was possible to obtain a unitary time of 1.1 h ha^{-1}, with a progress speed of 1,2 m s^{-1}, which is restricted by the requirement that the vegetation should not be bent backwards (that would cause undesirable not clear cut in the vine branches). There is a considerable saving in manpower in the pruning compared to the traditional method of bending and knotting shoots in the upper parts of the plant, called "*ammazzonatura*" (bending the shoots) quantified in 50 h ha^{-1} (Schillaci *et al* 2009) (figs. 3 e 4).

Multifunction tool-carrier – technical characteristics		
Transversal size	(m)	1.60
Longitudinal dimension	(m)	0.95
Ground clearance (excluding wheels)	(m)	1.40
Height of support headframe	(m)	1.80
Track	(m)	2.20
Tank capacity	(L)	300
Engine power	(kW)	65


Figs. 1 e 2 – the towed row-straddling carrier

Fig. 3 – Pruning

Fig. 4 – Chemical weed-killer

3. Results

3.1 Technical characteristics of the innovative machine

On the basis of the observations and trials carried out, a complete revision of the pre-prototype has been carried out, including detailed designs of the frame. The choice of technical solutions was made considering the form of goblet vines (wide foliage, short trunk, vegetation near the ground), the use of simple, dependable tools, and the stability and flexibility of the use of the tool. The frame was streamlined as regards weights, measures and sections; it is rectangular (1,80 m x 0,95 m), with a carriage of 2.24 m, ground clearance

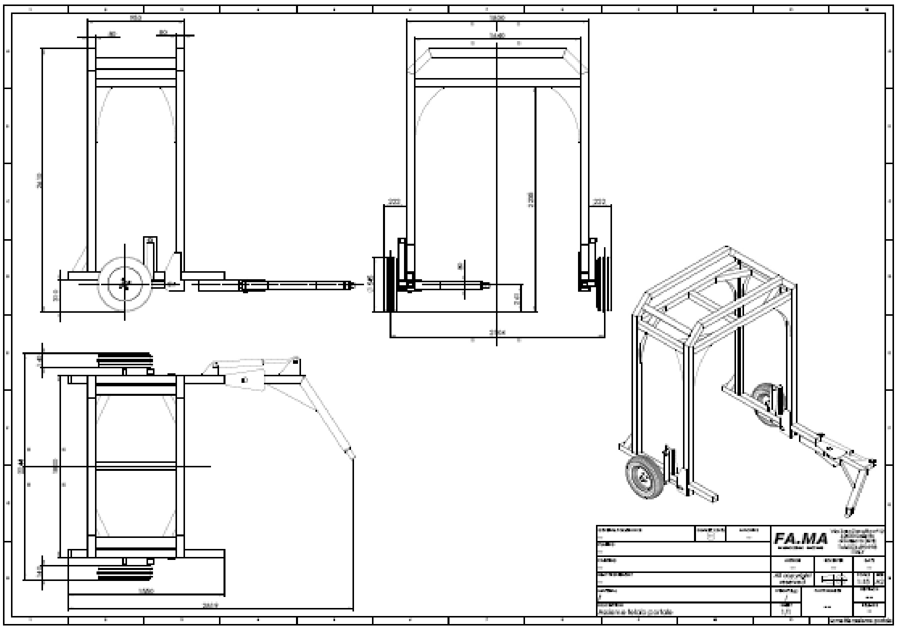
2,24 m and maximum height (including frame for tank) of 2,61 m.
The structure was raised by 50 cm compared to the initial model in order to be able to apply a standard system of tunnel spraying that can be found on the market. Two tires, each equipped with a hydraulic piston, adjust the height of the frame according to the desired height of the work. The tow-bar has also been equipped with a hydraulic piston able to keep the frame in the required path also on ground that is sloping and/or soft and makes turning easier at the end of the row, even in narrow spaces. The machine is equipped with supports for the application of mechanical systems, a piston pump, an extra tank for oil and oil-pressure components.

To obtain a swift, easy application of the utensils, a counter-frame has been prepared. For trimming and pruning, the lateral mowing bars are used and, where needed, the bars for topping, all equipped with mechanisms to regulate the distance between the bars and the rows.

The soil is turned over with a pair of rotovators, each with 4 blades that straddle the rows and stagger operations between them. They are equipped with rotors with a vertical axle and a mechanism that makes them withdraw automatically on contact with a trunk. In the case of compact soil, also two inter-row cutters with a horizontal blade can be mounted.

The spraying apparatus is constituted by a tunnel system equipped for catching and recovering liquid released out of target (that often reaches rates higher than 50% of the total amount sprayed (Ade *et al*. 2005, Baldoin *et al*. 2009, Pergher *et al*. 2007, 2009)).
The tunnel comprises two lateral sides (m 2,2 x m 1,20) each equipped with a bar with 5 nozzle-holders, nozzles (Albuz APE 80 red) and a lower recuperation tank linked to the recirculation of the recuperated liquid.

The frame allows the tunnel to be lowered so that it touches the surfaces of the ground, favoring the spraying of vegetation nearer to the ground. The tank, with a capacity of 500 litres (according to the standard, like all spraying machines), is situated in the upper part, in its own support frame with equipment.



Transversal dimension (including wheels)	(m)	2,24
Longitudinal dimension of the frame (without wheels)		1,80
Longitudinal dimension of the frame	(m)	1,55
Ground clearance (including wheels)	(m)	2,24
Track	(m)	2,10
Maximum height	(m)	2,61
Tank capacity	(L)	500
Engine power required	(kW)	65

4. Conclusions

The "multifunction towed row-straddling frame" is a specific proposal for the goblet vine, a cultivation form that was been practically abandoned because of the high level of manpower it requires. The row-straddling feature has the advantages of providing stability to the whole, and doubling the work front, compared to equipment that operates on only one side of the row.

The functions carried out by the machine, opportunely redesigned and perfected, make it particularly interesting for all vine-growing firms with surfaces cultivated with single stake goblet vines, without wires and support poles, and with wide rows which allow common vine tractors to pass through.

Currently, the frame holds the tools for pruning, tilling the land, using chemical weed-killing and spraying the foliage. Other operations can be added, as shoot tipping and defoliation.

The innovative prototype doubtlessly brings ecological-environmental advantages, thanks to the spraying apparatus which is equipped with a mechanism for spraying pesticides, which would otherwise be dispersed in the air and in the ground, thus enabling savings in the use of such products.

As soon as the prototype is completed, it will undergo tests in the field to assess the functionality of each part.

We maintain that the completion of this machine will enable us to overcome the limits connected to the historical unavailability of adequate mechanization for goblet vines.

5 Bibliography

Ade G., Balloni S., Pezzi F. *Valutazione di una irroratrice a tunnel nei trattamenti al vigneto.* Informatore Fitopatologico 6(LV)37:43 (2005).

C. Baldoin, A. Dalla Pace, C. De Zanche, D. Bondesan, M. Bietresato. *Effetto del volume e della polverizzazione sull'efficienza del recupero e sull'efficacia fitoiatrica di un'irroratrice a tunnel nei vigneti.* Atti su CD-rom del IX Convegno Nazionale AIIA "Ricerca e innovazione nell'ingegneria dei biosistemi agro-territoriali". 12 – 16 Settembre, Ischia Porto (NA) (2009)

Balloni S., Bonsignore R., Caruso L., Schillaci G. (2008). *Fabbisogno di meccanizzazione innovativa nei vigneti allevati ad alberello nella Sicilia sud-orientale.* Atti del 2° Convegno Nazionale di Viticoltura, Marsala, Italia, 14-19 luglio (2008).

ENAMA. Selezione tecnica per la concessione di contributi allo sviluppo di linee di meccanizzazione innovative (2009)

Fregoni M., 2005 – *Viticoltura di qualità*. Ed. Phytoline.

G. Pergher, R. Petris. *Effetto della portata d'aria sulla deposizione di un'irroratrice ad aeroconvenzione in vigneto allevato a Guyot.* Atti su CD-rom del IX Convegno Nazionale AIIA "Ricerca e innovazione nell'ingegneria dei biosistemi agro-territoriali". 12 – 16 Settembre, Ischia Porto (NA) (2009)

G. Pergher, R. Petris. *Canopy structure and deposition efficiency of Vineyard sprayers*. Journal of Agricultural Engineering, 2 pp. 53-60 (2007);

Schillaci G., Caruso L., Conti A., Bonsignore R. *Una nuova operatrice per la meccanizzazione dei vigneti ad alberello.* Atti su CD-rom del IX Convegno Nazionale AIIA "Ricerca e innovazione nell'ingegneria dei biosistemi agro-territoriali". 12 – 16 Settembre, Ischia Porto (NA) (2009)

Schillaci G., Caruso L., Bonsignore R., Balloni S., Conti A. *Sviluppo di meccanizzazione innovativa per la coltivazione dei vigneti ad alberello.* WWW.INFOWINE.COM – Rivista Internet di Viticoltura ed Enologia, n°11/2 (2009)

Schillaci G., Manetto G., Bonsignore R., Balloni S., Caruso L., 2010. *Sviluppo di telaio scavallatore multifunzione trainato per la coltivazione del vigneto ad alberello.* Third International Congress on Mountain Viticulture CERVIM, Castiglione di Sicilia (Italy), May 12/14.

Spezia G., Vieri M., 2008. *La gestione della chioma nella moderna viticoltura.* MMW n°5/2008.

Evaluation of the Risk Arising From Repetitive Movements During Manual Pruning in Vineyards by Using Measured Forces

Camillieri D., Bonsignore R., Caruso L., Schillaci G.
University of Catania. DIA, Mechanics Section
Via Santa Sofia, 100 – 95123 Catania, ITALY.
Tel. +39 095 7147512, Fax +39 095 7147600, giampaolo.schillaci@unict.it

Abstract
Winter vineyard pruning is mainly manual (., 2009), with the use of traditional secateurs. During pruning cuts follow on from one another in rapid succession and with a certain regularity and hence this operation characterised by high frequency and a stereotypic load on the upper limbs can in time cause , ( ). The aim of the work was to assess the risk arising from repetitive movements of the upper limbs during manual pruning in vineyards. The Ocra Index ( ) was used. The research was carried out in a vineyard situated on the north face of Etna. Seven sites were studied, this involving 30 pruning operators and 12 hours of observation. The process was broken down into component phases and the times and method of execution were recorded for the various operations. The number of cuts per trunk was also noted. Besides data collecting and observations in the field, examination of the video film shot during the work made it possible to obtain or confirm further information about the frequency, stereotypic nature and posture. To assess the force used, a questionnaire on the perception of force required was given to each worker at the end of the survey. Also the health problems correlated with the various tasks were found by means of a questionnaire. The evaluations show that the dominant limb that holds the shears and makes the cut is at risk. This is confirmed by the answers to the questionnaire, as nearly all those interviewed stated they suffered from pain in their upper limbs. The most important factor, besides frequency and posture is the lack or inadequate distribution of rest periods together with the force required, as although the latter is not excessive, it is repeated throughout the work shift. The simulations showed that redesign of workstations can lead to OCRA indices reflecting a low or borderline risk level.

Keywords: OCRA, WMSDs, vine cultivation, health, safety

Introduction
Vineyard winter pruning is still carried out manually even when preceded by mechanised pre-pruning. Although facilitating equipment is becoming more widespread, traditional manual secateurs and long handled shears remain the tools most often utilised. During pruning cuts follow on from one another rapidly and with a certain regularity, particularly when the manual pruning is preceded by use of a pre-pruning machine. These operations, which are characterised by high frequency and a stereotypic load on the upper limbs, can in time, put the muscular skeletal system at risk and cause WMSDs (*Work related Muscular Skeletal Disorders*). In order to describe and assess tasks involving a potential biomechanical overloading of the upper limbs, given that individual movements must be examined, a synthetic analytical index is used (the OCRA Index) as recommended by regulations EN 1005-5 and ISO 11228-3. The method, which was proposed in 1996 and subsequently updated (*Colombini & Occhipinti, 2005, 2007*), on one hand involves a highly detailed description of the work process and on the other makes it possible to summarise the data derived from the analyses and present a global vision of the work. With reference to activities

in the Agro-Food industry, the OCRA method has been used to assess the risk to the muscular skeletal system in poultry slaughter houses (*Caso et al.,* 2007), in dairy production plants (*Porceddu et al.,* 2008) and in field operations such as pruning, harvesting and transplanting (*Colombini & Occhipinti*, 2008). As far as protected crops are concerned OCRA has been used to assess risks run by operators during spraying (*Schillaci, Rapisarda et al.,* 2008) and while tying tomato plants (*Schillaci et al*., 2009).
Recent studies have also been carried out on the clinical risk of upper limb biomechanical overloading in vine and olive cultivation (*Montomoli et al*., 2008), and on the assessment of muscular skeletal risk during manual vine pruning (*Schillaci et al*., 2009). From both studies it emerged that the cuts made by the operator during manual pruning follow on from one another rapidly for the whole work shift and are characterised by great repetitiveness and frequency, this putting the muscular skeletal system of the upper limbs at risk.
This work uses the OCRA Index to assess the risk involved in repetitive upper limb movements during manual vine pruning, using as strain values both the average values measured by sensorised secateurs weighted on the Borg CR10 scale and subjective values of the effort (*Schillaci et al., 2010*).

Materials and methods

A questionnaire about any muscular skeletal disorders they had noticed during the pruning season was given to the operators to fill in. "MidaOCRAmulticompiti" software (*Colombini & Occhipinti*, 2005) was used to assess muscular skeletal risk.
Data was collected by breaking down the task into component phases. The method used and times taken for the execution of the operations were recorded and the cuts per trunk were counted. From the sites studied a typical day was 'extracted'. This was made up of 7 non-consecutive hours (420 minutes), that is to say 4 hours in the morning (from 7.00 to 11.00), a lunch break of one hour (between 11.00 and 12.00) and three hours in the afternoon (from 12.00 to 15.00).
Besides the data recorded and field observations, video films shot during the work period made it possible to deduce or confirm information about frequency, posture and the stereotypic nature of the work.
Seven sites in eastern Sicily were studied, this involving 30 operators and 12 hours of observation (Tab. 1).

Tab. 1 – Characteristics of the sites assessed.

Site	Vine species	Year planted	Type of cultivation	Vine spacing [m]	Number of operators	Tool
1	Nerello mascalese	2003	Sapling	0,80 x 1,10	3	Secateurs
2	Nerello mascalese	1950	Sapling	1,10 x 1,20	3	Secateurs
3	Nerello mascalese	1984	Spurred cordon	1,20 x 2,10	10	Long handled shears
4	Nero d'Avola	2000	Spurred cordon	1,00 x 2,20	6	Secateurs
5	Nerello cappuccio	1997	Spurred cordon	0,90 x 2,00	2	Secateurs
6	Chardonnay	2003	Guyot	0,90 x 2,00	2	Secateurs
7	Merlot	2004	Guyot	0,80 x 1,80	4	Secateurs + hacksaw

For each cultivar the number of cuts per minute was counted and from this the technical actions per minute could be seen. The work period consists of 420 minutes per day and the movements are repeated the whole time. In the case of the secateurs the Ocra Index was calculated considering only the dominant limb as it is this that is subject to most strain while in the case of the long handled shears a single Ocra index was calculated taking both limbs into consideration as they both carry out the same movements. As regards both the subjective and measured strain values, the ones considered are those deduced from cutting trials using sensorised secateurs and weighted according to the Borg CR10 scale (*Colombini e Occhipinti, 2005*). For each vine cvv 2 indices were calculated using the values for the measured forces (case A) and the subjective values obtained from the operators' questionnaires respectively (case B). These were then compared.

Results and discussion

Muscular skeletal disorders. From the questionnaire it emerged that during the pruning period, the operators suffer from pain, above all in the shoulder and hand of the limb carrying out the cut. The pain is felt during both the first minutes of work and in rest periods some hours after the work shift.

Work description. The operation is carried out by workers who move along the row holding the secateurs in their right hand, using their left to hold the vegetation and at times (when the cut is more difficult) to help the right grip the cutters. Each operator uses the right and left limb differently. Unlike the secateurs, the shears require simultaneous use of both limbs. The activity is characterised by stereotyped movements repeated for more than 2/3 of the time cycle. Besides the lunch break no other breaks are programmed. Although at times the operators stop pruning to sharpen the blades, this interruption cannot be considered a 'rest' period.

Goblet vines. When pruning goblet (*Fig. 1*) the operator carries out manual pruning with traditional secateurs and while pruning also removes the cut shoots. The tool are held in a 'pinch' mode, characterised by opposition between the thumb and the other fingers. The left hand holds back the vegetation with a wide grip requiring slight effort. The operator extends his left arm to grip the shoot to be pruned and with his right reaches the vegetation and makes the cut. Subsequently he uses his left arm to throw the cut shoot to the ground or grips another to be pruned, which is again cut by the right hand. In the latter case, when he has several shoots in his hand he throws them to the ground. As soon as the pruning of one plant is complete he moves on to the next one. At times he cuts without using the left limb to hold the plant, for example when pruning a small shoot. The low goblet vine (0,4-0,50 m) obliges the operator to work with his back bent.

Fig. 1 – Goblet cultivation

Guyot vines. the operator grips the cutters with his right hand, reaches the vegetation by extending his arm, makes the cut while holding the shoot with his left hand (*Fig. 2*). Having pruned the new growth, the operator uses a hacksaw to cut the residual spur. The tool is held in a 'pinch grip' while the hacksaw requires a 'power grip'. Because of the height of the spur, the operator is obliged to work with his back bent.

Fig. 2 – Guyot cultivation

Spurred cordon vines (*Figs. 3 and 4*). The operator grips the tool with his right hand, reaches the vegetation by extending his arm and makes the cut. According to the consistency of the wood he either cuts using only the right hand (Nero d'Avola) or uses both hands (Nerello Cappuccio), meaning that the latter cultivar requires more effort (*Schillaci et al*, 2009, 2010). The tool is held in a 'pinch grip'. In the case of pruning with long handled shears, the operator uses both hands to grip the shears and make the cut. Both arms continually make bending movements and the height of the work means the operator's back is bent.

Fig. 3 – Spurred cordon cultivation

Fig.4 – Spurred cordon cultivation

OCRA Index calculation. Table 2 shows the indices calculated for each species in the two cases studied (A and B).
In the case of the risk index calculated using the measured force values (case A), it is possible to state that the indices fall into the red zone, except for sites 2 and 7. The spurred cordon

Nerello cappuccio pruning carried out with traditional secateurs gave the highest risk index, this being determined mainly by the force necessary to make the cut.
As regards the tool employed, in general use of shears in Nerello mascalese pruning reduces the effort required for each cut but does not reduce the risk index as it worsens the posture and increases the precision (attention) necessary to carry out the work. The risk indices relative to goblet pruning of Nerello mascalese are not significantly different from those for spurred cordon pruning. It should, however, be pointed out that work on the goblet vines requires the use of the left limb, which during pruning often holds the shoots and removes them once cut.
Figure 5 shows all the Ocra indices calculated for each site.

Tab. 2 – Average Ocra Indices for pruning sites.

Cantiere	**Species**	**Technical actions no./min**	**Case A* Ocra Risk Index**	**Case B** Ocra Risk Index**
1	Nerello mascalese	49	4.8 **medium**	7.6 **medium**
2	Nerello mascalese	44	4.3 **Low**	6.4 **medium**
3	Nerello mascalese	49	4.9 **medium**	6.4 **medium**
4	Nero d'Avola	49	6.4 **medium**	7.6 **medium**
5	Nerello cappuccio	44	8.3 **medium**	10.7 **high**
6	Chardonnay	54	6.5 **medium**	7.1 **medium**
7	Merlot	33	3.3 **borderline**	4.3 **low**

* *case A* Ocra Indices with measured force values
** *case B* Ocra Indices with subjective force values

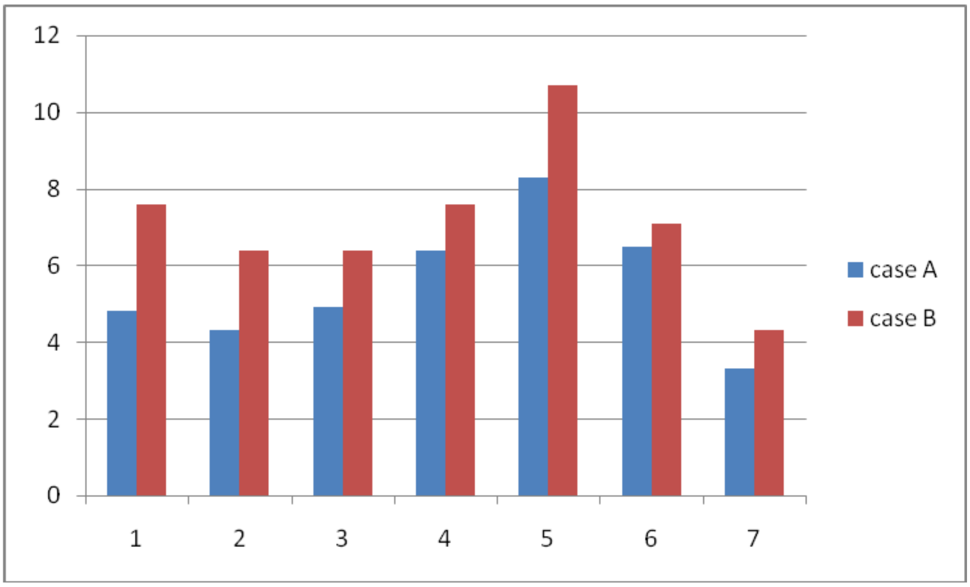


Fig.5 – Ocra Indices calculated for each site

Conclusions

It is significant that in the questionnaire nearly all the workers stated they suffered from discomfort or pain or during the pruning period.

The results obtained in the sites examined show that the dominant limb gripping the tool is at risk. In the case of the long handled shears both limbs are at risk. Factors contributing to the risk besides frequency of the same movement and posture, are the lack of or poorly scheduled rest periods and the effort repeatedly required during the entire work shift. The use of facilitating tools (as electronic ones) should be carefully considered in the light of the loads, the muscular skeletal system involved and the posture required.

As regards the indices calculated with the two methods of measuring the forces – the one based on Borg and the one based on measuring the forces by means of sensorised tool, it was seen that the latter always gave lower values. For this reason it might be prudent to always use the conventional index, as this protects the workers from underestimation of their effort. However, in further studies, the indices will be calculated again, this time using the maximum values given by the shears as opposed to the average ones. The aim will be to show more clearly which parts of the body are constantly involved in the greatest effort and must therefore be considered at risk. It is foreseeable that the use of the maximum values measured - as opposed to the average values measured and the average Borg (subjective) values – will provide more indication of the muscular skeletal areas actually at risk.

Bibliography

Balloni S., Caruso L., Conti A., Schillaci G., Valentino M., Loreto C., Fenga C., Rapisarda V. 2008. *Use of a Helmet Endowed with Forced Ventilation and Air Filtration Devices in Greenhouse Application of Agrochemical Treatments Using an Innovative Prototype of Self-Propelled Sprayer Vehicle.* Proc. CD-rom Int. Cong. "Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems". 15-17 sept, Ragusa, Italy.

Colombini D., Occhipinti E., Fanti M. 2005. *Il metodo OCRA per l'analisi e la prevenzione del rischio da movimenti ripetuti*. Collana Salute e lavoro, Franco Angeli Editore.

Colombini D., Occhipinti E. 2006. *Preventing upper limb work-related muskoloskeletal disorders (UL-WMSDS): new approaches in job (re)design and current trends in standardization*. Appl Ergon., 37, 441-450.

Montomoli L., Colombini D., Fanti M., Ruschioni A., Ardissone S., Sarrini D., Coppola G., Sartorelli P. 2008. *Risultati degli studi e dell'analisi del rischio clinico da sovraccarico biomeccanico degli arti superiori in viticoltura e olivicoltura.* Seminario EPM, giugno 2008.

Occhipinti E., Colombini D. 2007. *Updating reference values and predictive models of the OCRA method in the risk assessment of work-related muskoloskeletal disorders of the upper limbs.* Ergonomics, 50, 1727-1739.

Occhipinti E., Colombini D., Occhipinti M. 2008. *Metodo OCRA: messa a punto di una nuova procedura per l'analisi di compiti multipli con rotazioni infrequenti.* La Medicina del Lavoro, 99 n. 3, 234-241.

Porceddu R., Rosati L. 2008. *Repetitive manual operations in the dairy sector: analyses and criteria for intervention.* Journal of Agricultural Engineering, XXXIX n. 1, 1-9.

Schillaci G., Balloni S., Caruso L., Conti A., Rapisarda V. 2009. *Health and safety aspects connected with the use of a self propelled sprayer in greenhouses.* Proc. XXXIII CIOSTA - CIGR V Conference "Technology and management to ensure sustainable agriculture, agro-systems, forestry and safety", Reggio Calabria, 17-19 June, 2, 1583-1587.

Schillaci G., Balloni S., Rapisarda V., Romano E., Bonsignore R., Camillieri D. 2009. *Valutazione del rischio da esposizione a movimenti ripetitivi degli arti superiori nella potatura manuale del vigneto.* CD-rom Proc. IX Convegno Nazionale dell'Associazione Italiana di Ingegneria Agraria. Ischia Porto (NA), 12-16 Settembre.

Schillaci G., Balloni S., Bonsignore R., Camillieri D., Romano E. 2010. *Forze misurate e sforzi percepiti nel taglio dei sarmenti di vite*. III Convegno Nazionale di Viticoltura - CONAVI 2010, 5-9 luglio, IASMA, San Michele all'Adige (TN).

Schillaci G., Balloni S., Bonsignore R., Camillieri D., Romano E. 2010. *Hand forces during manual vine branches cutting.* CD-Rom Proc. Third International Congress on Mountain Viticulture, Castiglione di Sicilia (Italy), May 12/14.

The Effect of Task Frequency on the Risk of Biomechanical Overloading of the Upper Limb During Tomato Binding

Camillieri D.[1], Rapisarda V.[2-3], Balloni S.[1], Schillaci G.[1]
[1]*University of Catania. DIA, Mechanics Section Via Santa Sofia, 100 – 95123 Catania, ITALY Tel. +39 095 7147512, Fax +39 095 7147600, giampaolo.schillaci@unict.it*
[2]*Occupational Medicine, Policlinico Universitario "G. Rodolico", via S. Sofia 78, 95100 Catania ITALY. Tel. +39 095 7021 412 e-mail: nandorapisarda@libero.it*
[3]*Occupational Medicine, Azienda Foreste Demaniali, Enna, ITALY.*

Abstracts

Greenhouse tomato growing involves specific cultivation operations, such as green pruning, tying the plants and distribution of pesticides and fertilisers. Although they do not require particular effort they involve repetitive movements of the upper limbs and often they induce the operator to assume an incorrect posture. As regards the tying of tomato plants, this study shows how the task frequency influences the risk of biomechanical overloading of the upper limbs. It also deals both with the degree of saturation of the limbs and its effect on the daily productivity curve. It intends to enhance if there are any differences between the Ocra Index when this is calculated on the basis of the average daily frequency and when it is calculated on the basis of representative frequency values for different periods of time obtained from field observations. The data was obtained by observing the work carried out by operators standing on a mobile platform. The data regarded the tying of the plants to vertical wire supports and the removal of side-growths next to the apex, operations that may be performed at the same time. All the details of the work were recorded as were the execution times and methods. The action frequency was calculated with an analytical counting of the technical actions examining a video film of the work in slow motion.

A statistical analysis of the frequency carried out with publicly available software, was performed on the data collected in two work sites, each composed of two operators responsible for the manual tying of tomato plants. The operators were on a mobile platform. Analyses of the saturation of the limbs and the exposure indices were carried out using the software "midaOCRAmulticompiti". The analyses confirm the high level of saturation of the limbs. From the numerous data obtained it can be seen that the work productivity of the operators depends on the characteristics of the site and the tiredness of the operator, which was found to be variable during the day. To reduce the risk arising from the high levels of repetitiveness and obtain a suitable action frequency it would be necessary to reduce the work rhythm with a consequent increase in cycle time and reduction in productivity, a solution farms are reluctant to accept. Facilitating machines, such as the mobile platform, increase productivity and they should be designed in such a way as to permit more correct posture.

Keywords: OCRA, greenhouse, frequency, productivity

Introduction

One of the main aspects of ergonomics concerns the so-called WMSDs (Work related muscle-skeletal disorders), a generic definition of muscle-skeletal disorders that affect workers subject to incorrect postures and who do repetitive work. Among these pathologies, generally of a multifactorial origin, we may mention some that concern professional illnesses: tendinitis, epicondilitis (tennis elbow), and the carpal tunnel syndrome (*Colombini et al.*, 2005).

The cultivation of tomatoes in greenhouses is carried out with specific cultivating operations, such as green pruning, tying the plants and the distribution of pesticides and fertilizers. They do not require particular effort, but repeated movements of the upper limbs often induce workers to assume postures that are not correct (*Schillaci et al*., 2009).
Regarding tying tomatoes, this research aims to ascertain:
a) the extent to which the frequency of the work affects the risk of biomechanical overloading of the upper limbs,
b) if there are any differences between the OCRA Index calculated on the basis of the average daily frequency and that calculated on the basis of the average frequency for each hourly time slot,
c) the daily productivity curve and, if this is positive, highlight the progression.

Materials and methods
The trials were carried out in a greenhouse situated in the south east of Sicily (province of Ragusa). It has a surface area of about 5,000 m^2 and the metallic structure, covered with a plastic film, is subdivided into 10 sections, each 70 m long and 9 m wide. The highest point is 5.8 m, and the tomato plants cultivated there during the tests were on average 2.70 m high. The distance between the double rows is 1.80 m, while the distance between single rows is 0.85; the distance between the plants on each row is 0.75 m. Considering the double structure form of cultivation there were about 180 plants for each row.
The investigations involved tying the plants on vertical support wires, and green pruning that can be done at the same time. (*Fig. 1*).

Fig. 1- Tying the tomatoes

The tying consists in manually twisting the stem of the tomato plant around a vertical support wire. The work of two sites was timed, each comprising 2 workers positioned on a mobile caterpillar platform (*Schillaci et al.*, 2009); the working day begins at 7.00 a.m. and finishes at 4.00 p.m. and was broken down into time slots of an hour.
All the details of the work and the times and ways of carrying out the work were recorded according to the C.I.O.S.T.A. - A.I.G.R. methodology.

The movements were assessed and counted re-examining the technical actions in the field and subsequently through films shown in slow motion. The strength value was obtained by the assessment of the pruners
The exposure indices were calculated using the software "midaOCRAmulticompiti", using both the average daily frequency and the average frequency of each timeslot.
Beginning with the real capacity (plant/h), the frequency was deduced (cycles/min), which represents one of the main parameters of calculations in the OCRA index.

Results and discussion

Organization of the work
Each operator works standing up on the platform and uses his upper right and left limbs in a different way. Both workers are right-handed and carry out the main action with their right hand. The operator holds the stem of the plant with his left hand while he twists the stem around the vertical support wire with his right hand. Given the kind of work, the exposure indices are calculated only for the right hand that is subjected to greater strain. The activity is the same for the entire work cycle and does not require particular effort, but a repetitive movement of the upper limbs; besides, the posture is punishing because the arms are often held above the shoulders. The activity is characterized by the same set of movements kept up for more than 2/3 of the time of the cycle.
The average time taken to work a row is 1024 s, with a standard deviation of 116, and a variation coefficient (%) of 11.34% (Tab 1).

Tab. 1 – Average times of timeslots

Tomato tying	s/row
Timeslot	**s**
7÷8	1151
8÷9	985
9÷10	840
10÷11	872
11÷12	1080
12÷13	pause
13÷14	1080
14÷15	998
15÷16	1186
Average	1024

Beginning with the average times per row and the number of plants per row, the capacity of the work site (plant/h), the productivity (plant/h·op.), the frequency (cycles/min·op.), and the time unit (s/plant) are obtained. The average productivity is 588 plants per hour per worker, with a standard deviation of 69.66 and a CV% of 11.85% (Tab. 2).

Tab. 2 – Productivity and frequency

	Productivity plants/h·op.	**Frequency** cycles/min·op.	s/plant
7÷8	516	8.6	7.0
8÷9	603	10.1	6.0
9÷10	707	11.8	5.1
10÷11	681	11.4	5.3
11÷12	550	9.2	6.5
12÷13	Pause		
13÷14	550	9.2	6.5
14÷15	595	9.9	6.0
15÷16	501	8.3	7.2
media	588	10	6
Σ	69.66	1.16	0.70
CV%	11.85%	11.85%	11.34%

Productivity tendency

The productivity indices were calculated by using the ratio between the daily productivity and the average hourly one, relative to the work (Tab. 3).

Tab. 3 – Work productivity of tying tomatoes in the green house

Tying tomatoes	Productivity	Average productivity	Productivity Index	Difference
Timeslots	Plants/h·Op.	Plants/h·Op.	%	%
7÷8	516	588	87.77	-12.23
8÷9	603		102.56	2.56
9÷10	707		120.26	20.26
10÷11	681		115.85	15.85
11÷12	550		93.54	-6.46
12÷13	PAUSE		-	-
13÷14	550	588	93.54	-6.46
14÷15	595		101.22	1.22
15÷16	501		85.18	-14.82

The maximum values of productivity are reached in the timeslot 9÷10 (+ 20.26%). The lowest productivity level takes place during the first hour (-12.23%), the last hour of work (-14.82%) and the one close to the lunch break (-6.46%). We made the work productivity curve from the values we obtained. (*Fig. 2*).

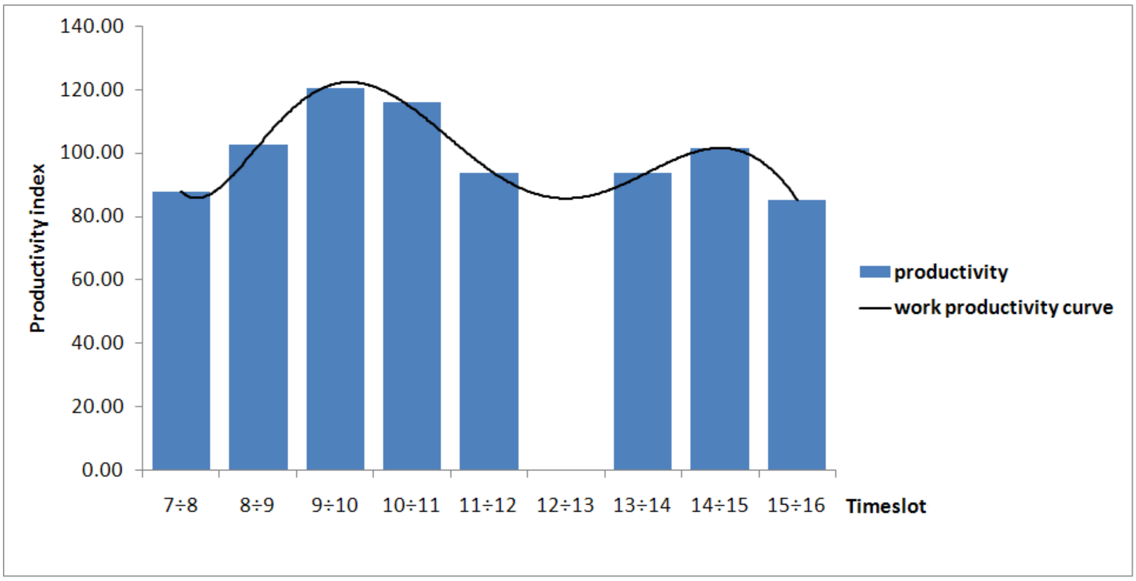


Fig. 2 – Indices and work productivity curve

The OCRA indices

The data for the calculation of the exposure index are listed below (Tab. 4). The effort required is almost zero (FF = 1); the posture is punishing (FP = 0.5); the activity is characterized by repetitive mechanized movements (FS = 0.85); no complementary factors were noted (FC= 1); and a "recuperation" adequate for each hour of work was assigned (FR = 1).

Tab. 4 – **Data for the calculation of the exposure index**

	Tying of tomatoes
Duration of shift (min)	480
Average duration of cycle (s)	5
CF (constant of frequency)	30
FF (strength factor)	1
FP (posture factor)	0.50
FS (stereotype factor)	0.85
FC (complementary factors)	1
Du (duration factor)	1
FR (recuperation factor)	1
D (duration repetitive task) (min)	440

Beginning with the average frequency of each timeslot (cycles min^{-1}), the number of technical actions per minute was obtained and the OCRA indices were calculated (Tab. 5).

Tab. 5 **– Calculation OCRA Index**

Timeslot	actions / min	OCRA Index
7÷8	43	3.4
8÷9	50	3.9
9÷10	59	4.6
10÷11	57	4.5
11÷12	46	3.6
13÷14	46	3.6
14÷15	50	3.9
15÷16	42	3.3
Daily	49	**3.8**

The daily index of exposure is 3.8, and can be relegated to the slot of light red risk, in which the risk is slight.
The recording of the frequency for separate hourly timeslots has highlighted that for 50% of the time of daily work, the OCRA Index stays above the OCRA Index calculated by resorting to the average daily frequency (3.8). The greatest exposure to risk is between 9 and 10 (equal to 12.5% of the working day), in which the index is set in the slot of highest risk (medium risk, 4.6). In the time slots 7÷8 and 15÷16 (25% of the working day) there is lower exposure to risk that is relegated to the yellow slot or borderline (*Fig. 3*).

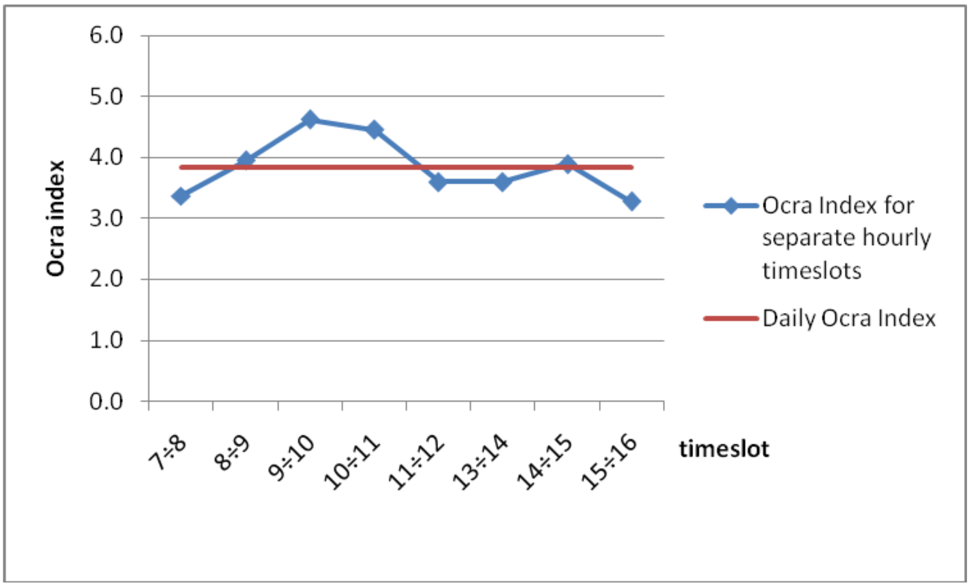


Fig. 3 – Comparison of OCRA indices

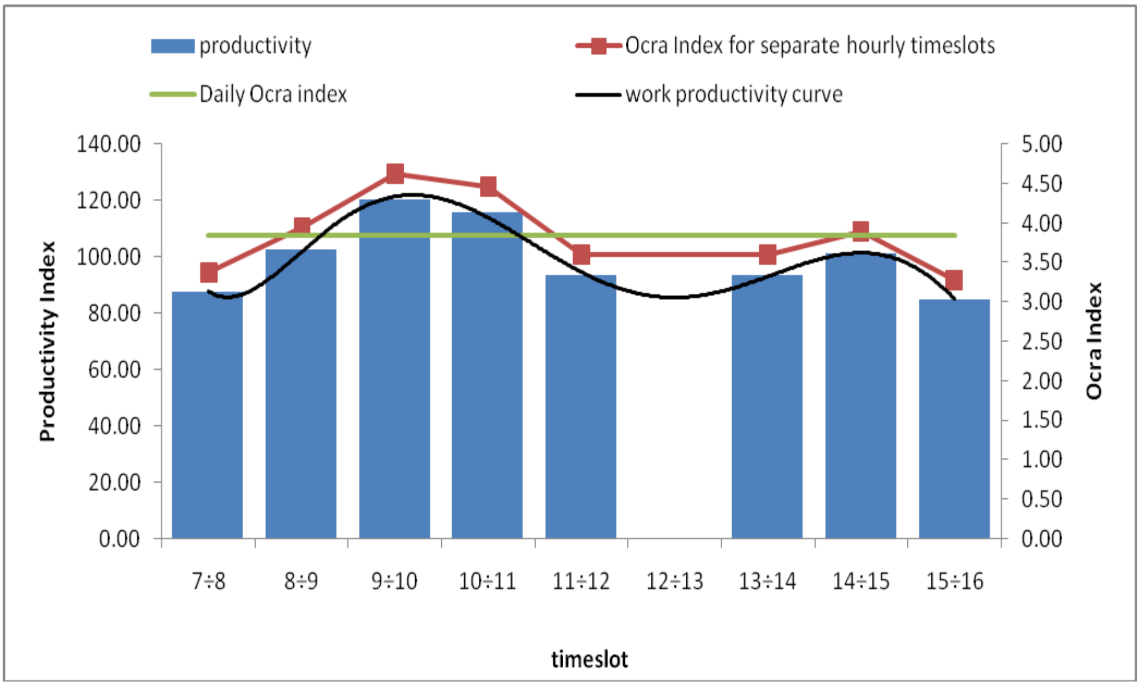


Fig. 4

The productivity curves and the OCRA index on an hourly basis can overlap and show an elevated affinity and confirm how much the index depends on productivity; the line parallel to the axis of the abscissa represents the OCRA index calculated on a daily basis (*Fig. 4*).

Conclusions and recommendations

The survey leads us to state that the presence of potentially repetitive tasks, like pruning fruit crops, the high visibility of the objective (the shoots to be eliminated), and the closeness between one objective and another, can be considered indicators of exposure to risk. These conditions appear to be satisfied in the winter pruning of vines too.

For this work, the productivity (number of worker divided by real work capacity) and the frequency (according to OCRA equal to the number of movements per minute) are closely correlated, because of the high incidence of repetitiveness of movements and the reduced instances of pauses between one movement and the next. Over the course of the working day, the productivity follows an undulating tendency and may be represented by a curve that presents two peaks, corresponding to the central hours of the morning and afternoon, and a minimum, near the lunch break, which corresponds to results of other studies (*CNR*, 1981; *Bonsignore et al.*, 2010). This is indicative of how the tiredness of the worker affects the frequency of the work.

The importance of the frequency can be seen also by consulting the OCRA Indices calculated with the average frequency of each timeslot with that calculated on the basis of the average daily frequency. A decrease of the index of exposure corresponds to a reduction of the frequency, and consequently there is a reduced risk of biomechanical overloading of the upper limbs.

We can state that the OCRA index calculated on the basis of average daily frequency provides an underestimation of risk for 50% of work and disguises the increase to a higher level of risk for 12.5 % of the time.

Bibliography

Balloni S., Caruso L., Conti A., Schillaci G., Valentino M., Loreto C., Fenga C., Rapisarda V. 2008. *Use of a Helmet Endowed with Forced Ventilation and Air Filtration Devices in Greenhouse Application of Agrochemical Treatments Using an Innovative Prototype of Self-Propelled Sprayer Vehicle*. CD-rom Proc. Int. Congr.
"Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems". 15-17 sept, Ragusa, Italy.

Balloni, S., Caruso, L., Cerruto, E., Emma, G., Schillaci, G. 2008. *A prototype of self-propelled sprayer to reduce operator exposure in greenhouse treatment*. CD-rom Proc. Int. Conf. "Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems" 15-17 sept, 2008, Ragusa, Italy.

Balloni, S., Caruso, L., Romano, E., Schillaci, G. 2009. *Field Test of an Electrical Autonomous Versatile Platform to modern greenhouses*. Proceedings of the XXXIII CIOSTA - CIGR V Conference "Technology and management to ensure sustainable agriculture, agro-systems, forestry and safety".

Bonsignore R., Camillieri D., Rapisarda V., Schillaci G. 2010. *The effect of task frequency on risk of biomechanical overloading of the upper limbs in manual pruning in vineyards*. CD-rom Proc. Int. Conf. "Work safety and risk prevention in agro-food and forest systems", Sept 16-18, Ragusa, Italy.

Colombini D., Occhipinti E., Fanti M. 2005. *Il metodo OCRA per l'analisi e la prevenzione del rischio da movimenti ripetuti.* Collana Salute e lavoro, Franco Angeli Editore.

Consiglio Nazionale delle Ricerche. 1981. *Meccanizzazione della potatura e della raccolta degli agrumi.* Accademia nazionale di Agricoltura. Bologna

Occhipinti E , Colombini D. 2007. *Updating reference values and predictive models of the OCRA method in the risk assessment of work-related muskoloskeletal disorders of the upper limbs*. Ergonomics.; 50: 1727-39

Schillaci, G., Balloni, S., Caruso, L., Conti, A., Rapisarda, V. 2009. *Health and safety aspects connected with the use of a self propelled sprayer in greenhouses*. Proceedings of the XXXIII CIOSTA - CIGR V Conference "Technology and management to ensure sustainable agriculture, agro-systems, forestry and safety

Schillaci G., Romano E., Balloni S., Caruso L. 2009. *Prestazioni di Piattaforme Semoventi Multifunzionali ad Azionamento Elettrico nelle Operazioni Ricorrenti in Serra.* Atti su CD-rom del IX Convegno Nazionale dell'Associazione Italiana di Ingegneria Agraria. Ischia Porto (NA), 12-16 Settembre.

Survey on Vineyards Treatment and Pesticide Remnant Management in Sicilian Vine-Growing Farms

Cerruto E., Emma G., Failla S., Manetto G.
Dipartimento di Ingegneria Agraria (DIA), Via Santa. Sofia, 100 – 95123 Catania, Italy
Tel. +39 0957147514, Fax +39 0957147600
ecerruto@unict.it

Abstract
Some aspects of plant protection treatments can affect strongly the environmental pollution, mainly of soils and subsurface waters. The internal-external washing water and the residues of mixture after treatments represent a source of diffuse and localized pollution.
A survey of 21 wine-growing farms was carried out in order to assess the main aspects related to phytosanitary treatments. The most widespread sprayers are conventional atomizers, with hydraulic pulverization, and about 57% of them are equipped with washing tank and with an easy system to empty the main tank. But only in 33% of cases it is possible to recover the final mixture. The average number of treatments per year is about 14: 62% of farms with 12–18 and the remaining with 4–10.
With regards to the residual mixture, 60% of farms produce from 5 to 50 litres and this mixture is sprayed in the same or in other vineyards, or spilled on the ground.
The internal cleaning of the sprayer is carried out with the washing system (only 3 farms out of 21), with the washing system and external water (only 3 farms out of 21), or using external water (15 farms out of 21). About the frequency of cleaning, the answers are not very reassuring, as well as those regarding the place where the mixture is drained.
The external cleaning is carried out in the same place of the farm in the majority of cases (86%) and only one farm is equipped with a lined , designed to treat pesticide solutions.

Keywords: safety, pesticide application, environment

Introduction
Several studies demonstrate that environmental pollution and operator exposure coming from pesticide distribution are mostly attributable to the use of obsolete and not very functional sprayers, and to the choice of wrong operating parameters as high working pressures and high sprayed volume rates (Balsari and Oggero, 2001; Balsari *et al*., 2008; Balsari and Oggero, 2009; Cerruto *et al*., 2008). Beside this, it must be added that chemical product applications is not always done correctly and prudently during all phases concerning their use.

How sprayers are internally and externally cleaned and the places where washing is carried out are crucial aspects of phytosanitary treatments, as they can affect strongly and negatively the environmental pollution, mainly of soils and subsurface waters. The residues of mixture after treatments, when not safely disposed, constitute a source of pollution from point sources too, much more serious than the washing waters. Unfortunately, in the agricultural world it is considered negligible the polluting capabilities of these remnants and the necessity to provide for their safe disposal is considered of minor importance (D'Antonio *et al*., 2005).

The Authors equally contributed to the present study.

A recent survey at national level carried out on a representative sample of about 100 wine-growing farms, pointed out that the residual mixture after treatment is on average 270 litres a year and that the amount of water used to clean the sprayer (internally and externally) is about 1300 litres a year. This implies an amount of active substance of at least 1.6 kg a year, dispersed on the soil and absorbed, in time, by the subsoil (Balsari *et al*., 2006). Moreover, the disposal of the washing waters is generally carried out in the same place, which is very often near to the supply source, so producing a form of pollution from point source, very noxious for the environment and human beings.

Since 2000, when the European Water Framework Directive was adopted, which fixes the maximum allowable threshold of plant protection product concentration in drinkable water at 0.1 μg/L, prevention of water contamination from pesticides has come into particular focus. Exceeding the admitted threshold, in fact, could mean a ban for some pesticides from the market, hence reducing the range of available crop protection solutions for farmers (Balsari *et al*., 2008). Moreover, the European directives 127 and 128 of 21 October 2009 must be considered: the former amends the Directive 2006/42/EC with regard to machinery for pesticide application and the latter establishes a framework for Community action to achieve the sustainable use of pesticides. In detail, the Directive 127 recognises the use of pesticides as posing threats both to human health and the environment and quotes (Article 1, Section 2.4.6.1, concerning the sprayer washing) "The machinery must be designed and constructed to allow its easy and thorough cleaning without contamination of the environment". The Directive 128 pays special attention to the protection of the aquatic environment, defining (Article 11) some "Specific measures to protect the aquatic environment and drinking water". Among these, it should be promoted the "use of mitigation measures which minimise the risk of off-site pollution caused by spray drift, drain-flow and run-off".

So, as it can be observed, during the last years there has been, both from the scientific community and the law-maker, a growing and pressing attention towards the bad effects on the environment and the human health coming from an improper use of pesticides in the agricultural world.

In this context, it was carried out a survey on a sample of 21 wine-growing farms, mainly located in the provinces of Catania and Ragusa, aimed at assessing the main aspects related to phytosanitary treatments: number of applications per year, application modalities, type of sprayer, management and disposal of residual mixture and washing waters.

Materials and Methods

A questionnaire was prepared and submitted to 21 wine-growers in the South-East of Sicily. It covered several aspects related to pesticide applications in vineyards, among which:

Farm statistics: cultivated areas, land morphology (flat or hilly land), type of crop (wine- or table-grape), plant layout;

Machinery used: type of sprayer, distribution system, presence of cleaning system, emptying tank system and possibility for remnant recovery;

Operating parameters: type of pesticides, number of treatments per year, volume rates with respect to the phenological stages;

Post-treatment activities: presence of residual mixture and its management, frequency of sprayer cleaning (internal and external), place of cleaning and its typology, distance from the nearest surface watercourse.

The replies were statistically analysed and the distributions of the main quantities were computed. All statistical analyses and graphical representations were carried out by means of the open source software R.

Results and Discussions

Farm statistics

The 21 surveyed farms are in the provinces of Ragusa (7), Catania (11), and Caltanissetta (1); two farms extend over both provinces of Catania and Ragusa. Their total surface ranges from 4 up to 150 ha (mean about 32 ha), whereas that with vineyards ranges from 2.5 up to 70 ha. The average surface is about 18 ha and the majority of farms (60%) extend over a surface smaller than 8 ha (Figure 1). Approximately one out of three farms is on flat ground, one out of three on hilly ground, and one out of three on both; when the land is hilly, vineyard rows are always arranged along the lines of maximum slope.

Out of the entire sample, one farm produces only wine-grapes, 18 farms only table-grapes, and two farms both. The typical plant growth system for table-grapes is the "*Tendone*", present in almost all the surveyed farms (20). Wine-grapes are produced in two espalier vineyards and in one *tendone* vineyard. In five farms, the vineyards (*tendone*) are in greenhouses.

The plant layout distribution in *tendone* vineyards is reported in Figure 2. It shows that the most widespread layout in open field is 2.8 m × 2.8 m, which implies a plant density of 1276 ha^{-1}. The second most widespread layout in open field is the 3.0 m × 3.0 m (plant density of 1111 ha^{-1}), whereas narrower layouts are preferred in greenhouse (2.5 m × 2.5 m, 2.5 m × 1.9 m, 3.0 m × 2.0 m), which imply higher plant densities (1600, 2105, 1667 ha^{-1}, respectively).

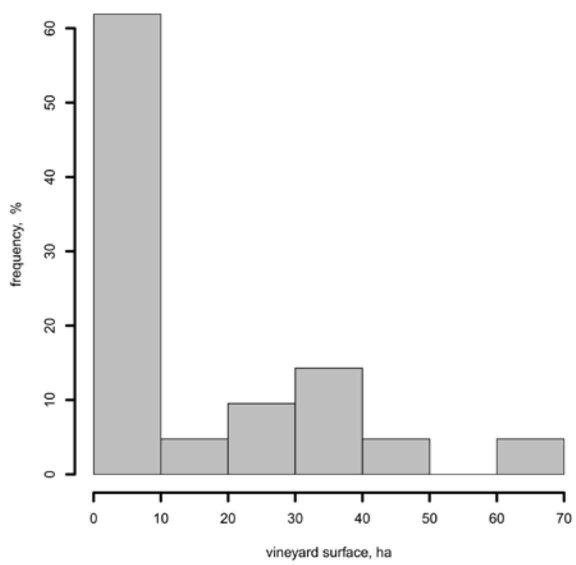


Figure 1. Vineyard surface distribution.

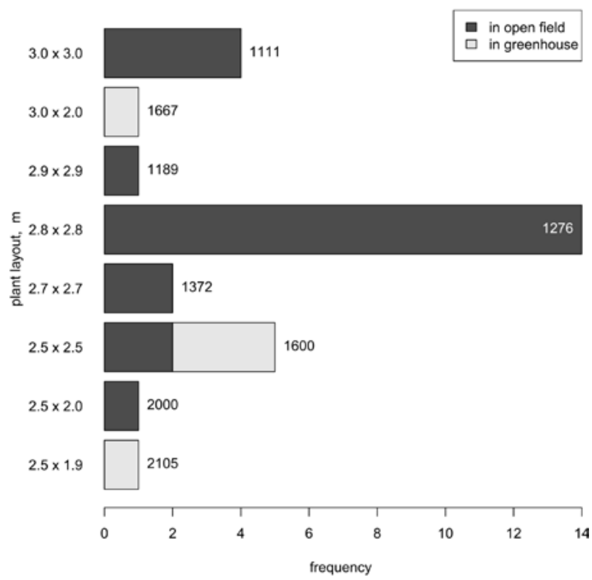


Figure 2. Plant layout and plant density (ha^{-1}, on the bars) in vineyards.

Sprayers

The most widespread sprayer type is the conventional atomiser, with hydraulic pulverisation, air assisted spray, towed by a tractor. In detail, 20 out of 21 sprayers are towed and only 1 is carried, 19 out of 21 present a hydraulic system for drop pulverisation and only 2 a pneumatic one. The distribution system is the conventional one when the pulverisation is hydraulic and made of adjustable diffusers when the pulverisation is pneumatic.

About 57 percent (12 out of 21) of sprayers are equipped with washing tank and all offer the facility of emptying the main tank (33% by means of washer and 67% by means of plug), but only in 33% of cases it is possible to recover the mixture due to the inadequacy of the emptying device positioning.

Phytosanitary treatments

The number of phytosanitary treatments per year ranges from 4 up to 18 (Figure 3), with an average value of about 14. In the majority of farms (62%), the number is between 12 and 18, while in the remaining 38% it is between 4 and 10. Moreover, in 62% of farms, treatments are shared half-and-half between insecticidal and fungicidal, in 29% of farms fungicidal treatments are prevalent (60% vs. 40%), and in the remaining 9% of farms insecticidal treatments prevail over the fungicidal ones (60% vs. 40%). Active substances in most cases (41%) act by contact (from 20 up to 70%), in 39 percent of cases are systemic (from 10 up to 50%), and in 20% of cases are cytotropic (from 10 up to 40%).

The volume of mixture sprayed per hectare changes according to the phenological development (Figure 4): in early stages, volumes vary from 400 up to 1000 L/ha (average value of about 640 L/ha), whereas in late stages vary from 300 up to 600 L/ha (mean of about 440 L/ha). This reduction in volumes rates is due to the necessity to preserve the aesthetic integrity of the bunches of table-grapes (greater volumes may stain the berries, so depreciating the crop).

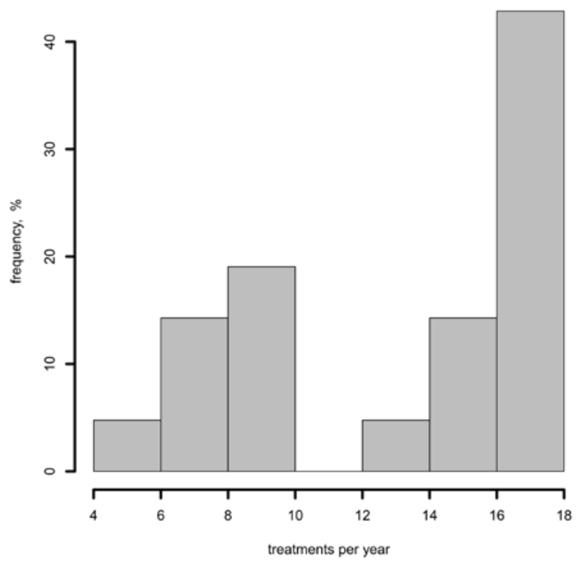


Figure 3. Number of treatments per year in the surveyed farms.

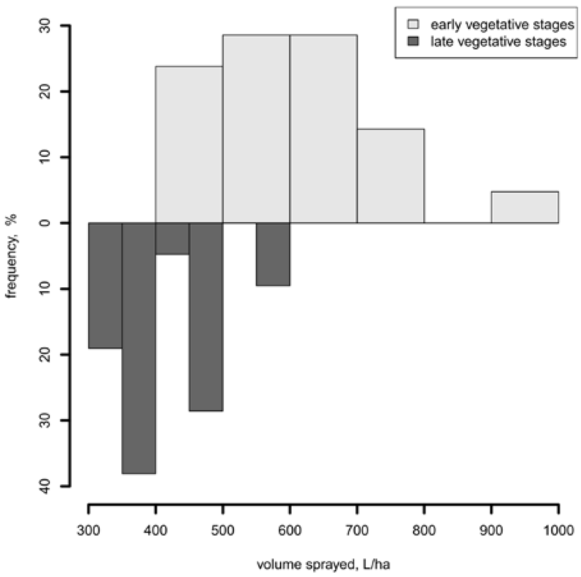


Figure 4. Volume per hectare sprayed in the surveyed farms.

After treatment activities

As regards the post-treatment activities, which can make strongly worse the environmental effects of phytosanitary treatments due to the pollution from point sources, the questionnaire covered several aspects.

About the residual mixture after each treatment, 60% of interviewed replied that it ranged from few litres (about 5) up to 50 litres (mean of 8 litres), while 40% replied that no mixture was present in tank after treatment. The residual mixture, when present, was sprayed in the same (77%) or other vineyard (8%), or, simply and incorrectly, spilled on the ground (15%). Nobody stores it for further applications. A summary of the replies is reported in Figure 5.

All the operators perform the internal cleaning of the sprayer: 95% (20 out of 21), correctly, of both tank and hydraulic plant, 5% (1 out of 21) of the tank only, so exposing the nozzles at risk of blockage. Only a quarter of operators (3 out of 12) use the washing system when present on the sprayer, another quarter use both the washing system and external water, and 50% use external water. When the washing system isn't present (43% of the cases), external water is used. The results are graphically reported in Figure 6.

The frequency of internal washing is quite varied: only 57% of interviewed operate correctly, cleaning the sprayer after the treatments. Moreover, 10% of operators clean the sprayer when the active substance is changed, 23% randomly, and 10% at the end of the season's yield, so neglecting any problem of possible phyto-toxicity resulting from the mixing of more chemicals or the risks of corrosion of tank and pump. Only 24% (5 out of 21) of interviewed provide an estimate of the water used to wash internally the sprayer: according to their replies, it ranges from 10 to 20 litres (mean of 17 litres). Taking into account the 14 treatments per year, it results about 240 litres of mixture per farm to be drained. To this end, operators act differently: the majority of them (57%) drain it on the ground in vineyard or at the farm centre, 29%, beside this, spray it in vineyard, 10% drain it on the ground in vineyard, and the remaining part (4%), drain it on the ground at the farm centre or spray it in vineyard. No information is provided about the draining place. The replies regarding the internal washing of the sprayer are represented graphically in Figure 7.

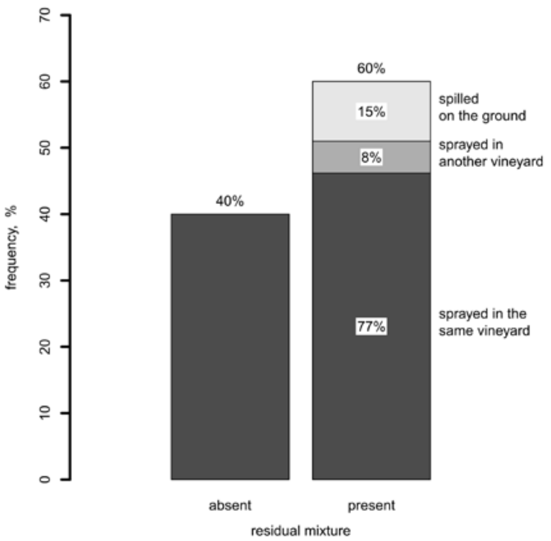


Figure 5. Management of the residual mixture after treatments.

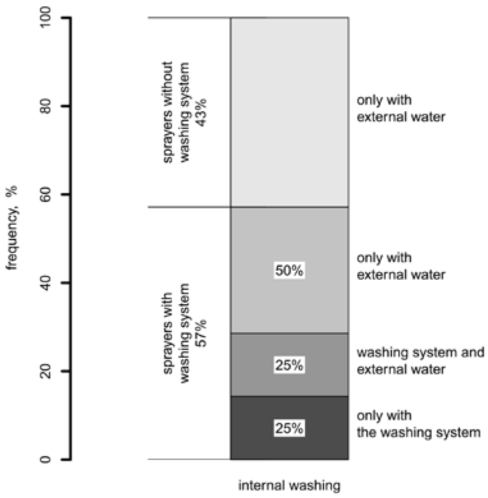
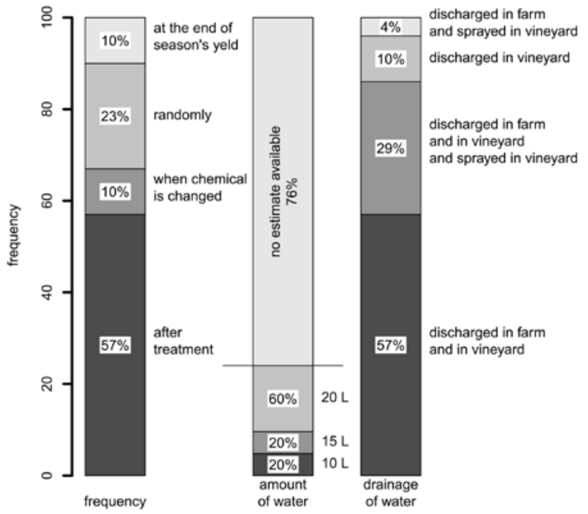


Figure 6. Sprayer's internal washing modality.

The external washing of the sprayer is mainly related to the operator's safety. Very often it is carried out jointly to the internal one. The majority of operators (48%) do it at the end of the treatment, 14% at the end of the season's yield, 5% when change the active substance, and 1 out of 3 (33%) randomly. To ignore the external washing of the sprayer can expose the operator at high risk of contamination during the preparation of the mixture, as some studies have demonstrated that up to 2 percent of the sprayed product can settle on the external surface of the sprayer.

The place where external washing is performed is always the same in the majority of cases (86%) and varied in the other cases (14%). To choice the same place for the sprayer washing activities is a common practice that leads to pollution from point sources. Some researches carried out in Great Britain and published by Crop Protection Association have pointed out that almost 50% of the surface water contamination is due to an improper disposal of the sprayer washing water. Considering a dose of 2.5 kg/ha of active substance, on average 7 g reach water-bearing layers and about 30 percent of them come from sprayer's cleaning.

To these results contributes also the typology of the place and its permeability: the present research pointed out that it is terrain (covered—33%—or not—48%—with grass) or a small floor of about 6–8 m^2 (14%). Only one farm is equipped with a lined *biobed* designed to treat pesticide solutions. The land is not very permeable in the majority of cases (62%), very permeable in 24% of cases, and varied in the remaining cases (14%). The water-bearing layer depth range from 5 up to 80 m (mean of about 25 m), while the distance from the nearest surface watercourse is less than 50 m in 10% of cases, less than 100 m in 14% of cases, and greater than 500 m in the remaining cases (76%). The replies to the questionnaire are summarised in Figure 8.



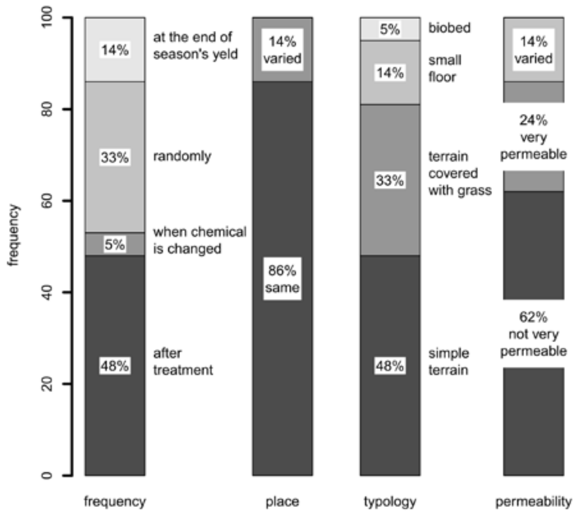


Figure 7. Internal washing of the sprayer. **Figure 8. External washing of the sprayer.**

Conclusions

The study shows the surveyed wine-growing farms consider of minor importance the post-treatments activities and underestimate the risks of environmental pollution, mainly of soils and subsurface waters.

A main aspect concerns the used machines: only 57% of sprayers are equipped with washing tank and with an easy system to empty the main tank, but only in 33% of cases it is possible to recover the final mixture due to the inadequacy of the emptying device positioning. Other important aspects involve the management of the residual mixture and also the internal-external cleaning of the sprayer. The results show the need to inform the farmers of the right modalities of the post-treatments activities. In fact, only one farm is equipped with a lined *biobed*, designed to treat pesticide solutions.

Actually, the residual mixture is sprayed in the same or in other vineyards, or incorrectly spilled on the ground; nobody stores it for further treatments.
Especially the frequency of the internal cleaning is not very reassuring, as well as the place of mixture draining, because only 57% of farmers clean the sprayer after the treatments and all of them drain the washing water on arbitrary places.
The external cleaning of the sprayer, mainly related to the operator's safety during the preparation of the mixture, is regularly done only by 48% of the operators and it is carried out in the same place in the majority of cases. In terms of environmental pollution, to choice the same place is a practice very dangerous, leading to pollution from point sources.

References

Balsari P., Ade G., Cerruto E., Giametta G., Guarella P., Pergher G., Vieri M. 2006. Indagine sulle modalità di lavaggio delle irroratrici e sulla gestione delle acque reflue. Research activity developed within the two year MIUR project on "Riduzione dell'inquinamento da prodotti antiparassitari nelle coltivazioni arboree". Booklet printed by DISA—Udine, July 2006, 3–9.

Balsari P., Marucco P., Oggero G. 2008. Reduction of water contamination from pesticides through the application of the Best Management Practices defined by the TOPPS project. Proceedings of International Conference "Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems". September 15−17, 2008 Ragusa.

Balsari P., Oggero G. 2001. Evaluation of human exposure of pesticides during spray application in greenhouse. Proceedings of the International Workshop Greenhouse design and crop engineering, Vieste del Gargano, Italy, 2001.

Balsari P., Oggero G. 2009. La distribuzione dei prodotti fitosanitari nell'ortofloricoltura ligure: la situazione attuale e i risultati ottenuti dai primi controlli funzionali effettuati. Proceedings of IX Convegno Nazionale AIIA. Ischia Porto, September 12−16, 2009.

Balsari P., Oggero G., Cerruto E., Friso D., Guarella P., Raffaelli M. 2008. Comparison among different pesticide application methods in greenhouse in Italy: first results. Acta Horticulturae 801 (1), 661−668.

Cerruto E., Balsari P., Oggero G., Friso D., Guarella A., Raffaelli M. 2008. Operator safety during pesticide application in greenhouse: a survey on Italian situation. Acta Horticulturae 801 (2), 1507−1514.

D'Antonio C., Pergher G., Cividino S.R.S. 2005. Gestione delle acque di lavaggio e della miscela residua delle irroratrici. Proceedings of VIII Convegno Nazionale AIIA, Catania, June 27−30, 2005.

European Directive 2009/127/EC of the European Parliament and of the Council of 21 October 2009 amending Directive 2006/42/EC with regard to machinery for pesticide application.

European Directive 2009/128/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides.

R Development Core Team. 2007. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria, ISBN 3-900051-07-0, URL http://www.R-project.org.

Whole Body Vibrations of Tractor Driver in Citrus Orchard

Cerruto E., Emma G., Manetto G.
Dipartimento di Ingegneria Agraria (DIA), Via Santa. Sofia, 100 – 95123 Catania, Italy
Tel. +39 0957147514, Fax +39 0957147600
ecerruto@unict.it; gemma@unict.it; gmanetto@unict.it

Abstract

This paper reports the results of the first analyses carried out to evaluate the vibration level the tractor driver is subject to during pesticide application in a citrus orchard. The measurements were carried out during ordinary working conditions by using a triaxial accelerometer placed on the seat of a 4-wheel (all with the same diameter) drive tractor. The sprayer used was a trailed conventional one with hydraulic pulverisation and axial fan.

The vibration exposure was computed globally and for each working phase (transfer, spraying, turnings, transients, etc.). The main results showed that, with reference to the whole working cycle, the weighted root mean square (RMS) values of acceleration (around 0.6 m/s^2), were always slightly higher than the daily exposure action value fixed by the 2002/44/EC directive; among the different working phases, the highest values of acceleration occurred during transfers from and by the farm centre, where the tank of the sprayer was filled, due the higher forward speed. Finally, the FFT analysis showed the main harmonic between 35 and 37 Hz, corresponding to the engine speed. Furthermore, other lower frequency harmonics, at around 2–3 Hz, were present, due to the forward movement of the tractor.

Keywords: safety, comfort, pesticide applications

Introduction

Vibration exposure of agricultural workers is one of the most important topic concerning safety and comfort (Pessina and Bonalume, 2009). The problem can be exacerbated by the increase in mechanisation level of many activities recognised in the last decades. This is particularly true for tractor drivers, whose exposure can be time prolonged. Exposure takes place mainly through the seat and is related to several factors, among which agricultural activity, forward speed, ground profile, engine speed, seat features, can be cited (Butkta *et al.*, 1998; Cutini and Bisaglia, 2007; Giunchi *et al.*, 2008).

Several researches have been carried out to measure the levels of whole body vibration to which tractor drivers are exposed during farm activities (Scarlett *et al.*, 2007; Pessina and Bonalume, 2009). These Authors report high levels of exposure during transfers and when old tractors are used, whose seats are often deteriorated or without an efficient suspension system.

Even if the only documented relationship between whole body vibration exposure and medical pathologies is related to the backache and the trauma on the rachis, several other consequences (muscular pain, alteration of the gastro-enteric apparatus, the peripheral venous system, the reproductive female apparatus and the cochleovestibular system) are related to the exposition to specific vibration frequencies, even if these would be also provoked by other causes (Enama, 2005; Ispesl, 2001). For example, troubles of the cervical-brachialis district could be also provoked by repetitive movements to control the machine.

Since the vibration risk is increasing in Europe both for the safety consequence of

---

The Authors equally contributed to the present study.

workers and the social costs, in the last 15 years the regulatory activity has produced several European Directives to improve the safety characteristics of the machines. The main Directives were accepted in Italy by means of the D.P.R. (Presidential Decree) no. 459 of 24th July 1996 and of the government decree no. 187 of 19th August 2005. The first, known as "Machine Directive", obliges the machinery-maker to reduce at the source the risks for the workers, also from the point of view of vibratory phenomena; therefore it stimulates the designing of new machinery taking into account the reduction of the vibration level connected with its functioning. The second government decree implements in Italy the Directive 2002/44/EC, that establishes the limits to the daily vibration exposure for the workers. Furthermore, from July 2010, it prohibits the use of machinery that does not allow the observance of these limits; only for the agro-forestry machinery there is 4 years' extension. The government decree no. 81 of 9th April 2008 completes the main regulatory framework on safety workers. It obliges employers to carry out a risk evaluation for all the work activities and to take appropriate measures for accident prevention and workers' health safeguard.

Objective of this study is the measurement of the whole body vibrations transmitted to the tractor driver during pesticide application in a citrus orchard when using a four wheeled isodiametric tractor and a conventional air assisted sprayer. This is only the first approach and other measurements will be carried out to cover all the activities in citrus orchards and to analyse other operative conditions.

Materials and Methods

Operative conditions

To carry out the pesticide application, a trailed conventional sprayer with 1500 L main tank, hydraulic pulverisation, and arc-shaped spray boom equipped with 14 nozzles was used (Figure 1). The sprayer was also equipped with an axial fan and was run by a 55 kW four wheel drive isodiametric tractor. The engine speed was 2200 rpm and the average forward velocity was 1.21 m/s. The trials were carried out during pesticide application in a citrus orchard with tree lay-out of 4 m × 6 m. Any row was 270 m long and the headlands were large enough to allow the fast turning of the machines used for cultivations. Two farm roads, around 6 m large, intersected the orchard that, therefore, was divided into three sectors. The driver stopped spraying during the turning and in correspondence of only one transversal farm road (Figure 2).

Figure 1. Tractor and sprayer used.

Figure 2. The transversal farm road.

Measurement equipment

Vibration measurements were carried out by using an AP Tech triaxial seat transducer, designed in accordance with the criteria stated in the European Standard EN 1032:1996 and intended for measurement of whole body vibration according to the UNI EN ISO 2631-1997. The device was fixed to the seat with adhesive tape (Figure 3) and the accelerometer was oriented in accordance with the ISO 2631 regulation (Figure 4).

Figure 3. The triaxial seat transducer.

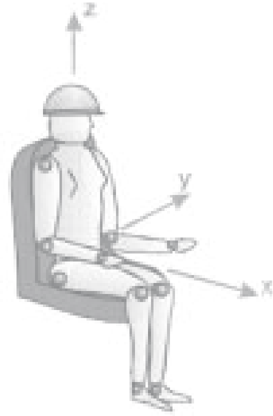


Figure 4. The reference coordinate system adopted.

The vibration signals were recorded by using a PC-based acquisition system made up of a four-channel USB-II data acquisition unit (dB4), a notebook and dedicated software 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 2631 regulation.

Experimental conditions and data analysis

The measurement time covered the whole working cycle, including spraying and transfers from the field to the supplying point and vice versa, so to obtain the global value of exposition to the vibrations for the driver. Four replicates were carried out and the signals were recorded with sampling frequency of 1600 Hz.

Successively the signals were analysed in laboratory by computing narrow band (FFT) and third octave analysis. They were analysed in the range 1–104 Hz (third of octave bands from 1 to 80 Hz) by applying the FFT and the 1/3 octave analysis and by computing the frequency weighted accelerations for each axis (a_{wx}, a_{wy}, and a_{wz}) and then the highest acceleration value a_w:

$$a_w = \max\{1.4\, a_{wx};\ 1.4\, a_{wy};\ a_{wz}\},$$

from which the daily vibration exposure values, A(8), standardized to an 8-hour reference period, were obtained:

$$A(8) = a_w \sqrt{T / T_0},$$

being T_0 = 8 hours and T the total exposure time associated with a_w.

The A(8) values were compared with the *Daily Exposure Action Value* of 0.5 m/s^2 and the *Daily Exposure Limit Value* of 1.15 m/s^2 established by the EU 2002/44/EC directive, implemented in Italy with the government decree 187/2005.

As during the trials the starting times of each working phase (spraying, turning and transfers) were recorded with a chronometer, the respective daily exposure values were calculated by analysing the correspondent signal extrapolated from the whole signal (Figure 5). Graphical representations were carried out by using the open source software R.

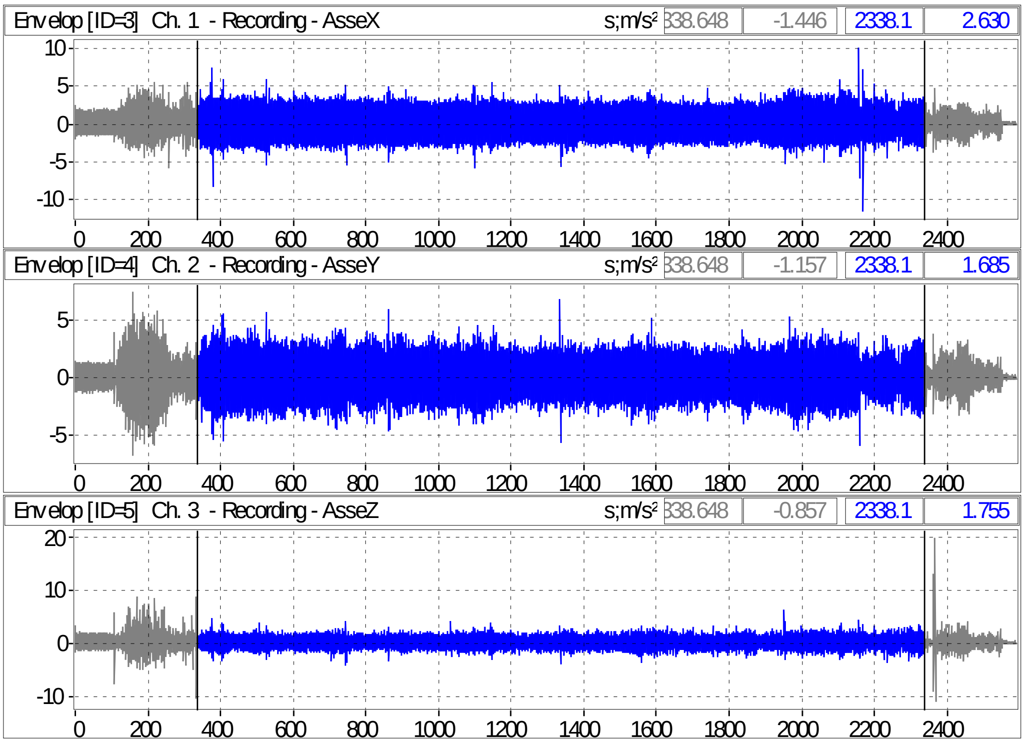


Figure 5. Signal selection to analyse only the spraying activity.

Results

By analysing the times recorded during the trials, it was found that it was hourly need to fill the main tank of the sprayer. This activity required around 10 minutes so, considering a working day of 7 hours, the effective exposure time was about 6 hours. Furthermore, it was calculated that the incidence of the transfer times on the total time (spraying and transfer time) was around 20 percent.

With reference to the signal analysis, taking into account the recorded times, in Figure 5 it is possible to note peaks in correspondence of the turning phase, when the driver restarts spraying. Nevertheless, their intensities are not very different with respect to the stationary signal and the time lapse between two consecutive peaks is so large that the vibration dose value (VDV) computation is not necessary.

From each signal elaborated, the weighted acceleration values were computed via the 1/3 octave analysis. It was considered both the whole signal and sub-intervals to distinguish working phases: spraying and transfers. Consequently several replications, but with different duration, were obtained and the average value for each working phase was computed as weighted mean, taking as weight the duration of the analysed signal.

Successively, taking into account the daily exposure times, the A(8) values were obtained. In all cases the A(8) values were under the limits imposed by the regulations (Table 1) as daily exposure action value. It must be observed that these results are a consequence of the daily exposure time less than 8 hours. In fact, the maximum weighted acceleration values, especially the *z*-component during the transfer phase, when the forward speed was higher, were greater than 0.5 m/s^2 (Figure 6). Furthermore, the weighted acceleration values in each replication showed lower data dispersion for *x*- and *y*-components, pointing to constant exposure intensity. Then the working conditions must be continually monitored because of the proximity to the daily exposure action value: different ground profile or different incidence of the transfer phase could cause an increase in the exposure values. Alternatively, it could be necessary to change the seat because of its wear (Figure 3), but the installation of new model seat, able to damp dawn vibrations, should be evaluated with the maker.

Table 1. Daily vibration exposure value for different working phases.

Working phase	A(8), m/s^2
Spraying	0.39
Transfer	0.29
Whole	0.45

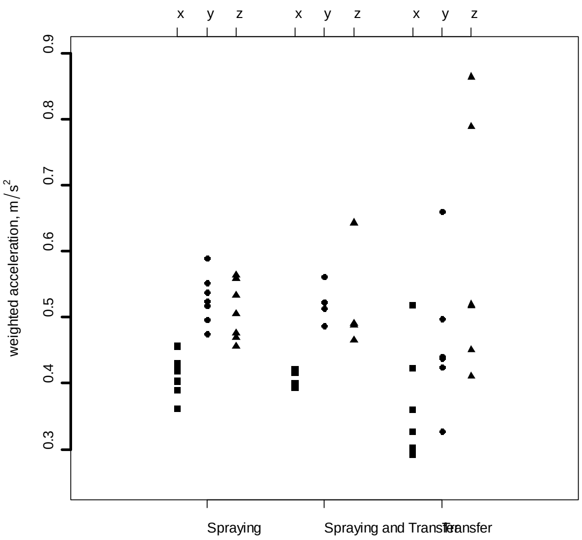


Figure 6. Weighted acceleration values computed in each replication.

Looking at the weighted acceleration components (Figure 6), it is possible to observe that the lowest vibrations were always those along the longitudinal axis (*x*-direction), while the other components showed different trends for the different working phases. In fact, during the transfer phase there were the highest weighted acceleration values along the vertical axis (*z*-direction). This is due to the higher forward speed, especially during the transfer to come back to the supplying point. Instead, during the spraying phase and the whole working cycle, the components along the transversal and vertical axis are comparable. There was a reduction in the *z*-component and an increase in the *y*-component. These variations are explicable respectively with the lower forward speed and the higher engine speed of the tractor during the spraying.

FFT analysis

Figure 7 reports an example of FFT spectra in the range 0–104 Hz for the three directions during the transfer phase. Similar spectra were found for all the other measures in the same conditions. The spectra show appreciable harmonics along all the three directions in the range 2–4 Hz due to the ground profile. Other harmonics are present at 7 Hz (*y*-direction) and 15 Hz (*x*-direction), probably due to the high forward speed. However, the main harmonics are found between 29 and 34 Hz, corresponding to the engine speed. At last, several harmonics between 50 and 72 Hz are present mainly along the longitudinal axis (*x*-direction). These could be caused by the empty tank of the sprayer towed by the tractor.

The other FFT spectra obtained by analysing the spraying phase or the whole working activity show some little differences:

the harmonics at 7 and 15 Hz and those in the range 50–72 Hz were no longer present, confirming the influence of the high forward speed for the former and the effect of the empty tank of the sprayer for the latter;

the main harmonic now took place between 35 and 37 Hz, corresponding to the engine speed during the working phase.

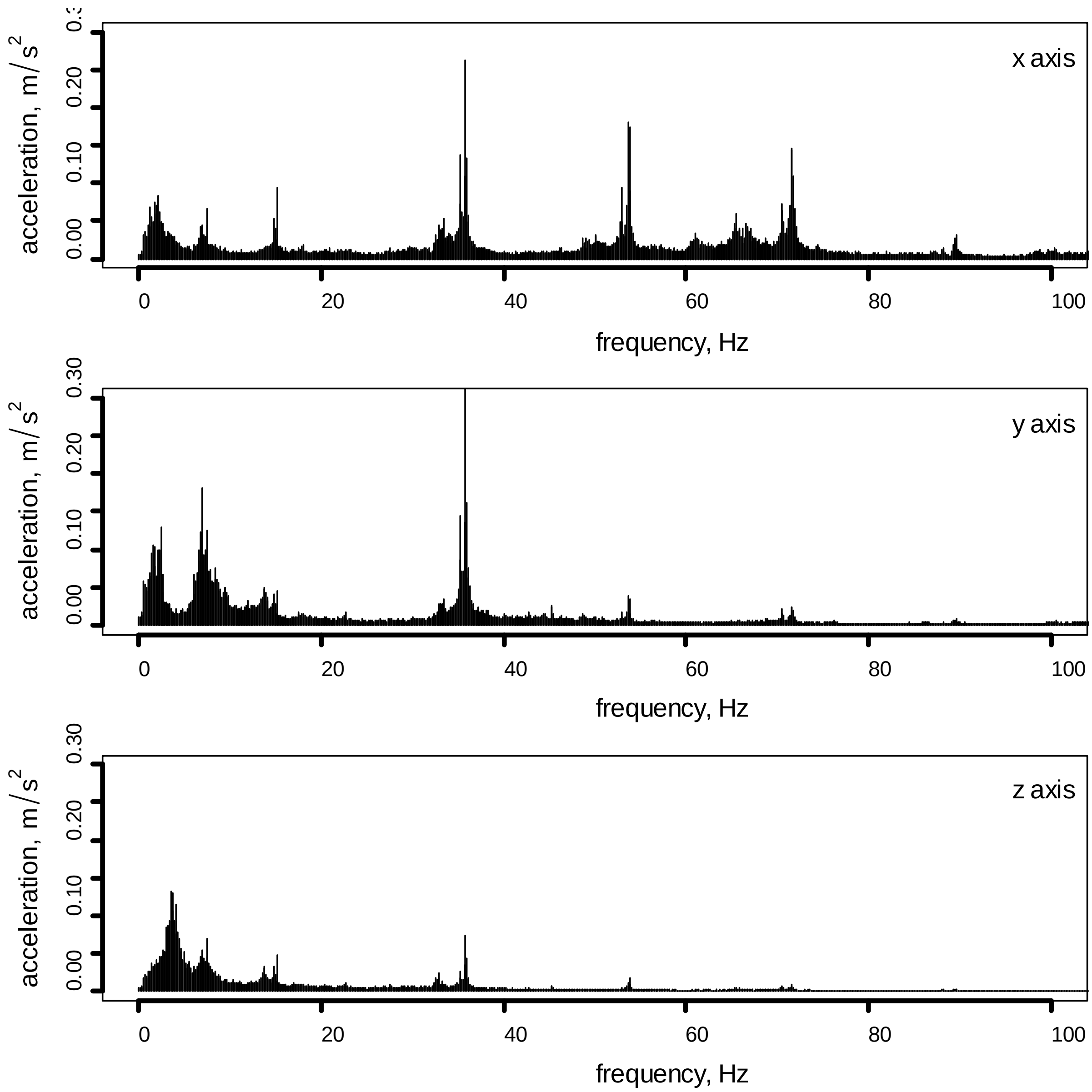


Figure 7. Examples of FFT spectra.

Conclusions

The study, even if preliminary, allows for some considerations:

The procedure adopted proved to be effective in assessing the daily vibration exposure of operators during pesticide distribution in citrus orchards. By timing the agricultural activities and by recording the whole signal, it is possible to evaluate the influence of the several working phases on the daily acceleration values. The methodology can be extended to other agricultural activities concerning citrus cultivation so to assess the effective risk of vibration for operators.

With reference to the situation analysed, the measured daily exposure values A(8) were under, but near, the limits established by the current regulation, so in different working conditions (different incidence of the transfer times with respect to the whole operating cycle, different ground profiles, machine features, forward speeds, etc.), it is possible to get an increase in the exposure values and then appropriate cautions should be taken into consideration.

Given the previous observations, further studies are necessary to investigate different working conditions so to prepare a complete database useful to assess the real risk of operator's vibration exposure in citrus fruit sector.

References

Bovenzi M., Hulshof C. 1998. An updated review of epidemiologic studies on the relationship between exposure to whole-body vibration and low back pain. Journal of Sound and Vibration, vol. 215, n. 4, 595–611.

Bukta A. J., Sakai K., Sasao A., Shibusawa S. 2002. Free play as a source of non linearity in tractor-implement systems during transport. Applied Engineering in Agriculture, vol. 45, n. 3, 503–508.

Cutini M., Bisaglia C. 2007. Indirect influence of mounted implements on agricultural tractor operator comfort. Proceedings of the XXXII CIOSTA-CIGR Section V Conference, vol. 1, 173–178.

D.P.R. (Presidential Decree) no. 459 of 24th July 1996. Regolamento per l'attuazione delle direttive 89/392/CEE, 91/368, 93/44 e 93/68 concernenti il riavvicinamento delle legislazioni degli Stati membri relative alle macchine. Gazzetta Ufficiale Supplemento Ordinario n. 209, September 6, 1996.

Directive 2002/44/EC of the European Parliament and of the Council of 25 June 2002 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration). Official Journal of the European Communities no. L 177/13, July 6, 2002.

EN 1032-1996. Mechanical vibration - Testing of mobile machinery in order to determine the whole-body vibration emission value - General

ENAMA. 2005. Produzione documentale tecnica sulla problematica delle vibrazioni connessa all'uso delle macchine agricole.

Fornaciari L., Pochi D., Vassalini G., Gallucci F. 2008. Investigation of the vibrations transmitted by agricultural tractor to the driver under operative conditions. Proceedings on CD-ROM of the International Conference: "Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-Food Systems", September 15–17, 2008, Ragusa, Italy.

Giunchi A., Cutini M., Ragni L., Bisaglia C. 2008. Assessment of Vibration Influence on Comfort Level of an Agricultural Narrow Tractor in Vineyard Operations. Proceedings CD-ROM of International Conference on Agricultural Engineering & Industry exhibition AgEng 2008.

Government Decree no. 187 of 19th August 2005. Attuazione della direttiva 2002/44/CE sulle prescrizioni minime di sicurezza e di salute relative all'esposizione dei lavoratori ai rischi derivanti da vibrazioni meccaniche. Gazzetta Ufficiale n. 220, September 21, 2005.

Government Decree no. 81 of 9th April 2008. Attuazione dell'articolo 1 della legge 3 agosto 2007, n. 123, in materia di tutela della salute e della sicurezza nei luoghi di lavoro. Gazzetta Ufficiale n. 101, April 30, 2008.

Hulshof C.T.J., Van der Laan G.J. 2000. Criteria for recognition of whole-body vibration injury as occupational disease: a review. Proceedings of the II International Conference on Whole Body Vibration Injuries. November 2000, Siena, Italy.

ISO 2631-1997. Mechanical vibration and shock - Evaluation of human exposure to whole-body vibration - Part 1: General requirements.

ISPESL. 2001. Linee guida per la prevenzione del rischio vibrazioni negli ambienti di lavoro.

Kornecki T.S., Price A.J., R. Raper L. 2006. Performance of different roller designs in terminating rye cover crop and reducing vibration. Applied Engineering in Agriculture, vol. 22, n. 5, 633–641.

Monarca D., Cecchini M., Vassalini G. 2005. Il rischio da esposizione a vibrazioni per gli addetti all'uso delle tosaerba semoventi. Proceedings on CD-ROM of the AIIA2005, June 27–30, 2005, Catania, Italy.

Pessina D., Bonalume V. 2009. Esposizione a vibrazioni nella filiera viticola. Proceedings on CD-ROM of the AIIA2009, September 12–16, 2009, Ischia Porto (NA), Italy.

R Development Core Team. 2007. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria, ISBN 3-900051-07-0, URL http://www.R-project.org.

Scarlett A.J.; Price J.S.; Stayner R.M. (2007). Whole-body vibration: evaluation of emission and exposure levels arising from agricultural tractors. Journal of Terramechanics, vol. 44, 65–73.

Dust Exposure of Operators During Citrus Orchard Cultivation

Cerruto E., Failla S., Manetto G., Emma G., Balloni S.
Dipartimento di Ingegneria Agraria (DIA), Via Santa. Sofia, 100 – 95123 Catania, Italy
Tel. +39 0957147514, Fax +39 0957147600
ecerruto@unict.it

Abstract

This study is focused on operator's dust exposure during some cultural operations: soil tillage, fertilisation, and pruning trituration. Soil tillage was performed by using a disc harrow, a tooth harrow, and a rototiller, fertilisation by using a centrifugal fertiliser, and pruning trituration by using a pruning triturator. Moreover, tractors equipped or not with cab were used. Dust was measured by using a portable particle dust monitor, whose operating principle lies in light scattering, and results were expressed as count per minute (cpm). They can be converted in mg/m^3 by using the standard calibration factor (1 cpm = 0.001 mg/m^3) or by carrying out parallel gravimetric measurements.
During soil tillage and fertilisation, the experiments showed a significant reduction (from 124 to 37 cpm, less than a third) in the exposure when working with the tractor equipped with cab. The highest exposure was measured during pruning trituration (1825 cpm). Assuming the standard calibration factor, these values are lower than the ACIGH exposure limits, but STEL values over 15 minute when working with pruning triturator without cab are near to those established by ACGIH.

Keywords: safety, soil tillage, fertilisation, pruning trituration

Introduction

Although many cultural operations in citrus orchards have been mechanised since a long time by using tractors and operating machines, risks for the operators' safety are still present. Among this, it may be cited dust, volatile organic compound (VOC), noise and whole body vibration exposures. Dust exposure may occur, as an example, during soil tillage or pruning crushing, or when fertilisers or dusters are used, while VOC exposure is due, for example, to the engines' exhaust or the pesticides sprayed during treatments of trees or soil. Noise and vibration exposure is always present when tractors are used.

In this study, the attention is focused on dust exposure, taking into consideration some cultural operations: soil tillage, fertilisation, and pruning trituration.

Similar studies have been conducted on confined spaces as greenhouses to evaluate the re-entry times (Siebers and Mattusch, 1996; Carrara *et al*., 2005; Conte *et al*., 2008; Gambino *et al*., 2008), nurseries (Madsen *et al*., 2009), farm animal houses (Hartung and Schulz, 2008; Costa and Guarino, 2007), during grain handling, when the risk to breathe mycotoxins is also present (Geng, 2008), industrial companies as pasta factories (Bianchi *et al*., 2008) or wood factories (Biondi *et al*., 2002).

Some studies in open filed have concerned the mechanised harvesting of hazelnuts (Cecchini et al., 2005; Monarca et al., 2008), as well as the use of motorised handheld

---

The Authors equally contributed to the present study.

machines as chainsaws and portable brush-cutters, which expel the exhausts near the operator (Monarca et al., 2005).

During some cultural operations in citrus orchards as fertilisation, soil tillage with rototillers (widespread in many hilly areas), or pruning trituration, due to the limited space between the rows that prevent using tractors equipped with cab, the risk of dust exposure could be quite high. This research is a first approach to afford the problem, that will be expanded in the future by other measurement sessions in different working conditions.

Materials and Methods

Dust exposure was measured during soil tillage with a tooth harrow, a disc harrow, and a rototiller, during pruning trituration with a pruning triturator, and during fertilisation with a centrifugal fertiliser. Soil tillage and fertilisation were carried out in one citrus orchard and pruning trituration in another one, with two tree layout: 4 m × 6 m and 4 m × 8 m. Moreover, tractors equipped or not with cab were used (Tab. 1 and Fig. 1).

Table 1. Cultural operations and machinery involved in the experimental tests.

Cultural operations	Operating machines	Tractors	
Soil tillage	Tooth harrow	33 kW, tracked, without cab	59 kW, wheeled, with cab
	Disk harrow	33 kW, tracked, without cab	59 kW, wheeled, with cab
	Rototiller		
Fertilisation	Centrifugal fertiliser	33 kW, tracked, without cab	59 kW, wheeled, with cab
Pruning trituration	Pruning triturator	55 kW, wheeled, without cab	

Figure 1. Tractors and operating machines used for the experimental tests (from top to bottom, from left to right): wheeled tractor with cab; tracked tractor; rototiller; wheeled tractor without cab; disk harrow; tooth harrow; fertiliser; pruning triturator.

Dust was measured by using a portable particle dust monitor, the model 3431 by Kanomax, whose main characteristics are shown in Table 2. Its operating principle lies in light scattering: when a laser hits particle matter, light scattering occurs. The dust monitor detector unit (photo diode) collects the amount of scattered light, converts it into electrical signal, and adds it as count value (count per minute: cpm). Given the pump flow rate of 1 dm^3/minute, it follows that 1 cpm is equivalent to 1 count per cubic decimetre. If density of particle matter is known, count can be converted to mass concentration (mg/m^3) in proportion to the scattering light, otherwise gravimetric sampling is required. In this study the standard factory calibration is used, for which 1 cpm = 0.001 mg/m^3 for 0.3 µm stearic acid particles. Applications for light scattering dust monitor include indoor air quality investigations, point source monitoring, and personal exposure monitoring.

Table 2. Main characteristics of the 3431 digital particle counter by Kanomax.

Measuring Method	Light Scattering Method
Particle Size Range	0.1–10 µm
Measuring Range	1–9999 count per minute (cpm)
Pump Flow Rate	1 dm^3/minute
Accuracy	±10% of reading ±1 cpm
Measuring Time	1 minute / 3 minutes / 10 minutes with built-in timer, and continuous mode
Light Source	Laser diode
Detector	Photo diode
Display	4-digit LCD, dust count value (cpm), relative mass concentration value
Output	Analog output, instant value 0–4000 cpm = 0–2.5 V
Power Supply	AC 100 V adapter and dry cell batteries (6 × AA batteries)
Dimensions	162 × 62 × 100 mm
Weight	1 kg, not including batteries

Figure 2. Dust monitor and data logger unit.

Figure 3. Positioning of the dust monitor during the experimental tests.

As the device is lacking in datalogging capability, to monitor continuously the particle concentration its analog output was connected to an external data logger. The management software HOBOware Pro allows for the main graphical and numerical analyses, as well as for the raw data export. A picture of both dust monitor and data logger unit is shown in Figure 2. Measurement sessions ranged from about 6 up to 41 minutes. During measurements, the dust monitor was hung to the operator's neck by means of a suitable shoulder belt (Fig. 3) or placed inside a pocket of a jacket worn by the operator. The air sampling point was situated at about 30 cm from the respiratory tract. Monitoring was carried out continuously with a sampling time of one second and average values were calculated at every minute for each cultural operation. All calculations and graphical representations were carried out by using the open source software R.

Results and Discussions

Figures 4 and 5 report the cpm values (average values at every minute) for each cultural operation. Whole average values and standard deviation among the minutes are reported in Figure 6.

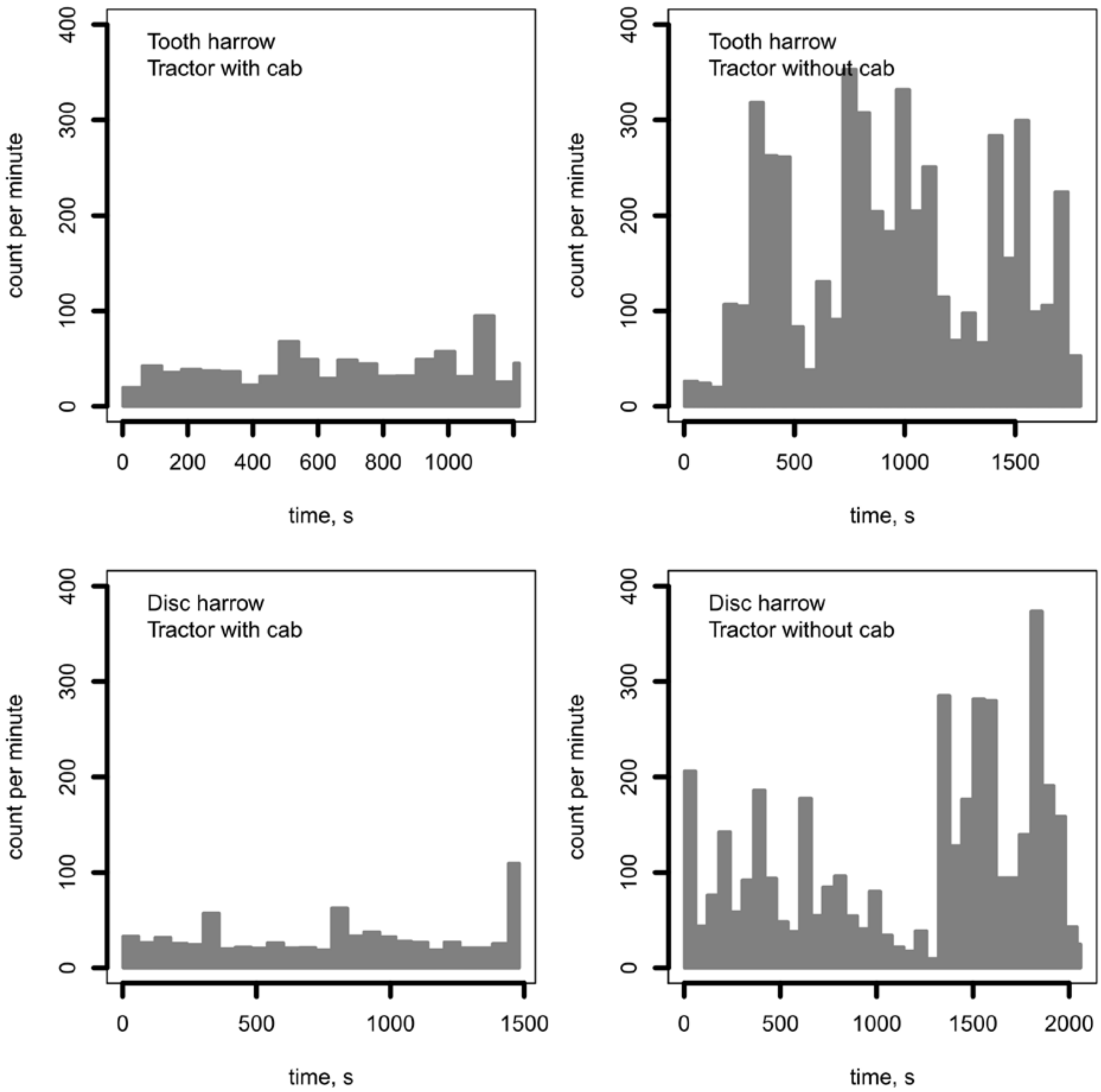


Figure 4. Dust concentration (average values at every minute).

When considering soil tillage and fertilisation, both operations performed in the same citrus grove, the graphs show a significant reduction in the cpm values when working with the tractor equipped with cab. In fact, the average cpm value was 37 when using the tractor equipped with cab (41 cpm for the tooth harrow, 31 cpm for the disc harrow, and 37 cpm for the fertiliser) and more than three times as much when working with the tractor without cab (163 cpm for the tooth harrow, 115 cpm for the disc harrow, and 94 cpm for the fertiliser). The highest average value (174 cpm), as expected, was measured when working with the rototiller, whose operating tools are very near to the operator.

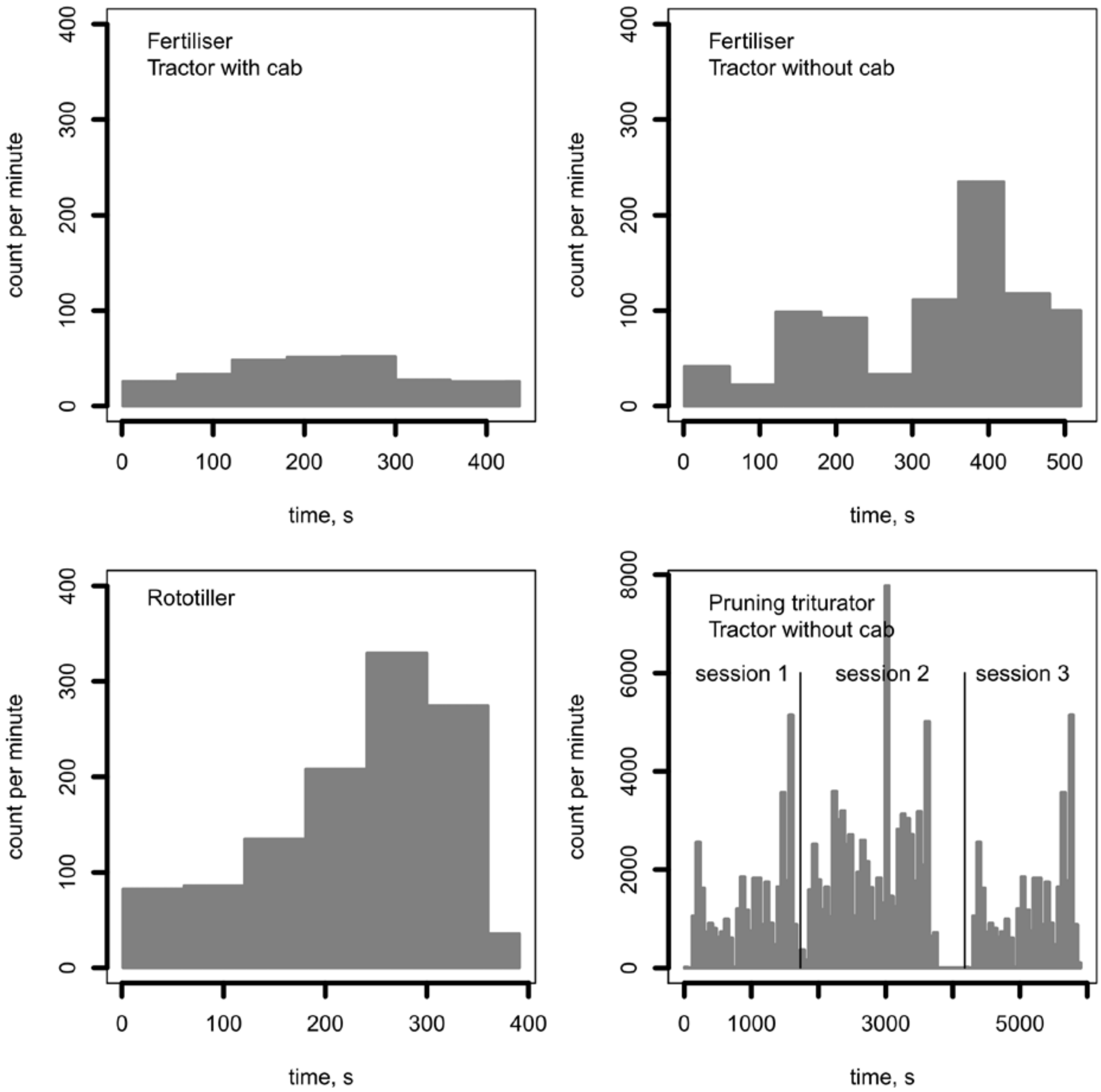


Figure 5. Dust concentration (average values at every minute).

Pruning trituration, performed in a different citrus orchard, was characterised by a much high dust production. The average cpm values ranged from 332 to 1825 for the three replicates. This was due both to the mode of functioning of the operating machine (the high speed rotating tools triturate pruning and whip up dust) and to the different soil characteristics (in the first citrus orchard the soil was partly covered with grass).

In order to evaluate the exposure, cpm values have to be converted in mg/m^3: assuming the standard factory calibration for which 1 cpm = 0.001 mg/m^3 (more precise determinations require parallel gravimetric measurements), it follows that average dust concentration ranges from 31 (disc harrow, tractor with cab) to 1825 g/m^3 (pruning triturator, tractor without cab).

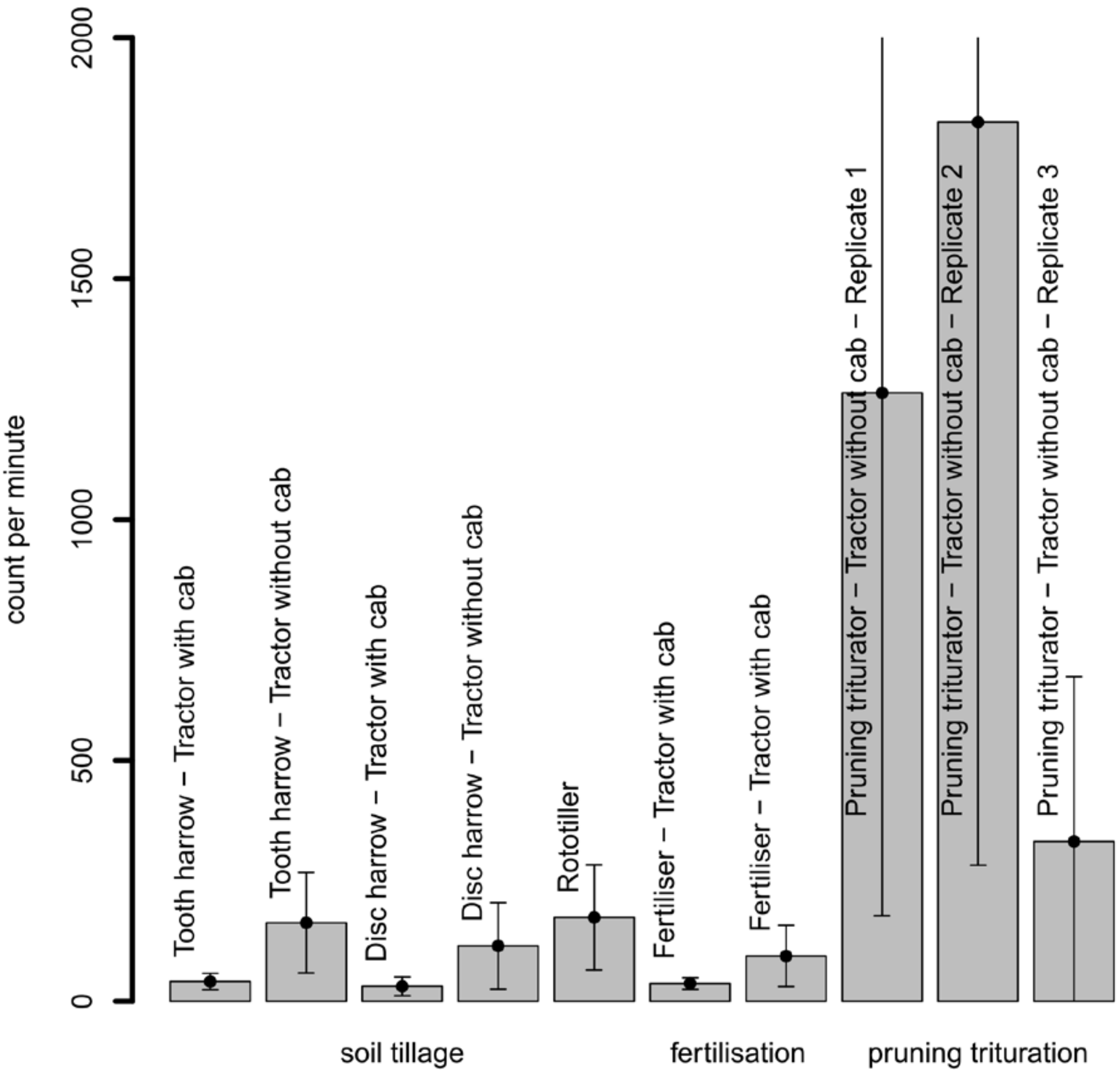


Figure 6. Dust concentration (average values and standard deviations for each cultural operation).

Threshold limits values (TLV), recommended exposure limits (REL), or permissible exposure limits (PEL), are fixed and annually updated by Organisms like ACIGH (American Conference of Governmental Industrial Hygienists), NIOSH (National Institute for Occupational Safety and Health), or OSHA (Occupational Safety and Health Administration), respectively. There are three categories of limits. The NIOSH defines:

1. Time-weighted average (TWA): time-weighted average concentration for up to a 10-hour workday during a 40-hour workweek;
2. Short-term exposure limit (STEL): unless noted otherwise, the STEL is a 15-minute TWA exposure that should not be exceeded at any time during a workday;
3. Ceiling REL: unless noted otherwise, the ceiling value should not be exceeded at any

time.

ACGIH and OSHA provide similar definitions.

The TLV-TWA limits established by ACGIH over an 8 hours exposure time and for (insoluble) particles not otherwise classified (PNOC), are (2007) 3 mg/m^3 for respirable dust (particle diameter from 0.5 to 5   m) and 10 mg/m^3 for inhalable dust (particle diameter from 5 to 10   m). In the present study, all the average values computed are lower than these limits. Only the tests with the pruning triturator are characterised by peak and STEL values (Tab. 3) that come near to 3 mg/m^3.

Table 3. STEL ranges (cpm or   g/m^3) measured during the experimental tests.

	Tractor	
Operating machine	With cab	Without cab
Tooth harrow	38–45	155–211
Disc harrow	27–32	59–154
Rototiller		174
Fertiliser	37	94
Pruning triturator		269–2665

The low values measured during soil tillage are to be related to the soil characteristics, partly covered with grass, so, continuing the researches, other different working conditions—different soil status and composition, lower humidity, other operating machines and different working time—will have to be investigated.

Conclusions

The study, even if preliminary, allows for some interesting considerations:

- Average values of dust concentration during the experimental tests were quite low and under the threshold limit values established by the ACGIH;
- Cab was efficient in reducing dust exposure during soil tillage: on average, dust concentration when working with tractors equipped with cab was lower than a third of that measured when working without cab;
- Pruning trituration produced much higher dust concentration values. When performed by using tractors without cab, the STEL values were near to those established by ACGIH, so in different working conditions (different pruning density, different operating machine features, different soil characteristics), to exceed limits have to be expected; consequently, during this activity, a tractor with cab would be used or proper PPE would be wore;
- Further studies are necessary to investigate different working conditions so to prepare a complete database useful to assess the real risk of operator's dust exposure in citrus fruit sector.

References

Bianchi B., Cassano F., Mongelli C. 2008. Experimental Trials to Evaluate Risks from Noise and Particulate Matter in a Pasta Factory. Proceedings on CD-ROM of the International Conference: "Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-Food Systems", September 15–17, 2008, Ragusa, Italy.

Biondi P., Monarca D., Cecchini M. 2002. La valutazione del rischio da esposizione a polveri di legno duro: indagine sperimentale e metodologica. Proceedings of the AIIA Congress "La sicurezza delle macchine agricole e degli impianti agroindustriali", Alghero, Sassari, September 11–15, 2002, 377–390.

Carrara M., Catania P., Morello G., Planeta A., Vallone M. 2005. Valutazione dei fattori di rischio chimico fisico nelle serre. Proceedings on CD-ROM of the AIIA 2005, Catania, June 27–30, 2005.

Cecchini M., Monarca D., Biondi P., Colantoni A., Panaro A. 2005. Il rischio da esposizione a polveri per gli addetti alla raccolta delle nocciole. Proceedings on CD-ROM of the AIIA 2005, Catania, June 27–30, 2005.

Conte E., Faraci A., Caffarelli V., Gatti R., Zappa G. 2008. Indagine sulla persistenza in ambiente protetto di alcuni prodotti fitosanitari per la valutazione del rischio dermico ed inalatorio: risultati di due anni di attività. Proceedings of Giornate Fitopatologiche 2008, vol. 1, 495–502.

Costa A., Guarino M. 2008. PM10 and Fine Particulate Matter Concentration and Emission from three different type of Laying Hens Houses. Proceedings on CD-ROM of the International Conference: "Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-Food Systems", Ragusa, September 15–17, 2008.

Department of Health and Human Services. 2007. NIOSH Pocket Guide to Chemical Hazards. DHHS (NIOSH) Publication no. 2005–149.

Gambino L., Merulla M., Amato F., Flori P. 2008. Presenza di metal-isocianato in serre geodisinfestate. L'Informatore Agrario, 2008, 44, 39–42.

Geng Q. 2008. Dust Exposure during Grain Handling at Farms – A Pilot Study. Proceedings on CD-ROM of the AGENG 2008, Hersonissos, Creta, June 23–25, 2008.

Hartung J., Schulz J. 2008. Occupational and Environmental Risks Caused by Bio-Aerosols in and from Farm Animal Houses. Proceedings on CD-ROM of the International Conference: "Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-Food Systems", Ragusa, September 15–17, 2008.

Madesn A.M., Hansen V.M., Nielsen S.H., Olsen T.T. 2009. Exposure to Dust and Endotoxin of Employees in Cucumber and Tomato Nurseries. Ann. Occup. Hyg., vol. 53, no. 2, 129–138, 2009.

Monarca D., Cecchini M., Bernini M., Panaro A. 2005. Il rischio da esposizione a gas di scarico durante l'uso di motoseghe e decespugliatori. Proceedings on CD-ROM of the AIIA 2005, Catania, June 27–30, 2005.

Monarca D., Biondi P., Cecchini M., Santi M., Guerrieri M., Colantoni A. 2008. Evaluation of Respirable Dust Exposure during Hazelnut and Chestnut Mechanized Harvesting. Proceedings ob CD-ROM of the International Conference: "Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-Food Systems", September 15–17, 2008, Ragusa.

R Development Core Team. 2007. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria, ISBN 3-900051-07-0, URL http://www.R-project.org.

Siebers J., Mattusch, P. 1996. Determination of Airborne Residues in Greenhouses after Application of Pesticides. Chemosphere, 1996, vol. 33, no. 8, 1597–1607.

Safety Management in Horticulture and Floriculture: First Results of a Study in Friuli-Venezia Giulia

Cividino S.R.S.[1,2], Vello M.[1,2], Maroncelli E.[1], Gubiani R.[1], Pergher G.[1]
DISA, Department of Agriculture and Environmental Sciences, Via delle Scienze 208, 33100 - Udine – Italy; michela.vello@uniud.it, +39 0432 558656, fax +39 0432 558603
[2]GEMINI Department, Tuscia University, via S. Camillo De Lellis s.n.c., Viterbo, Italy +39 0761 357357, fax +39 0761 357356; michela.vello@uniud.it

Abstract
Agriculture remains, in Italy, one of the sectors of economic activity in which accidents still occur with a high frequency and the index that measures the number of accidents per 1000 workers is higher than in the other sectors. This leads to the need of corrective actions to increase safety levels. The objective of this research, realized during 2009 by collecting data of 10 farms located in different areas of Friuli-Venezia Giulia region, was to analyse in particular the horticulture and floriculture sectors, made up of medium-small farms, with the aim to individualize risk typologies that occur with greater frequency and all the aspects that don't fulfil the law in force. The first results underline a low attention to the obligations currently imposed by laws in force and the presence of risk sources common to the studied firms, despite the heterogeneity of productive trend.

Keywords: risks analysis, greenhouses, check lists

Introduction

The present search analyzes the actual state of the management of the safety at the workplace in the horticulture and floriculture areas, that has been being considered as a unique sector since few years. Such productive orientation represents an important fraction of the agricultural compartment and is characterized for the small involved surfaces and the elevated value of the production (MIPAF 2009). According to the most recent data, the horticulture and floriculture represent the 7,9% of the Gross Saleable Production of the Italian agriculture and is present with a number of 28.831 specialized firms. In the Friuli-Venezia Giulia region, according to the ISTAT data, 422 firms are present and in the last two years this number is grown of 111%. The present work wants to analyze the situation of the safety in this sector, starting from the individuation of the main risks and their classification for priority of management; to identify possible operative solutions to increase the safety level at the workplace; to furnish, if concrete applicative solutions for the elimination of the risks can't be individualized, the measures of prevention and protection for the reduction of the residual risk.

Methods

The attainment of the preset objectives has foreseen the individualization and realization of intermediary steps:

1. cognitive analysis: individualization of the principals firms' aspects to be considered; individualization of the potential risks; definition of a sample of 5 firms, located on the regional territory and available to collaborate in the study;
2. check-list elaboration: the inspections in the individualized firms as well as the

support of guides, indicative documents, manuals, brochures and the recurs to example available in literature lead up to the definition of the used check-lists

3. risks evaluation: quantification and assignment of a value to the risk factors present in the analyzed reality and consequent definition of a hierarchy of the emerged problems. The risks evaluation has foreseen the preliminary definition of an experimental protocol that considers possible measures already adopted by the employer for the reduction of the risks and determines therefore the entity of the residual risks;
4. individualization of possible operational solutions, able to improve the safety levels. The cognitive investigation, with the purpose to identify the risk factors mainly diffused in the examined context

The check lists have been developed with reference to four macro-areas of investigation: equipments, workplaces, formal fulfilments, operational duties.
For the qualitative risk assessment, a risk matrix expressed as a function of frequency and magnitude has been used. In the traditional analysis of the safety at the workplace, the risk frequency can't be interpreted in statistical terms, but rather derives from the interpolation of subjective and objective data. Therefore, the following sources were asked:

- Inail (the Workers Compensation Authority) data (2006-2009): evolution of occupational accidents;
- Analytic reports and publications: "Guidelines for the analysis of the horticultural industry" and "Guidelines for the analysis of the horticultural sector";
- Log of Work-Related Injuries of the firms involved in the survey technical analysis and interviews of employees on the importance of the "near-misses".

Frequency	Value	Criteria
Not probable	1	The dangerous situation may occur only in conjunction with independent and unlikely events. There were no known episodes already occurring
Few probable	2	The dangerous situation may occur only in conjunction with unlikely events. Extremely rare episodes are known
Probable	3	The dangerous situation may occur, even not automatically. Some episode, in which to the dangerous situation the damage is followed, is known
Highly probable	4	A direct correlation among dangerous situation and damage event exists . Damages are already verified with reference to similar situations.

Table 2. Method of evaluation

In order to assess the risk, on the basis of acquired data, four classes of frequency or probability of occurrence of the damage, and magnitude have been identified, according to the criteria given in table 2.
On the basis of the data inferred from the bibliography and from the available statistics, the classes of frequency (named f(xSB)) shown in the table 3 have been attributed to the different typologies of risk.

Code	Risk	Frequency	Code	Risk	Frequency
1	Trip hazards, fall hazards from the same level	4	21	Pregnant workers	1
2	Crash against moving objects	3	22	Allergen	2
3	Risk of falling on the stairs	3	23	Working alone	3
4	Burns or contact with material at high temperatures	2	24	Dusty and dirty activities	2
5	Contact with aerosols	1	25	Chemical risk	4
6	VDU Risk	1	26	Fire and explosion risk	1
7	Cut risk	2	27	Exposure to carcinogens or mutagens	1
8	Contact with sharp or cutting equipment	3	28	Vibrations	3
9	Incorrect postures	4	29	Biological risk	2
10	Eye strain	1	30	Noise	3
11	Illumination	1	31	Dusts	3
12	Manual Handling	4	32	Exposure to radiations	1
13	Stress	2	33	Drowning	2
14	Repetetive Movements	4	34	Monotony	4
15	Electrocution	1	35	Bust flexion and extension frequent movements	3
16	Mental Workloads	2	36	Fall, tripping, slipping	2
17	Microclimate	4	37	Carpal tunnel	3
18	Heat stress risk	2	38	Entanglement, dragging	2
19	Cold climate risk	4	39	Bust torsion frequent movements	3
20	Physical Workloads	4	40	Cimate changes	3

Table 3. Classes of frequency, f(xSB)

The frequency identified through table 3 with the symbol *f(xSB)*, must be contextualized the analyzed sample, also considering the following variables:

CCO = organizational lacks;
CCG = managerial lacks;
CCTA = technical lacks of the environmental system;
CCU = human-behavioural lacks.

Therefore the assigned frequency, f (xR), in reference to each identified risk, has been evaluated according to the following report:

$$f (xR) = f (xSB) \times (CCO \times CCG \times CCTA \times CCU)$$

and is calibrated to the surveyed sample (Cividino et al, 2008).

For each area, data have been collected during 2009 by a survey in 10 farms located in different areas of Friuli-Venezia Giulia region.

Results

The first results underline a low attention to the obligations currently imposed by laws in force and the presence of risk sources common to the studied firms, despite the heterogeneity of productive trend.

The punctual analysis of the studies in the different productive addresses has allowed to individualize with precision those duties characterized by a more complex and serious profile of risk. Despite the deep heterogeneity that characterizes the firms involved in the study, derived by the realization of different productive purpose and by the different management, clearly emerges that some activities are very similar can be considered communes to the firms that operate inside the compartment.

These activities can be brought back to four great groups:
1-loading, unloading and transportation of the product;
2-preparation and distribution of treatments;
3-potting and transplantation;
4-pruning of Ornamentals.
The results emerged by data processing underline the inadequacy of working conditions, due to a mismanagement of the safety inside the firms, predisposing conditions of risk for workers. Frequent failure in terms of safety emerges especially in the using of personal protective equipments and in the training of workers

Conclusions

The results of this work, even if obtained referring to a reduced sample of companies, have highlighted the effective presence of a situation still very far from the ideal: risks are often underestimated and the safety management is not a priority in the general management of a company. This suggests additional studies, designed to sensitize the workers on the importance of the safety at the workplace.

References

Yang, J.N., 1976. Statistical estimation of service cracks and maintenance costs for aircraft structures, Journal of Aircraft, 13(12), 929-937.
Cividino S. R. S., Colantoni A., Vello M., 2008. "New methodologies to evaluate risks in the agricultural sector", "International conference: -Innovation technology to empower SA-, Ragusa, 15-17 settembre 2008, isbn/issn: 978-88-903151-1-4.
ISTAT, "Annuario Statistico Italiano 2008", pag 769: "Glossario".
ISTAT, "Rapporto annuale: La situazione del Paese nel 2008", maggio 2009.
ISTAT, "Annuario Statistico Italiano 2008", pag 346 Tav. 13.8: "Superficie e produzione delle coltivazioni agricole. Anni 2003-2007".
ISTAT "Struttura e produzioni delle aziende agricole, periodo di riferimento annata agraria 2006-2007, diffuso il 03 dicembre 2008". Disponibile su www.istat.it.
Gubiani R., Vello M., Zoppello G., 2008. "La situazione del rischio alimentare, dell'operatore e ambientale nella vitivinicoltura friulana". Atti del convegno "La sicurezza negli ambienti agroforestali: aspetti tecnici, gestione e controllo dei rischi", Gemona del Friuli, 18 gennaio 2008.

Equipment and Installations for the Distribution of Pesticides in Greenhouses: Aspects Connected with Testing and Bringing Into Compliance with Standing Regulations

Conti A., Balloni S., Tirrò G., Emma G., Caruso L., Schillaci G.
University of Catania. DIA, Mechanics Section
Via Santa Sofia, 100 – 95123 Catania, ITALY.
Tel 0039 0957147518, Fax 0039 0957147600,

Abstract
Fixed or semi-fixed installations for the distribution of pesticides are becoming more and more common in Sicilian greenhouses. As in the case of spraying machinery, these installations have to be periodically tested in order to detect any malfunctioning that could lead to inefficacious treatment, risk to human health and environmental damage. The aim of this work is to investigate the real possibility of carrying out the checks required by current regulations and also to provide information for the drawing up of guide lines for operators intending to provide their greenhouses with fixed or semi-fixed installations for the distribution of pesticides. This paper presents the results of research carried out in greenhouses provided with various types of installations in the southeast of Sicily. For each distribution system the possibility of checking the working order of the components in accordance with the protocol drawn up by an ENAMA project National Work Group was examined. The results obtained show the current situation as regards installations for the treatment of protected crops on the southeast coast of Sicily. Moreover suggestions are given for the construction of installations complying with the current regulations and which can be periodically tested as required by those regulations and GDO recommendations.

Keywords: mechanisation, safety, health, treatment, ENAMA protocol

Introduction

Pesticide defence in Mediterranean greenhouses is either carried out with backpack or towed equipment or with installed plants (complete with distributors positioned around the greenhouse or made up of a tank, hoses and guns equipped with one or more nozzles handled by operators. In environments with a wide central corridor, treatments are sometimes carried out with sprayers towed by tractors (Bellissima *et al.* 1998, Cerruto *et al.* 1997, Balsari *et al*. 2008, Schillaci *et al.* 2009) Recently, a small self-propelled tracked vehicle has begun to be used and semi-automatic and automatic versions are being developed (Balloni *et al.* 2008 Balloni *et al.* 2009). Working towards more efficient distribution of the pesticides numerous trials have been carried out to perfect the boom (Schillaci *et al*. 2009, Cerruto et al. 2009, Nuyttens S. *et al.* 2005,) For periodic control of the spraying machines commonly in use, the EN 13790 regulation (currently being revised) applies. Moreover, recently directive 2009/128/EC was issued and this was accepted also in Italy. Functional control of spraying equipment is urgently required by the GDO also for equipment not included in the current regulations, with the aim of eliminating the problem of residue accumulating on the products currently on the market. Moreover, only by subjecting processes to control can a firm hope to obtain quality certification ISO 9001 *Vision* and following modifications. The heterogeneity of the equipment present in Sicilian greenhouses and the pressures applied by the regulations and market forces led to the idea of carrying out a survey in south-east Sicily as regards installations for the distribution of pesticides and their ability to conform to the periodic tests required by the current regulations.

Materials and Methods

The study was carried out in greenhouses on the south-east coast of Sicily, where greenhouse cultivation is very widespread. The greenhouses investigated were of a common and, at the same time, modern type with metal supporting structures, plastic film covers and lateral closable openings. During the inspections the spraying equipment was examined and the presence and condition of components necessary for a positive outcome of a hypothetical functional test (ENAMA 2007) was checked. Finally, the critical points of the installations and the standing procedures for pesticide distribution and the disposal of waste were noted, with reference to the TOPPS project guidelines, the GlobalGap protocol recommendations and the regulations contained in the Safety Consolidating Act (Legislative Decree 81/08).

Results

The research made it possible to identify certain recurrent types of equipment for distribution. There is always an operator that directs the nozzle and a helper that moves the hose.

Tractor-sprayer complex at fixed place outside the greenhouse. When there is not sufficient space inside the greenhouse a stationary external tractor-sprayer complex is used. Spraying takes place by means of a flexible hose with a gun at the end of it. This is probably a widespread combination.

Semi-fixed centralised plant Here there is a conventional fibreglass, PE or brickwork tank inside a centrally positioned greenhouse. Pipes starting from a medium – high pressure pump arrive at the other greenhouses: these pipes maybe underground or aerial. In each greenhouse the pipes end with a connection to other tubes around ten metres long and ending with a common gun.

Semi-fixed installations. When there is enough room in the greenhouse corridors, sprayers assembled on a trolley and manufactured by local craftsman are used. There is a motor-pump, a tank and a hose reel. Spraying takes place from a gun at the end of a long hose.

There are also, although these are not common, fixed installations with aerial pipes and fixed sprayers installed on them at regular intervals. Moreover, as already said, there are rare cases in which the sprayer, pulled by a tractor, can operate inside the greenhouse.



For each component of the three main types of installation, the ability to meet the requirements of the functional ENAMA test was examined (Tab. 1).

Tab. 1 – Components of defence equipment, requirements and findings

Components checked	**Requirememts**	**Sem-fixed installations**	**Spraying machine**	**Fixed installations**
	Main pump			
Capacity	Must be able to guarantee adequate pulverisation at the furthest spraying point, working at the maximum pressure indicated by the constructor of the spraying device and at the same time guaranteeing visible mixing, or else must be ≥90% of nominal capacity	YES	YES	YES
Pulsations and leaks	There must not be visible pulsations caused by the pump	YES	YES	YES
Over pressure valve	If present must function correctly	N.P.	YES	YES

N.P not present

Components checked	**Requirements**	**Semi-fixed installations**	**Spraying machines**	**Fixed installations**
	Main tank			
Leaks	There must not be leaks from the tank	NO	YES	NO
Emptying	It must be possible to easily and reliably collect the liquid from the tank, without any leaks	NO	YES	NO
Non-return device	If present it must operate correctly	N.P.	N.P.	N.P.
MIXING	A clearly visible recircling must be obtained when spraying is carried out according to the nominal regime of the ptd, with the tank filled to half of its nominal capacity	NO	YES	NO
Liquid level indicator	There must be at least one tank liquid level indicator. This must be visible and legible during filling	NO	YES	NO
Measuring and regulation system	All the devices for measuring, switching on and switching off and pressure and/or capacity regulation must function correctly and there must be no leaks. All devices for pressure regulation must maintain a constant pressure with a ±10% tolerance and constant capacity and reach the same work pressure after the equipment has been stopped and restarted.	YES	YES	YES

Components checked	**Requisiti**	**Semi-fixed installations**	**Spraying machines**	**Fixed installations**
	Manometer			
Presence	There must be at least one manometer near the pump and preferably one near the gun	Y/N	Y/N	Y/N
Functioning	The hand of the manometer(s) must be stable and permit the work pressure to be read. The manometer(s) must measure with a precision of ±10% with respect to the actual value	NO	YES	YES
Reading scale	The manometer's (s') reading scale must be clearly visible and legible by the operator for the entire duration of the spraying and it should be suitable for the work pressure interval used. The manometer's (s') reading scale must have a reading interval ≤0,2 bar for work pressures of ≤5 bar; ≤1,0 bar for work pressures between 5 and 20 bar; ≤2,0 bar for work pressures ≥20 bar	NO	NO	NO
Conduits and hoses	These must be in a good state of repair and show no signs of damage. Their construction characteristics must be compatible with the working pressure. There must not be leaks from the conduits or hoses when tried with the maximum working pressure indicated by the constructor of the spraying machine. In the case of breakage of the pipes/hoses it must be possible to possible to interrupt spraying immediately (for example with one or more taps situated on the delivery pipe).	YES	YES	NO

Components checked	Requirements	Semi-fixed installations	Spraying machines	Fixed installations
Filtration system, conduits and hoses				
Filters	There must be a filter in the filling opening of the tank and at least one filter on the delivery pipe or pump aspiration. The filters must be in good condition and with link sizes suitable for the assembled nozzles	NO	YES	YES
Insulating device	There must be an insulating filter device which, even when there is liquid in the tank, permits cleaning of the filter with no loss of liquid except for that which could be inside the filter itself or in the aspiration pipe.	NO	YES	YES
Load/charge loss	The working pressure indicated by the manometer mounted near the lance must be compared with the pressure shown by the manometer near the pump. The two values must be shown in the trial report.	NO	NO	NO

Components checked	Requirements	Semi-fixed installations	Spraying machines	Fixed installations
Nozzles				
Nozzle capacity	The capacity of each nozzle mounted on the lance must not differ by more than ±10% from the nominal value. If it is not possible to find the nominal capacity of the nozzle, this should be indicated on the trial report, and, if possible, its capacity should be compared with that obtained using a brand new lance or nozzle. Determine the capacity of each nozzle to the working pressure normally used by the operator, checking, in the case of several nozzles of the same type that the capacities do not differ by more than ±5% from the mean value calculated	YES	YES	YES
Loss through dripping	After switching off, the nozzles should not drip. Once five seconds have passed after switch off there should be no dripping.	YES	YES	YES

It should be pointed out that often for treatments at fixed sites outside the greenhouse, an obsolete spraying machine is used, with a tank and other components that do not meet current regulations. As regards fixed or semi-fixed installations, with a single tank or tanks in each greenhouse, as these are the result of artisan type assembly, they often lack the requirements of DPR 459/96: EU marking, identification plate (only the pump has one); the pipes connecting the pump to the tank are not covered with a sheath, the tank does not have devices inside to mix the contents; moreover, the tank lid is not hermetic or may even be absent. Often the installations and equipment lack devices for washing the circuits and neither are there auxiliary tanks (15L) for hand washing, even if this might not be necessary in greenhouses with running water.

Besides the components, particular attention was paid to the procedures, or better preparation and transport of the pesticide mixture, washing of the spraying equipment (tanks, conduits and guns) and to the disposal of waste matter. In the light of Global Gap protocol and the current regulations various critical points emerged (Tab. 2).

Tab. 2 – Critical points relative to preparation and transport of misture, washing of the equipment and disposal of waste.

Critical points found	Global Gap	Regulation
Bench for preparation of mixture		D.Lgs. 81/08 attachment IV – paragraph 2– points 2.1.5 and 2.1.8.1; UNI EN 14175 (requirements for chemical and aspiration hood)
Tools for misture preparation	**CB 8.7.11 – mm** **CB 8.9.6 - MM**	D.Lgs. 81/08 attachment IV – paragraph 2 – point 2.1.3
Inert materials in store	**CB 8.7.12 - mm**	D.Lgs. 81/08 attachment IV – paragraph 2 – point 2.1.12
Transport containers		D.Lgs. 81/08 attachment IV – paragraph 3 – Point 3.10
Washing after each treatment.	**CB 8.4.1 – mm** **CB 8.5.2 - R**	Dir. 1600/2002/EU Dir. 2000/60/EU Dir. 2006/42/EU
Washing water container	**CB 8.5.2 – R**	
Devices for container washing or alternative procedure	**CB 8.9.6 – MM**	
Mixture left in tank	**CB 8.5.1 – mm**	Dir 1600/2002/CE Dir 2000/60/CE Dir 2006/42/CE
Disposal of rinsing liquid for the containers and washing water. Partial disposal of the containers.	**CB 8.9.1 – mm** **CB 8.9.7 – mm**	D.lgs. 5 February 1997 n. 22 e s.m.i. "actuation of directives 91/156/eec regarding waste, 91/689/eec regarding dangerous waste and 94/62/eec on packaging and packaging waste". D.lgs. 22 May 1999, n. 209 "actuation of directive 96/59/ec regarding disposal of polychlorodiphenyls and dipolychlorotriphenyls"

From an analysis of the critical points, it emerges that the mixture preparation phase should be radically re-organised, avoiding the use of artisan-type equipment and instead using the specific equipment available on the market, such as a pre-mixer.
The transport of the mixture from its place of preparation to the tank seems to be an underestimated phase, as is the cleaning of the equipment used for the treatments.
A very weak point is represented by the management of the residual pesticide mixture (i.e. the quantity left at the end of the treatment). It is necessary to calculate more accurately the volume of liquid to be sprayed, to use tanks that comply with current regulations and inspect and regulate the equipment appropriately. Any remaining mixture could be diluted and

disposed of in the field. Where this is not possible, firms should acquire commercially available systems for the biodegradation of pesticide waste.

Conclusions

Given this research is based on samples, it is certainly not complete, but it provides some indications that might be useful for farmers, companies and technicians involved in pesticide defence and/or the construction of relative installations.
With reference to the area of the research, the great heterogeneity of equipment installed in the greenhouses is confirmed. There is clearly a great trend towards ‘do it yourself’, with the contribution of the farmer himself or small artisan firms involved in the construction of the whole pesticide distribution plant or as suppliers of a part of it.
Critical points of these plants are represented by the tank, the pipes (whether aerial or embedded) used to channel the mixture from the tank to the spraying point (particularly as regards fixed plants), and by the guns manually used for spraying, at present not subjected to any periodical control.
Possible solutions are the elimination of self-made mixing tanks and the use of tanks complying with standing regulations (parts of modern spraying systems on the market), the elimination of delivery pipes (or plants with a centralised tank serving several greenhouses), the subjection of entire plants, however they are organised, as well as the guns to periodical tests.
To sum up, the distribution of pesticides in the greenhouse should take place with the use of equipment complying with current regulations – either equipment on the market or self-made equipment using parts complying with these regulations. In the case of mobile equipment, this can easily be periodically tested. As regards fixed or semi- fixed installations, these should be built and assembled on trolleys with wheels (tank, pump, filters, conduits, lance), so that they can be transported to the control centres.
As regards procedures, the dangerousness of the preparation phase should be lessened with pre-mixer devices. Moreover, transport should involve hermetic containers. A more accurate calculation of the volumes to be distributed would make it possible to drastically reduce the amount of waste to be disposed of. If the quantity to be disposed of is still too great for disposal in the field, firms should buy and install adequate plants for this purpose.

Bibliography

Balloni S., Bonsignore R., Camillieri D., Caruso L., Conti A., Schillaci G. (2008). *A Survey of Safety Aspects Concerning Horticultural Farm Machineries.* Atti su CD-rom del Congresso Internazionale “Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems”, Ragusa, Italy, 15-17 September.

Balloni, S., Caruso, L., Cerruto, E., Emma, G., Schillaci, G.(2008) *A prototype of self-propelled sprayer to reduce operator exposure in greenhouse treatment*, Atti su CD-ROM dell’International Conference on “Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems”, Ragusa, Italy 15–17 September.

Balloni S., Caruso L., Conti A., Schillaci G., Longo D., Muscato G. (2008). *Preliminary study for the development of an electrical autonomous vehicle for safe agricultural chemicals distribution inside greenhouses.* Atti su CD-ROM dell’International Conference on

"Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems", Ragusa, Italy 15–17 September.

Balloni S., Caruso L., Conti A., Schillaci G., Longo D., Muscato G. (2009). *Development of an electrical multifunctional autonomous vehicle able to cultivate covered crops and to safe distribute agricultural chemicals inside greenhouses.* Atti del XXXIII CIOSTA - CIGR V Conference 2009 "Technology and management to ensure sustainable agriculture, agro-systems, forestry and safety", Reggio Calabria, Italy, 17-19 june, Vol.1, pp. 355-359.

Balsari P., Marucco P., Oggero G. (2008). *Reduction of water contamination from pesticides through the application of the Best Management Practices defined by the TOPPS project.* Atti su CD-Rom di International Conference "Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems", Ragusa, Italy, 15-17 September .

Bellissima C., Cerruto E., Failla S., Schillaci G. (1998). *Valutazione di attrezzature per la distribuzione di fitofarmaci in serra. Atti del Seminario sul tema "Colture protette: aspetti agronomici, territoriali e tecnico-costruttivi"*, 24-26 giugno, Ragusa, pp. 351-362.

Cerruto E., D'amico R., Failla S., Manetto G., Schillaci G. (1997). *Comportamento in serra di attrezzature per la distribuzione di fitofarmaci.* Atti del VI Convegno Nazionale di Ingegneria Agraria. Ancona 11-12 Settembre. Vol. 3, pp.639 – 648.

CERRUTO E., EMMA G. (2009). *Indagine sulla sicurezza ambientale e degli operatori nei trattamenti fitosanitari in serra.* Atti su CD-rom del IX Convegno Nazionale dell'Associazione Italiana di Ingegneria Agraria "Ricerca e innovazione nell'ingegneria dei biosistemi agro-territoriali", Ischia Porto, Italia, 12-16 settembre.

Nuyttens S., Windey B., Sonck B. (2005). *Comparison of exposure for five different greenhouse spraying applications.* Atti del Convegno XXXI CIOSTA-CIGR V Congress "Increasing Work Efficiency in Agricolture, Horticolture and Forestry", September 19-21, University of Hohenheim, Stuttgart, Germany, ISBN 3-00-016346-8, pp. 98-105.

Pessina D. Guerretti M., Facchinetti D. (2001) *Applicazione del programma interregionale "Agricoltura e Qualità" (verifica funzionale delle irroratrici) nelle province di Milano e Bergamo: Risultati e commenti.* AIIA 2001: Ingegneria Agraria per lo sviluppo dei paesi del mediterraneo Vieste (Fg) 11,14 settembre 2001.

Schillaci G., Balloni S., Camillieri D., Conti A., Caruso L. (2009) *Punti critici e prevenzione nel rischio ambientale e nella sicurezza degli operatori in relazione alle operazioni di distribuzione degli agrofarmaci in serra.* Atti su CD-rom del IX Convegno Nazionale dell'Associazione Italiana di Ingegneria Agraria "Ricerca e innovazione nell'ingegneria dei biosistemi agro-territoriali", Ischia Porto, Italia, 12-16 settembre, ISBN 978-88-89972-13-

Schillaci G., Balloni S., Caruso L., Conti A., Pennisi A., Longo D., Muscato G. (2009). *Prove di funzionamento telecomandato e autonomo di un veicolo elettrico multifunzionale destinato alle colture in serra.* Atti su CD-rom del IX Convegno Nazionale dell'Associazione Italiana di Ingegneria Agraria "Ricerca e innovazione nell'ingegneria dei biosistemi agro-territoriali", Ischia Porto, Italia, 12-16 settembre.

D.Lgs. n. 81 del 9 aprile 2008. *Testo Unico in materia di tutela della salute e della sicurezza nei luoghi di lavoro*.

ENAMA (2007). *Attività di controllo funzionale e regolazione delle macchine irroratrici in Italia*. Novembre.

Sitography

http://www.fumimatic.com/primefumi.htm
http://www.globalgap.org

Assessment of Comfort Conditions of an Agricultural Tractor During Operations with Plough on Digh Roughness Surface

Cutini M., Romano E.
Consiglio per la Ricerca in Agricoltura– Unità di Ricerca per l'Ingegneria Agraria; via Milano 43, 24047 Treviglio BG, Italy; E-mail: maurizio.cutini@entecra.it

Abstract
For agricultural tractors irregularity of working terrains and forward speed are the most important causes of vibrations transmitted to the driver and on tool oscillations.
A typical situation of high roughness surface is that of working with the tractor on the perpendicular of the way of seeding, this working procedure has to be adopted for combining the shape of the field with the location of the irrigation source.
The CRA-ING research unit has investigated the influence on operator's comfort of a tractor during plowing in different conditions.
The roughness of the field was, as expected, the most important factor affecting driver's comfort. The increasing speed had influence on comfort value but not linearly for the effect of the resonance of the tires at certain speeds. Beside, during ploughing the discomfort was always lower than on transport on field.

Keywords: safety, vibrations, transport

Introduction
The professional drivers are exposed at whole body vibrations and, in particular, agricultural vehicle operators could be at risk of high levels of exposure.
The protection of workers is reported in the European Parliament Directive 2002/44/EEC (EEC, 2002), that defines the minimum safety requirements. Moreover, in 2008, Italy adopted a specific national regulation on safety (Decree no. 81/2008).
For agricultural tractors, considering normal conditions of use, irregularity of working terrains and forward speed are the most important causes of vibrations transmitted to the driver (Scarlett et al., 2002), on tool oscillations and impact on work quality (Bisaglia et al., 2006).
A typical situation of high roughness surface is that of working with the tractor on the perpendicular of the way of seeding, this working procedure has to be adopted for combining the shape of the field with the irrigation source.
The CRA-ING research unit has investigated the influence on operator's comfort of a tractor during ploughing in different conditions. Tests aimed to evaluate the ride comfort index (CI) and the safety level of the driver measuring the accelerations at the three axis of the back and of the seat. In particular, the study reports the comparison of the evaluation of the risk for the operator working with tractor on terrains with high roughness surface with ploughing on smooth surfaces.

Methods
The guidelines followed for the measurement of operator's safety and comfort were those established by the ISO 2631/1997, European Parliament Directive 2002/44/EEC and Italian Decree on safety no. 81/2008.
A 4WD tractor fitted with a plough (820 kg) and a front ballast (600 kg) has been used.
The tires were 540/65 R24 on the front and 600/65 R38 on the rear at 120 kPa.
The variables chosen for the test were the following:

different levels of roughness: L, G;
different forward speeds: 1.25, 1.39, 1.53, 1.67, 1.94, 2.08 ms^{-1};
on the same line and on the perpendicular way of seeding: S, T;
ploughing and transport on terrain: P; N

The mean values of the roughness of the surface were:
TL = 40 mm (std dev = 5,32)
TG = 79,6 mm (std dev = 17,56)

The forward speeds have been selected compatibly with the tractor gearbox and could change of +/- 0.07 ms^{-1} for the wheel slipping.
The complete list of the tests carried out is reported in table 1.

Table 1: The settings adopted for the test

Speed (ms^{-1})	1.25	1.39	1.53	1.67	1.94	2.08
PS	X	X	X	X	X	
PTL	X	X	X	X	X	
PTG	X	X	X	X	X	X
NS	X	X	X	X	X	X
NTG	X	X	X	X	X	X
Asf	X	X	X	X	X	X

The vehicle has been instrumented with a set of two triaxial accelerometer (range ±50 g, sensitivity 100 mV/g) placed in correspondence of the seat surface and of the back to evaluate the operator comfort.

Results
Apart the Asf condition that is used only as "zero reference" of the ground and of the tractor, the values of the equivalent level of daily exposure (A8) measured as safety were from 0.53 to 1.42 ms^{-2}.
The lowest values were obtained in the PS condition from 0.53 to 0.7 ms^{-2} respect to the highest values obtained in the NT configuration from 1.09 to 1.42 ms^{-2}.
The increasing forward speed increases the value of exposition to vibration also if not linearly and also if the highest value could not be at maximum tested speed for the influence of the resonance conditions of the tires.
Considering the results at the same speed, the roughness of the surface increases dramatically the discomfort value passing from values of 0.5 ms^{-2} for the PS condition to 1.2 ms^{-2} of the NTG condition and from 0.8 ms^{-2} of the NS condition to 1,4 ms^{-2} of the NTG condition.
The roughness resulted the factor more influencing the comfort, beside we've to consider the high difference between the activity of ploughing and of transport characterised from the different load on soil of the tractor. The activity of transport on field is always much more discomfortable than ploughing.
The measurements are reported in table 2.

Table 2: The A8 equivalent acceleration value for the operator safety.

Speed (ms^{-1})		1.25	1.39	1.53	1.67	1.94	2.08
A8 (ms^{-2})	PS	0.7	0.658	0.63	0.532	0.588	NA
	PTL	0.644	0.7	0.798	0.85	0.95	NA
	PTG	0.672	0.79	1.2	1.16	1	1.05
	NS	0.644	0.728	0.728	0.812	1.33	0.896
	NTG	1.15	1.13	1.38	1.42	1.23	1.092
	Asf	0.154	0.19	0.16	0.11	0.13	0.12

The risk analysis is obtained applying the Italian Directive n°81/2008 on safety. The action value is 0.5 ms^{-2} and has been always reached in all conditions, apart, as expected in Asf setting.
The safety limit is 1 ms^{-2} on the 8 hour daily work and it's possible to see how has been reached in PTG and NTG configuration. Beside an important novelty of the Italian Directive is a superior limit of 1.5 ms^{-2} over which is possible to work only for brief period. This has to be considered as no value on the 8 hour has reached the 1.5 ms^{-2} but we've to note the situations of NTG at 1.53 and 1.67 ms^{-1} that are very close.
The comfort analysis confirms the results obtained in the safety.
The condition PTG and NTG resulted extremely uncomfortable (>2 ms^{-2}) but all the values resulted always in the uncomfortable trend (>0.8 ms^{-2}).
The results are reported in table 3 and, as expected, all the considerations of safety are confirmed.

Table 3: The results of the comfort analysis.

Speed (ms^{-1})		1.25	1.39	1.53	1.67	1.94	2.08
A8 (ms^{-2})	PS	0.897	0.93	0.857	0.79	0.868	NA
	PTL	1.143	0.979	1.194	1.533	1.735	NA
	PTG	1.097	1.51	2.17	2.07	1.74	1.711
	NS	0.86	1.01	1.055	1.119	1.94	1.797
	NTG	2.307	2.208	2.59	2.6	2.2	1.85
	Asf	0.213	0.267	0.246	0.167	0.2	0.181

For better understanding the spreading of vibration on the operator it's necessary to analyse the components of the ride comfort that were the seat (S) and the back (B).
The values obtained were always very similar but some consideration can be carried out.
In PS, PTL and NS conditions, the values at the seat is greater than at the back while in case of high roughness surface the situation was different indicating that the growing roughness influences above all the pitching than the vertical pumping of the vehicle.

Table 4: Comfort analysis of the channels seat (S) and back (B).

Speed (ms^{-1})		1.25		1.39		1.53		1.67		1.94		2.08	
Channel		S	B	S	B	S	B	S	B	S	B	S	B
A8 (ms^{-2})	PS	0.74	0.51	0.75	0.55	0.7	0.5	0.63	0.47	0.67	0.55	-	-
	PTL	0.92	0.67	0.76	0.62	0.91	0.78	1.05	1.12	1.23	1.22	-	-
	PTG	0.81	0.74	1.01	1.12	1.45	1.62	1.37	1.55	1.21	1.25	1.25	1.17
	NS	0.66	0.55	0.76	0.67	0.78	0.71	0.83	0.75	1.4	1.34	1.32	1.22
	NTG	1.51	1.75	1.46	1.66	1.7	1.96	1.75	1.92	1.58	1.53	1.35	1.26
	Asf	0.17	0.12	0.22	0.16	0.19	0.15	0.13	0.1	0.16	0.12	0.14	0.11

This phenomena is clearer analysing the axis of solicitation always at the back and at the seat.

In fact reducing the analysis at the roughness surface it's possible to see that at the seat the highest value is always the Sz and at the back is always the Bx.
In the other situations, not reported as data in the paper, the channels' values are near and, in particular, the Sy and By values are of the same level of the x and z channels.

Table 5: Comfort analysis of the single channels of the seat (S) and of the back (B).

Speed (ms^{-1})		1.25		1.39		1.53		1.67		1.94		2.08	
Setting		PTG	NTG	PTG	NTG	PTG	NTG	PTG	NTG	PTG	NTG	PTG	NTG
A8 ms^{-2}	Sx	0.45	0.74	0.4	0.67	0.59	0.82	0.46	0.86	0.48	0.82	0.49	0.78
	Sy	0.48	0.7	0.54	0.7	0.64	0.63	0.63	0.66	0.56	0.65	0.75	0.59
	Sz												
	Bx												
	By	0.48	0.7	0.54	0.7	0.64	0.63	0.63	0.66	0.56	0.65	0.75	0.59
	Bz	0.45	0.74	0.4	0.67	0.59	0.82	0.46	0.86	0.48	0.82	0.49	0.78

The roughness of the field was. as expected. the most important factor affecting driver's comfort. The increasing speed had influence on CI value but not linearly for the effect of the resonance of the tires at certain speeds depending from the distance of seeding line (0.7 m). Beside. during ploughing the CI value was always lower than on transport on field.
The requirements of the Italian Directive of 2008 on safety resulted of particular interest in operations with plough and have to be taken into account and analysed for driver's risk analysis.
After verifying the conditions of normality and homoscedasticity on results, was conducted the analysis of variance that showed statistically significant influence of setting conditions in study on the values obtained from all accelerometers (p-value <0.05). Repeats showed no influence on the results ($p > 0.70$).
For the evaluation of differences between the averages was performed the Tukey test (Tab.6) for detecting the minimum significant difference between the means obtained in the variation of the factor surface and resulting in variations of the speed factor, against the ride number and its components.

Table 6: Tuckey test on the Ride number

Settings	RN Average	Speed ms^{-1}	RN Average
AL	0.86148 e	1.25	1.04708 c
Asf	0.21497 f	1.39	1.12646 c
ATG	1.67427 b	1.53	1.32556 b
ATL	1.28268 c	1.67	1.33622 ab
NL	1.15992 d	1.94	1.41674 a
NT	2.30915 a	2.08	

The same processing was performed (Table 7) on the averages obtained from 30 combinations. It highlighted average groups statistically homogeneous as in the case of the Asf setting.

Table 7: Tukey test on the Ride number

Settings	Speeds	RN Average	
AL	1.25	0.49203	n
	1.39	0.54897	lm
	1.53	0.50043	mn
	1.67	0.47110	n
	1.94	0.55637	lm
Asf	1.25	0.11853	o
	1.39	0.15970	o
	1.53	0.14530	o
	1.67	0.09727	o
	1.94	0.12287	o
ATG	1.25	0.72690	hi
	1.39	1.09287	g
	1.53	1.58033	bc
	1.67	1.54357	cd
	1.94	1.17343	fg
ATL	1.25	0.65097	hi
	1.39	0.59110	jl
	1.53	0.75207	h
	1.67	1.06710	g
	1.94	1.23923	ef
NL	1.25	0.53367	lm
	1.39	0.62527	ij
	1.53	0.70290	hi
	1.67	0.68677	hi
	1.94	1.33467	e
NT	1.25	1.67567	b
	1.39	1.64483	bc
	1.53	1.90543	a
	1.67	1.85953	a
	1.94	1.45837	d

The Tukey test showed within each group corresponding to the setting test, some average which deviate from the average speed of the group in almost every setting. This is especially true in cases which have the highest ride number and this suggests a connection with effects of the resonance of the tires.

Conclusions

The CRA-ING research unit has investigated the influence on operator's comfort of a tractor during plowing and transport on terrain surfaces of different roughness and at different speeds.

The roughness of the field was, as expected, the most important factor affecting driver's comfort. The increasing speed had influence on comfort value but not linearly for the effect of the resonance of the tires. The activity of transport on field was always more discomfortable than that of plowing.

Acknowledgements. The research has been carried out in the frame of the Vibramag Project (Evaluation and control of the vibrations of agricultural vehicles through analysis methods based on four-post test bench) funded by the Italian Ministry of Agriculture.

References

Bisaglia. C., Cutini. M. and Gruppo. G. 2006. Assessment of vibration reproducibility on agricultural tractors by a "four poster test stand". Proceedings of the XVI CIGR. EurAgEng 2006. 64th VDI-MEG and FAO joint "World Congress - Agricultural Engineering for a Better World". Bonn. Germany : s.n.. September 3-7. 2006. pp. 1-6.

Bukta A. J. K., Sakai. A., Sasao. S., Shibusawa 2002. "Free play as a source of non linearity in tractor-implement systems during transport". Applied Engineering in Agriculture; vol.45(3): 503-508

Chiang. C.F. and Liang C. C. 2006. A study on byodinamic models of seating human subjects exposed to vertical vibration. International Journal of Industrial Ergonomics. 2006. Vol. 36. pp. 869-890.

Cutini M., Bisaglia C., Romano E. 2007. "Assessment of tractor's tires influence on operator's confort". Advances in Labour and Machinery Management for a Profitable Agriculture and Forestry. Nitra. Slovakia. Conference Proceedings pp.183-189

Directive 2002/44/EC. 2002. Minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration). Official Journal. 2002. Vols. L 177 . 06/07/2002 P. 0013 - 0020.

Hostens I.J., Anthonis P., Kennes H., Ramon. 2000. Six-degrees-of-freedom test rig for simulation of mobile agricultural machinery vibration. Journal of Agricultural Engineering Research 77(2); 155-169

ISO standard 2631-1. 1997. Mechanical vibration ad shock - Evaluation of human exposure to whole-body vibration. 1997. Vol. Part. 1: General requirements.

Okunribido O., Magnusson M., Pope M. H. 2006. Low back pain in drivers: The relative role of whole body vibration. posture and manual materials handling. Journal of Sound and Vibration Vol. 298 (3). 540-555.

Scarlett A. J., Price J. S., Stayner R. M. 2007. Whole body vibration: Evaluation of emissions and exposure levels arising from agricultural tractors. Journal of Terramechanics. 44. 65-73.

Seidel, Helmut and Heide. Renate. 1986. Long-term effects of whole-body vibration: a critical survey of the literature. International Archives of Occupational and Environmental Health. s.l. : Springer Berlin / Heidelberg. 1986. Vol. 58. 1. pp. 1-26.

Effect of Tyre Pressure and Wheel Loads on Whole-Body Vibration Characteristics of Tractors

Cutini M., Romano E., Bisaglia C.
Consiglio per la Ricerca in Agricoltura – Unità di Ricerca per l'Ingegneria Agraria; via Milano 43, 24047 Treviglio BG, Italy; E-mail: maurizio.cutini@entecra.it

Abstract
Agricultural vehicle operators are exposed to high levels of Whole Body Vibrations (WBV), which is related, above all, to surface irregularities and forward speed. European Parliament Directive 2002/44/EEC sets the minimum requirements for the protection of workers from risks to their health and safety due to exposure to mechanical vibrations.
Tractor tyres play a key role in damping vibrations, their response varies according to the mass and inflation pressure and they have to be taken into account at different forward speeds. This study was aimed at evaluating the impact of each parameter on driver comfort. Two tests were carried out using tractors with different tyres mounted. Forward speed was found to be the most significant factor in the determination of operator comfort, and comfort depreciated with increasing speed; on average, the comfort index passed from 0.6 m/s^2 at 6.7 m/s to 1.2 m/s^2 at 14.2 m/s. Lower inflation pressure offers better results in terms of comfort index (CI), yet it is more critical under resonance conditions. The addition of ballast moderates CI variations and diminishes the effect of speed, as well as the resonance peaks. A complete methodology was carried out and validated.

Keywords: operator comfort, safety, testing configuration

Introduction
The professional drivers are exposed at whole body vibrations (Okunribido, 2006) and, in particular, agricultural vehicle operators could be at risk of high levels of exposure (Scarlett et al., 2007).
The protection of workers from risks to their health and safety due to exposure to mechanical hand/arm vibrations and whole body vibration is reported in the European Parliament Directive 2002/44/EEC (EEC, 2002), that defines the minimum safety requirements. Moreover, in 2008, Italy adopted a specific national regulation on physical agents control (Decree no. 81/2008).
This project, focused on whole body vibration, aims to define the correct tractor settings in order to evaluate comfort values during transport. In fact, the tyres' damping effectiveness depends on factors such as wheels eccentricity, load, pressure (Sherwin et al., 2004), resonance frequency, and elasticity characteristics (Taylor et al., 2000).
A first methodological approach on the role of the tires on the operator comfort was been developed by the CRA-ING Laboratory of Treviglio (Cutini et al., 2007) and allowed to focus the main boundary conditions (step forward speed, pressure and mass configuration) to be used for further research steps (Cutini et al., 2008). The analysis derived from the obtained results allowed to introduce the statistic approach herewith presented.

Theoretical considerations
As agricultural tyres can be considered as a system of springs and dumper, it is necessary, during tests on comfort, to take into account the factors that could affect the elastic behavior of the tyres and to evaluate their influence on the results. These factors are: the tractor mass distribution (impact on the value of resonance frequency), the tyre pressure (impact on tyre

stiffness) and the forward speed (which characterizes the solicitation frequency input). In order to reduce the variables, a flat test track surface was selected so that the source of vibrations resulted from the combination of tyre eccentricity and forward speed, and the vehicles had no suspension devices (or blocked when possible), apart of those on the seat.
The ISO 2631:1997 testing standard was used for this study to assess vibration exposure. The total vibration value of the weighted root-mean-square (RMS) acceleration was determined from the vibration in the orthogonal coordinates, calculated as follows:

$$a_v = (k_x^2 a_{wx}^2 + k_y^2 a_{wy}^2 + k_z^2 a_{wz}^2)^{1/2}$$

where k_i is a multiplying factor defined in the standard and a_{wi} is the weighted RMS acceleration. The filters for weighing the measured acceleration are defined in the standard and depend on the point of location and the solicitated axle. The Comfort Index (CI) is the overall total vibration value, determined from the root-sum-of-squares of the point vibration values.

Materials and methods
Tests were carried on a 400-meter, straight stretch of test track with an asphalt surface at the CRA-ING Laboratory in Treviglio, North Italy.
Considering the range of speeds that can affect comfort in when a tractor works on smooth surfaces (7-14 ms^{-1}) and with the aim of investigating the critical speed-related tractor settings for comfort, a first test (T1) was conducted to investigate the influence of pressure, mass distribution and speed. After analyzing the results, a second test (T2), focused on a more detailed investigation of the same parameters, was carried out. The two methodologies were:

The solicitations at the three points of seat, back and X and Y rotational axes (pitch and roll) in both tests, and the solicitation at the feet in T1, were taken into account.

Triaxial sensors were fitted onto the seat, at the back of the operator and onto the cabin floor, near the foot under the pedal brake. A monoaxial accelerometer measured the vertical acceleration at the front of the cab, and the second monoaxial accelerometer was placed on the right side of the cab, in order to obtain, in combination with the vertical channel of the triaxial accelerometer at the back, the driver's pitch and roll respectively.

A randomized complete block design (RCBD) was adopted. Each block was represented by the make of each tyre. CRAN's R statistical programme (Comprehensive R Archive Network) from WU (Wien-Umgebung), Austria, was used for the data analysis. The plots used for each

treatment consisted of 400 m of tarmac surface. The independent variables were: the make of the tyre, the tractor speed, the mass distribution on the tractor and the tyre inflation pressure.
Data processing was carried out on the results from the vectors (X, Y and Z) of the seat, the back and the rotation components.

Results

In T1 the CI value varied from 0.4-0.8 ms^{-2} at 6.9 ms^{-1} and 0.6 and 1.2 ms^{-2}.at 13.9 ms^{-1} The CI value increased with speed, but in a non-linear fashion (Fig. 1). Some speeds are critical for the resonance of the front and/or rear tyres.

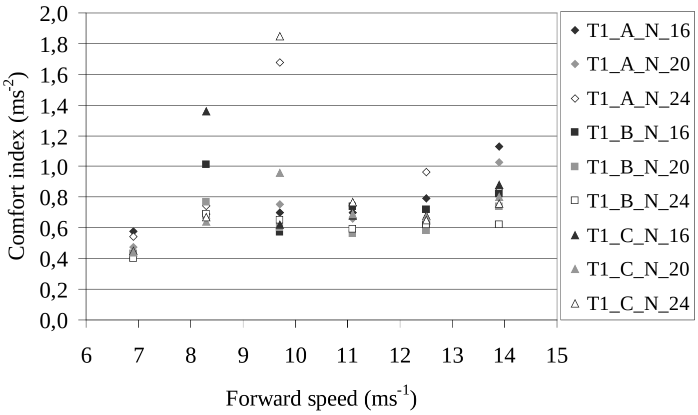


Figure 1. CI values obtained in T1 with: different tyre marks (A, B, C); the tractor without ballast (N); the pressure of the tyres at 160 kPa (16), 200 kPa (20) and 240 kPa (24).

In fact, the value changed from 0.6 ms^{-2} up to 1.8 ms^{-2} at the same forward speed. No difference was observed between the ballasted and non ballasted setting values but, in resonance conditions, the non ballasted setting was less comfortable, with values ranging from 0.9 ms^{-2} to 1.4 ms^{-2}. The same considerations can be made concerning pressure: no appreciable differences were observed for the CI value, apart from resonance conditions, where the same condition changed the CI value from 0.6 ms^{-2}, at 160 kPa, to 1.7 ms^{-2} at 240 kPa. The highest discomfort values, 1.7 - 1.8 ms^{-2}, were obtained at 240 kPa but were limited to critical speeds.

TEST2

The results obtained with T1 indicated that it was necessary to carry out a more detailed investigation of the critical speeds. The step was changed to 0.83 ms^{-1}, and the analyzed pressures were also changed. Two configurations were considered: a nominal one (160 kPa) and one at a lower pressure (120 kPa). The results confirm that a 0.83 ms^{-1} step was necessary for the importance of the front tires resonance.
The CI values (Fig. 2) in this test showed very limited differences, from 0.5 to 0.8 ms^{-2}, at low speeds, 6.7 and 7.5 ms^{-1}. This fact indicates that the starting speed of interest in the test is 8.3 ms^{-1}.
In terms of inflation pressure, T2 test gave more significant results.

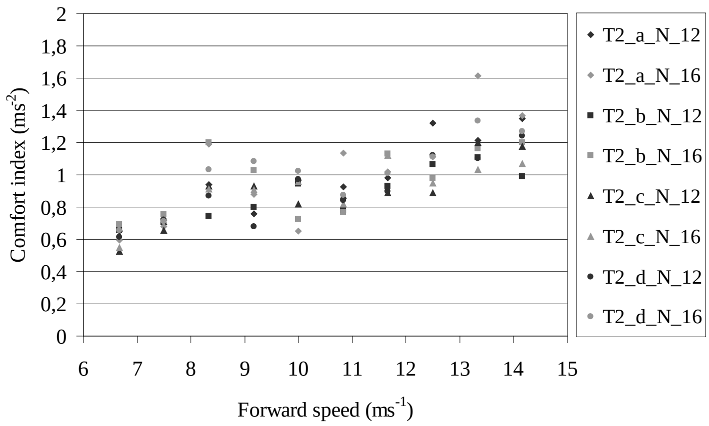


Figure 2. CI values obtained in T2 with: different tyre marks (a, b, c, d); the tractor without ballast (N); the pressure of the tyres at 120 kPa (12) and 160 kPa (16).

An higher inflation pressure value, generally gave a slightly higher CI value but, more importantly, the effect of switching resonance frequency, and consequently of the relevant speed. The effect of increasing speed and resonance peaks diminishes when the tractor is ballasted, and this leads to a levelling of the CI values.

Discussion

The maximum value for all the data on a single solicitation axis was 1.54 ms^{-2}, a value that was recorded under low pressure and no ballast conditions by vector X of the back component of CI; the minimum value was 0.01, which was recorded under low pressure and ballasted conditions by vector Y of the seat component of CI. Statistical analysis (tab. 1 and tab. 2) showed significance for forward speed, in particular in T2, and inflation pressure both on CI, both on its components (seat and back). The rotation component was not influenced from pressure. The impact of mass resulted significance in analysis on seat. Statistical significance for tyre make variable was find only on seat in T1.

Table 1. Comparison between T1 and T2

Variable	CI T1	CI T2	SEAT T1	SEAT T2	BACK T1	BACK T2	ROT T1	ROT T2	CI T1+T2
MK	.		**						
SP		***	*	***	.	***		***	***
MS			**	***	.				
PR		***		**		***			**
MK x SP									
MK x MS									
SP x MS	**	*	***	**	**	*			**
MK x PR									
SP x PR	.		**	.	.				.
MS x PR									
MK x SP x MS									

MK x SP x PR						.			
MK x MS x PR						.			
SP x MS x PR		**	.	*		**		.	*

MK=make; SP=speed; MS=mass; PR=pressure
Signif. Codes: "***"=0.001; "**"=0.01; "*"=0.05; "."=0.1; " ">1

Table 2. Analysis on the CI components

	SEAT				BACK				ROTATION		
Variable	TOT	X	Y	Z	TOT	X	Y	Z	TOT	X	Y
MK							**				.
SP	***	***	***	***	***	***	***	***	***	***	***
MS	***	***	***				***	***			
PR	**			***	***	***	*				
MK x SP											
MK x MS		*	*								
SP x MS	**	*		***	*	.	.	*			***
MK x PR											
SP x PR	.			*				*			*
MS x PR											
MK x SP x MS											
MK x SP x PR		**			.	**					
MK x MS x PR		*			.						
SP x MS x PR	*	**		*	**	**			.		

MK=make; SP=speed; MS=mass; PR=pressure
Signif. Codes: "***"=0.001; "**"=0.01; "*"=0.05; "."=0.1; " ">1

Analysis on seat showed an impact of mass on X and Y vectors and of pressure on Z component.
The developed methodology for the testing procedure involves:

- A starting speed of 8.3 ms^{-1};
- A step forward speed of 0.83 ms^{-1};
- Two pressure configurations: P1≤120 MPa; P2≥160 MPa;
- Two ballast configurations: not ballasted, ballasted;
- Main sensors: triaxial accelerometers at the seat and back.

Conclusions

Operator comfort has been evaluated on two tractors during road transfer fitted with different tires. The CI (ISO 2631:1997) was evaluated taking into consideration different mass distributions, tyre inflation pressures and forward speeds. Forward speed resulted to be the most significant factor. A lower inflation pressure generally provides better results, in terms of comfort index, but it is more critical in resonance conditions. Ballasting balances the CI values and diminishes the effect of increased speed as well as the resonance peaks. The study has shown the enormous importance of adopting suitable tractor settings, above all by working on mass and tyre pressure at the desired forward speed, in order to obtain better results, in terms of operator comfort, for agricultural tractors.

Acknowledgements
The research was funded within the framework of the Italian Ministry of Agricultural and Forestry Policies project "Vibra.M.Ag." (Evaluation and control of the vibrations in mechanical agricultural systems with research methods based on a four-poster test rig).

References
Cutini M., Bisaglia C., Romano E. 2007. Assessment of tractor's tires influence on operator's comfort. XXXII CIOSTA-CIGR Section V, Advances in Labour and Machinery Management for a profitable Agriculture and Forestry, Nitra, Slovakia, Conference Proceedings, 183-189

Cutini M., Romano E., Bisaglia C. 2008. Analysis of some main tractor's set-up influencing operator's comfort. In: Proceedings CD of International Conference on Agricultural Engineering & Industry exhibition AgEng 2008 "Agricultural & Biosystems Engineering for a Sustainable World", 23-25 June, Knossos Royal Village, Hersonissos, Crete (Greece), CD-ROM archive nr. 1177836, p. 1-6.

Okunribido O., Magnusson M., Pope M. H. 2006. Low back pain in drivers: The relative role of whole body vibration, posture and manual materials handling. Journal of Sound and Vibration Vol. 298 (3), 540-555.

Scarlett A. J., Price J. S., Stayner R. M. 2007. Whole body vibration: Evaluation of emissions and exposure levels arising from agricultural tractors. Journal of Terramechanics, 44, 65-73.
Sherwin L. M., Owende P. M. O., Kanali C. L., Lyons J., Ward S. M. 2004. Influence of tyre inflation pressure on whole-body vibrations transmitted to the operator in a cut-to-lenght timber. Applied Ergonomics, Vol. 35 (3), 235-261.

Taylor R. K., Bashford L. L., Schrock M. D. 2000. Methods for measuring vertical tire stiffness. Transactions of the ASAE, v. 43 (6), 1415-1419.

An Autonomous Electrical Vehicle Based on Low-cost Ultrasound Sensors for Safer Operations Inside Greenhouses

Longo D.[2], Pennisi A.[1], Caruso L.[1], Muscato G.[2], Schillaci G.[1]
[1]University of Catania – DIA, Mechanics Section, Via Santa Sofia 100 – 95123 Catania ITALY
Tel. +39 095 7147512, Fax +39 095 7147600 giampaolo.schillaci@unict.it
[2]University of Catania – DIEES, Viale A. Doria 6 – 95125 Catania ITALY, Tel. +39 095 7382321
Fax +39 095 330793 gmuscato@diees.unict.it

Keywords: autonomous robot navigation, safety, precision farming, low cost sensors

Abstract

The main target of this research activity is to develop and test different low cost sensors that can enable a multifunctional tracked electrical vehicle to move autonomously inside a greenhouse with tomatoes cultivation. Big effort has been put on finding solutions that require minimum or no apparatus installation in the greenhouses while performing centimetre-level accuracy at a fraction of the cost of a DGPS commercial system. The used low cost sensors are described, while description of the electrical vehicle and its capabilities can be found in previous works.

Two main kinds of sensors systems have been developed using low cost ultrasound sensors. The first system uses a set of eight ultrasound transmitter/receiver couple. These sensors can compute time by time the distance and the rotation angle of the robot with respect to the plants rows. This information could be used to correct the robot trajectory, allowing the system to move along the centre line between rows.

The second system that has been tested is a Local Positioning System (LPS). It uses a set of low cost ultrasound receiver sensors mounted on the greenhouse structure in a regular grid while an ultrasound transmitter is mounted onboard the robot that is moving between rows. The system allows to know the relative coordinate of the robot with respect to a reference inside the greenhouse. At this stage, different trials on the sensors have been performed inside a greenhouse in different condition; these trials allowed to evaluate systems accuracy and performance.

Introduction

Greenhouse activities often require hours of hard-work made by operators. Many of these works also can be very dangerous and uncomfortable because of chemicals, high temperature and humidity. With this environmental condition, even normal agricultural operation can became heavy and stressful. Moreover, because of high temperature and humidity, when they are required, operators often do not wear safety clothes, increasing health risk [Sammons *et al*., 2005].

In this condition an assist machine could be useful for operators in order to alleviate the work load. For example an autonomous machine can automatically perform chemical spraying tasks inside greenhouses, avoiding the presence of operators; otherwise it can perform transportation tasks, plants health check, environment check and so on.

To mitigate problems related to spraying tasks, in recent past, some semi-automatic distribution methodologies, based on some fixed facilities built inside each greenhouse, have been developed. These can operate without human intervention and are composed by a number of sliding rods with nozzles [Sammons *et al*., 2005]. Due to their high cost and huge impact on the greenhouse, they are not so common. Instead, because of greenhouses environments are highly structured and regular with respect to the open field, they are well suited to be operated by some automatic machines that do not implies much fixed cost for each greenhouse. Moreover automatic machines can be re-used in different place and can solve tasks other than spraying.

In [Pedersen *et al*., 2008] economical impact for different automatic approach in agriculture for different parameters (fuel consumption, labour costs, autonomy, chemicals cost, maintenance) is analysed against manual approach. In the last decade, different research group have been interested on these issues. The Aurora robot (Spain) is able to perform different tasks in an autonomous way with remote supervision [Mandow *et al*., 1996]. Within the Italian project Agrobot, a mobile rover bringing a 6 DOF manipulator with an end-effectors and a 'head' with 2 DOF, was developed. The system is dedicated to tomato cultivation inside greenhouse. The robot is able to inspect each plant and to plan individual treatment. Moreover it can distinguish the different maturity level of the fruits. In order to solve navigation problem, some visual feedback have been used [Dario *et al*., 1994]. At University of Genova a project named "Mobile robots in greenhouse cultivation: inspection and treatment of plants" [Acaccia *et al*., 2003] has been developed. In this work chemical hazard for operators and the usefulness of unmanned or human assisted operation by means of a support machine, is highlighted. The main target of the system was to monitor the health status of the plantation in order to plan dedicated treatment with precision farming methodology. Moreover the system can monitor the chemicals concentration inside the greenhouse and give information about the possibility for human operator to enter or not. That machine is powered by means of an internal combustion engine. A mobile platform for greenhouse chemicals spraying has been developed at University of Almeria [Sanchez *et al*., 2010] In this work, specifications for a greenhouses robot are first identified then the complete machine (named FitoRobot) has been built with ultrasonic sensors for the motion between plants rows. The machine is driven by an internal combustion engine. A commercial machine, named Fumimatic 400 [Fumimatic], is available in Spain. It is not autonomous nor teleoperated but it is a complete spraying machine with a powerful Diesel engine and a 400 l tank for chemicals.

In [Schillaci *et al*., 2009], [Balloni *et al*., 2008], [Balloni *et al*., 2009] a multifunctional electrical vehicle, named U-Go Robot, designed and realised at DIEES Robotic Laboratory in cooperation with DIA, is described. With a suitable choice of batteries, motors and control system, high payload (about 250 kg), high working capabilities (about 8 – 9 hours), suitable speed and manoeuvrability have been obtained using a tracked vehicle. Moreover electrical motors are well suited to work inside the confined space of a greenhouses because of they do not generate exhausts. Once the robot has been built, different navigation methodologies, mainly based on DGPS and 2D laser scanner, have been tested with good results [Schillaci *et al*., 2010]. The only drawback of these solutions is their high cost.

In next section, two different low cost solutions, both based on ultrasound sensors, for robot autonomous navigation in tomatoes greenhouse cultivations, are described.

Self-centering system

The first sensor system is composed by eight SFR08 sensors from Devantech and exploits the particular environment of tomatoes cultivation in greenhouse. Generally speaking, the system can operate in all those places where a wide, quite regular, vertical leaves surface is available.

Each sensor is a module that comprises both transmitter and receiver transducers and all the related electronics in order to perform distance measurement in the range 0.03 m – 6 m. The used ultrasound wave is in the 40 kHz band and the radiation diagram of the transducers is quite large. The module uses the acoustic wave generated by the transmitter and reflected by an obstacle in front of the module itself, to measure the distance by means of the wave time of flight (about 300 m/s in free air). The sensor module is shown in Figure 1.

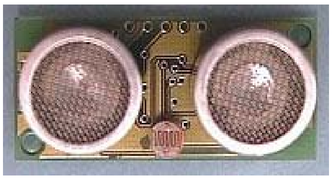


Figure 1. The SFR08 sensor module

Exploiting these features it was possible to use this sensor to measure distance against leaves walls. Due to the wide area covered by the sensor, the single measurement is not biased by the particular leaf or by local leaves structures but it takes a kind of mean value of the distance. In more detail, in the particular area covered by the sensor, if a single small leaf is on a different plane with respect to the most leaves vertical plane, its position will be neglected by the sensor because of the very small acoustic energy it can reflect; in fact the module has a threshold below which it cannot 'see' targets in front of it.

Using these considerations, a set of eight sensors and a small electronic board that collect data from each sensor, were mounted around a wooden-made robot mock-up (used only for testing purpose). In Figure 2 the experimental test-bed is shown. The front and rear sensors, during these experiments, are not used but they can be useful for safety reasons to avoid collision of the robot with obstacles and operators.

Figure 2. The experimental setup with eight SFR08 sensor modules

The other six lateral sensors are used in order to compute the position of the robot with respect to the plants rows. Each sensor measures its distance to the plants and all these measures, using some filtering algorithm and some trigonometric consideration, give back the robot position (offset with respect plant rows) and orientation. Actually only two lateral sensors could be necessary for this algorithm; the third sensor (the central one) is used for validating measurement of the other two and to compensate for wrong measurement that can happen. Information about robot offset and orientation are then used to correct the robot trajectory, allowing the system to move between rows. In Figure 3 and Figure 4 some data acquired during the real experiment are shown. During these tests, the eight sensors were put between the two rows with different orientation and offset. At the same time, the real position was measured by using the ultrasonic sensors and by using a rule and a goniometer. Using this methodology, it was possible to evaluate system performances and accuracy.

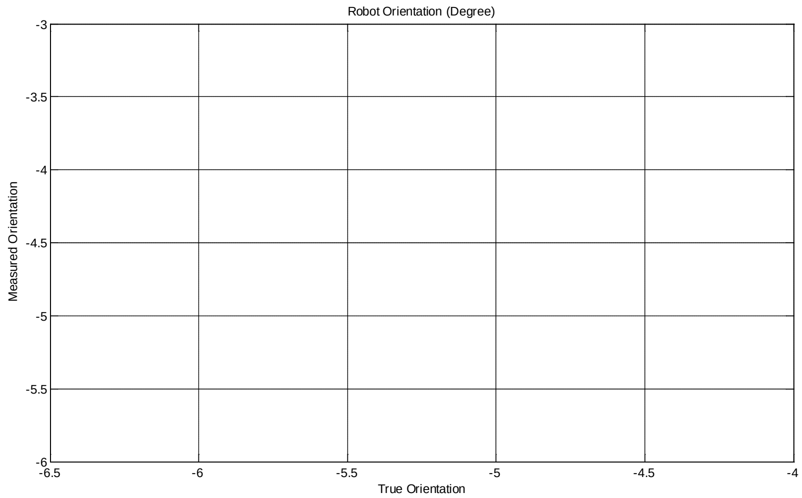


Figure 3. Orientation test: on the X axis there is the true orientation of the robot while along the Y axis there are orientation measures by using the SFR08 sensors

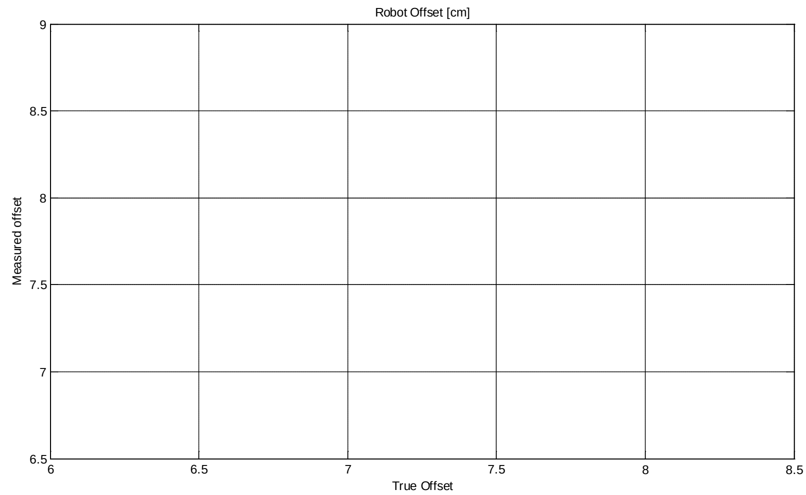


Figure 3. Offset test: on the X axis there is the true offset of the robot while along the Y axis there are offset measures by using the SFR08 sensors

The LPS system

The second system that has been developed is a Local Position System. Like the most common GPS system, the LPS give back the position of the system, for example the robot, while moving or standing still. The main difference is that the GPS uses absolute coordinates while the LPS uses relative coordinates with respect to a reference system locally defined, for example one of the vertex of the greenhouse [Parisek *et al*., 2009]. The LPS system that has been used was developed at DIEES during past research activities for different applications [Andò *et al*., 2006], [Andò *et al*., 2008], [Andò *et al*., 2009]. The system does not rely on some special structure of the greenhouse, but it can be used in all kind of environment indoor or outdoor. Moreover different tests performed in real greenhouse has shown that plants, cable, pipe and other infrastructures that normally can be found in every greenhouse, does not interfere with normal system operations. The LPS system uses a set of low cost ultrasound receiver mounted on the greenhouse structure in a regular grid (for example one sensor on each pillar). An ultrasound transmitter is then mounted on the robot that is moving between rows; every time the fixed receivers hear the signal sent by the robot, the system computes the robot position with respect to the reference system using a trilateration algorithm. Using the robot position and as the greenhouse map is known, it is possible to use standard navigation algorithms used for outdoor DGPS navigation, exploiting the same centimetre-level precision at a fraction of the cost of a DGPS commercial system.

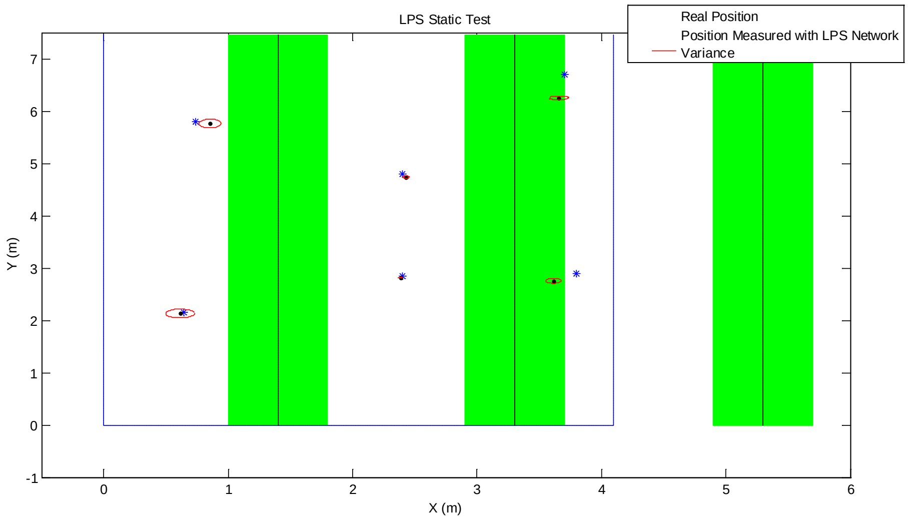


Figure 5. LPS system: static test.

Different tests have been performed in a greenhouse in order to validate the system capabilities. Eight fixed receivers have been mounted inside the greenhouse covering an area of about 14 m^2. Static tests have been performed in order to evaluate the system accuracy. The mobile transmitter has been placed on different position inside the area covered by the fixed sensors.

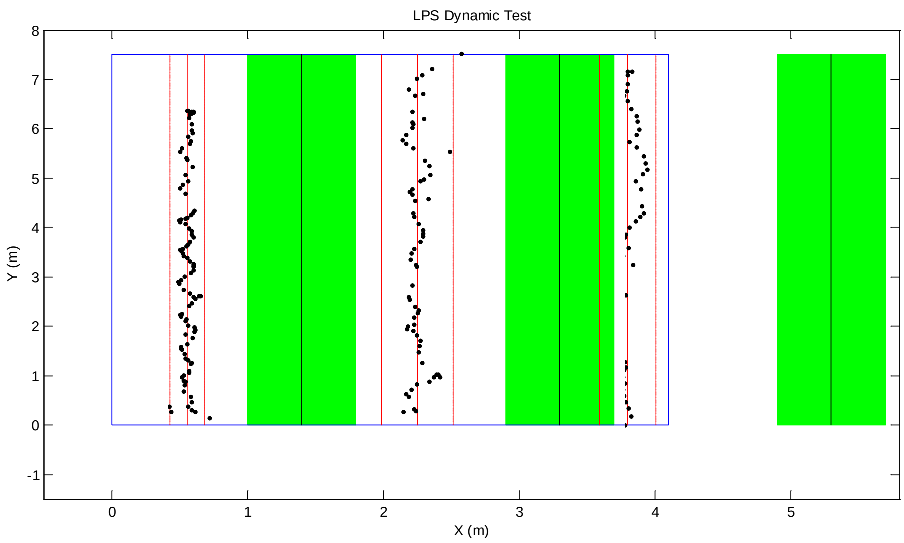


Figure 6. LPS system: dynamic test.

The real position has been measured with a rule and compared with the position estimated by the LPS system. In Figure 5 some results are shown. In Figure 6 the results of a dynamic test are shown. In this case, the mobile transmitter has been moved along rows and subsequent positions have been recorded. Dark dots represent the system measurement, while the solid line represents the trajectory mean value. Dash-dot lines represent the data variance. In both figures, green boxes represent the plants.

Conclusion

In this work, two special sensors systems for automatic guidance of an electrical vehicle have been shown. Sensors like DGPS and 2D Laser scanner are widely used and the Authors performed different test in other works. They have very good performance but the high cost and their use cannot be addressed to most SME in the agriculture field. The two methodologies proposed here are instead based on very low cost ultrasound sensors and suitable measurement algorithms. They allow to obtain the position of a moving machine along rows with respect to corridors boundary or with respect to a reference system defined in the greenhouse. The two systems can be used at the same time on the same machine for a better accuracy (smart data fusion algorithm could be developed) or it is possible to use only one of the two at time.

Different tests have been done in a real greenhouse in order to evaluate performance and capabilities of the two systems and results have been reported; the obtained accuracy is in any case in the order of few centimetres.

Acknowledgment

This work was supported by the project "Veicolo mobile a guida autonoma per la distribuzione di agrofarmaci in serra", co-funded by MIPAAF within the action "*Selezione di progetti di ricerca nel settore dell'agricoltura proposti dalle piccole e medie imprese condotte da giovani imprenditori agricoli, da realizzarsi attraverso la collaborazione di Istituzioni pubbliche di ricerca"*.

References

Acaccia G.M., Michelini R.C., Molfino R.M., Razzoli R.P., 2003. "Mobile robots in greenhouse cultivation: inspection and treatment of plants", in Proc. of ASER 2003, 1st International Workshop on Advances in Service Robotics, 13-15 March, Bardolino, Italy, ISBN 3-8167-6268-9

Andò B., "Sensors that provide security for people with depressed receptors", IEEE Magazine on Instrumentation and Measurements, Vol.9, N.2, pp. 58-63, April 2006.

Andò B., N. Savalli, "CANBUS Networked Sensors Use in Orientation Tools for the Visually Impaired Wired versus Wireless Technology", IEEE Magazine on Instrumentation and Measurements, Vol. 11 N.1, pp.49-52, February 2008.

Andò B., S. Baglio, S. La Malfa, V. Marletta, A "multisensor guide system" to assist visually impaired in unfamiliar environments, Proceedings of the ASME 2009 International Design Engineering Technical Conferences & Computers and Information in engineering Conference, IDETC/CIE 2009, pp.1-5

Balloni S., Caruso L., Conti A., Schillaci G., Longo D. Muscato G., "Preliminary Study for the Development of an Electrical Autonomous Vehicle for Safe Agricultural Chemicals Distribution Inside Greenhouses", "Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems", September 15-17, 2008 Ragusa - Italy

Balloni S., Caruso L., Conti A., Schillaci G., Longo D., Muscato G., "Development of an electrical multifunctional autonomous vehicle able to cultivate covered crops and to safe distribute agricultural chemicals inside greenhouses", Proceedings of the XXXIII CIOSTA - CIGR V Conference 2009, pp 355-359, Vol 1, June 17-19 2009, Reggio Calabria, Italy. ISBN 978-88-7583-031-2

Fumimatic, http://www.fumimatic.com/primefumi.htm.

Dario, P., Sandini, G., Allotta, B., Bucci, A., Buemi, F., Massa, M., Ferrari, F., Magrassi, M., Bosio, L., Valleggi, R., Gallo, E., Bologna, A., Cantatore, F., Torrielli, G. and Mannucci, A. 1994. "THE AGROBOT PROJECT FOR GREENHOUSE AUTOMATION", Acta Hort. (ISHS) 361:85-92

Mandow, A. Gomez-de-Gabriel, J.M. Martinez, J.L. Munoz, V.F. Ollero, A. Garcia-Cerezo, A., "The autonomous mobile robot AURORA for greenhouse operation", IEEE Robotics and Automation Magazine, Vol. 3, pp 18-28, 1996, DOI 10.1109/100.556479

PARISEK Z., RUZSA Z., GORDOS G., "Mathematical algorithms of an indoor ultrasonic localisation system", Infocommunications Journal 2009/IV VOLUME LXIV, 2009

Pedersen S. M., Fountas S. and Blackmore S. "Agricultural Robots - Applications and Economic Perspectives", Service Robot Applications, Yoshihiko Takahashi (Ed.), ISBN: 978-953-7619-00-8, InTech, Austria, 2008

Sammons P. J., Furukawa T. and Bulgin A., "Autonomous Pesticide Spraying Robot for Use in a Greenhouse," 2005 Australian Conference on Robotics and Automation (CD-ROM), December 5-7, 2005, Sydney, pp. 1-8, 2005

Sanchez-Hermosilla J., Rodriguez F., Gonzalez R., Guzman J. L. and Berenguel M. (2010). "A mechatronic description of an autonomous mobile robot for agricultural tasks in greenhouses", Mobile Robots Navigation, Alejandra Barrera (Ed.), ISBN: 978-953-307-076-6, INTECH,

Schillaci G., Balloni S., Caruso L., Conti A., Pennisi A., Longo D., Muscato G. "PROVE DI FUNZIONAMENTO TELECOMANDATO E AUTONOMO DI UN VEICOLO ELETTRICO MULTIFUNZIONALE DESTINATO ALLE COLTURE IN SERRA", Proceedings of the IX Convegno Nazionale dell'Associazione Italiana di Ingegneria Agraria AIIA 2009, Memoria n. 7-37, 12-16 september 2009, Ischia Porto, Italy

Schillaci G., Bonsignore R., Pennisi A., Longo D., Muscato G., "A multifunctional remote controlled and/or autonomous electrical vehicle able to operate in slope vineyard", Proceedings of the Third International Congress on Mountain Steep Slope Viticulture, Castiglione di Sicilia (CT), Italy, 12-14 May 2010.

Operator and Environmental Safety During Pesticide Application in Liguria Region Greenhouses

Oggero G., Balsari P.
University of Torino. DEIAFA, Mechanics Section
Via Leonardo da Vinci, 44 – 10095 Grugliasco (TO), ITALY.
Tel 0039 0116708608, Fax 0039 0112388608, gianluca.oggero@unito.it

Abstract

A survey has been carried out in 160 Liguria Region (north west Italy) greenhouse farms examining several aspects related to pesticide application and operator safety. About a half of the floricultural farmers interviewed make more than 40 treatments per year, and 45% of horticultural farmers make between 21 and 30 treatments per year. The most frequent (68%) volume rates are in the range between 1000 and 2000 L/ha and lances and spray guns, with both forward and backward movement, are the only type of spray equipment used. During pesticide application only 60% of workers use impermeable gloves, 92% respiratory masks, 60% wear impermeable overalls (17% wear textile overalls).

Almost all operators (92%) clean the empty pesticide containers and add the cleaning water to the pesticide mixture to be distributed. Empty containers are sent to specialised collecting centres (34%), thrown in dumping grounds (48%), burned (9%), or stored in the farm (9%). Most farmers (94%) use to clean the spray equipment after each pesticide application and with water only (98%). Average amount of water used for the equipment cleaning is 42 L. Rinsing water is drained on the ground (53%), sprayed on the crop (33%), thrown in the sewers (14%).

Keywords: greenhouse, pesticide application, operator and environmental safety

Introduction

Cultivation in glasshouses and greenhouses is featured by peculiar climatic (high temperatures an relative humidity) and agricultural conditions (frequent irrigation and fertilisation, high density crops, enclosed area), that may favour the development and spreading of plant pests and weeds more rapidly than in field cropping. This implies that in such conditions the use of PPP considerably arises. Within the 22000 ha of covered crops in Italy, a consume of about 300 tons is estimated just for the insecticides, referred to one single crop cycle. Considering the frequency of crop rotations during the whole year, values of pesticide consume referred to one year are expected to be much higher.

Taking into account that PPP are often featured by high toxicity levels, sprayers must comply with constructive and functional requisites able to minimise the risks for operators, enabling the preparation and distribution of the spray mixture in conditions of safety. The operator, however, has to be informed about the precautions to be adopted when making the spray applications, with special regard to the use of (Personal Protection Equipment (PPE). These information are especially needed when the application is made using hand-held or knapsack sprayers, widely spread in horticultural farms, as in these cases there is a higher risk of accidental operator contamination with pesticides (Bjugstad and Torgrimsen, 1996; Sutherland et al., 1990). A survey carried out in Southern Europe (Italy, Greece, Portugal and Spain) in horticultural glasshouses pointed out a worrying situation in terms of potential operator exposure to pesticides, with level of potential dermal exposure ranging from 70 up to over 900 ml/h. It is important to underline that these values of potential exposure to pesticides are considerably higher with respect to those assessed in similar studies made in Northern Europe, where the figures resulted not more than 20 ml/h. This difference is mainly related to the higher consideration for the operator safety and to the use of more efficient spraying equipment in the Northern European countries (Glass et *al*., 1999).

In Italy a survey on the application of PPPs (Cerruto et *al*., 2008), carried out in Piemonte, Veneto, Toscana Puglia and Sicilia Regions, has enlightened greenhouse crops to be characterised by high numbers of pesticide application (even more than 20 per cultural cycle, that in a year can double in consequence of rapid crop rotations), and by high volume rates (even more than 4000 l/ha). Beside this, the survey has also pointed out poor attention towards the equipment maintenance (pressure regulators absent, pressure gauges broken or not visible during applications), as well as towards the operator safety (improper use of PPE, especially during mixture preparation, when concentrated pesticides are manipulated) and the environmental safeguard (improper disposal of mixture remnants and machineries' washing waters).

The effects of pesticide exposure on operators health were investigated also in several medical studies, like the one made in Spain, in the Almeria region, (Martin Rubi et *al*., 1996), where there are 40000 ha of protected crops. Between 1981 and 1992, 506 cases of poisoning due to dermal absorption, inhalation or ingestion of PPP were recorded. Also in Italy, some studies carried out in the Imperia province (Lotti, 2001) pointed out an increasing number of persons affected by cancer in the areas where intensive agriculture (glasshouses) is practised.

Main objectives of this study were to know how pesticide application is managed in Liguria Region greenhouses (about 5000 ha), and to evaluate its potential impact on the operator and environmental safety. To discover the extent to which PPE are used and how the remnants of the spray applications are managed, a specific questionnaire was prepared and presented to a significant number of horticultural and floricultural farms.

Materials and methods

The survey was carried out in 160 horticultural and floricultural farms located in Liguria region, submitting to the farmers a specific questionnaire. The survey considered several aspects related to pesticide application and operator safety:

- farm statistics (farm surface, main cultivation)
- equipment used, its maintenance and operating parameters;
- number of treatments per year and volume rates applied;
- use PPE: during the preparation and the distribution of the pesticide mixture and during the cleaning of the equipment;
- environment protection: cleaning and management of the empty pesticide containers, management of the waste water.

Results

The cultivated surface involved in the survey amounted to about 200 ha, where 60 hectares were in glasshouses; the average farms surface resulted 1.22 ha, with 0.35 ha in glasshouses. 62% of the farms examined were mainly addressed to flowers production, while the remaining 38% were more focussed on horticultural production. The number of pesticide distribution carried out per year is very high, especially in the floricultural farms where in 46% of cases more than 40 applications are made in one year; on the other hand, in the horticultural farms, only 13% of the farmers interviewed declared to make more than 30 treatments per year (Fig 1).

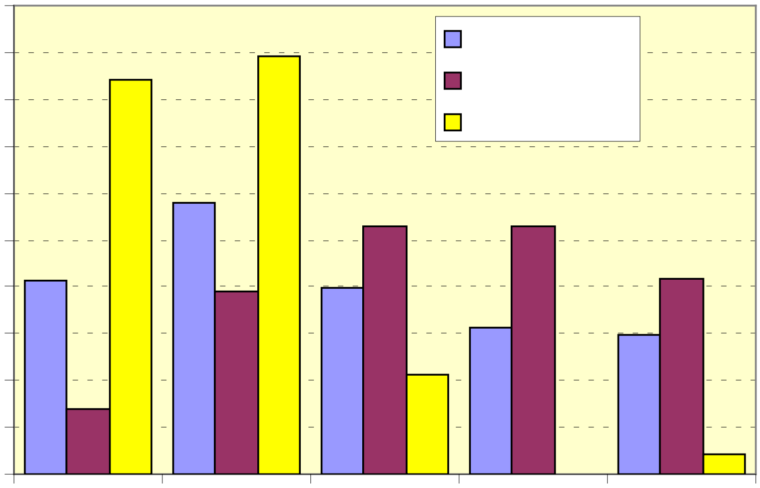


Figure 1 – Numbers of pesticide application per years in the surveyed farms.

Spraying equipment more used resulted short spray lances fitted with a large spout (n°1 in Fig. 2, 35% of cases) and long spray lances, (n° 2 in Fig. 2 - 31% of cases); especially in the floricultural farms located in the province of Imperia, spray lances fitted with three nozzles resulted very much spread (58% of cases) (n°3 in Fig. 2). The lance age ranges from 1 to 25 years, with a mean of 6 years.

Figure 2 – Main type of lances and spray guns for pesticides application used in the surveyed farms.

Average spray volume (145 l/1000 m^2 of glasshouse) as well as average operating pressure (21 bar) resulted very high. It is important to underline that in 20% of the farms examined average spray application rates higher than 200 l/1000 m^2 were employed and that in 18% of the farms surveyed operating pressure even over 25 bar were used (Fig. 3 and Fig. 4). In the flowers farms spray application rates were usually higher (175 l/1000 m^2) than those adopted in the horticultural farms; in this latter case, operating pressures were generally higher.

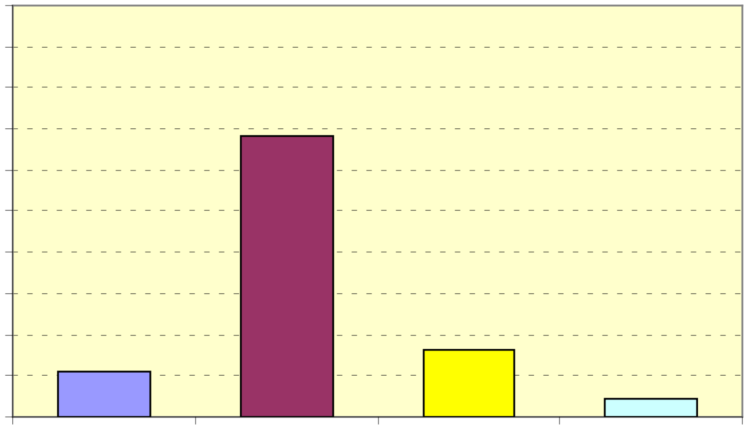


Figure 3 - Volume rate used in the surveyed farms.

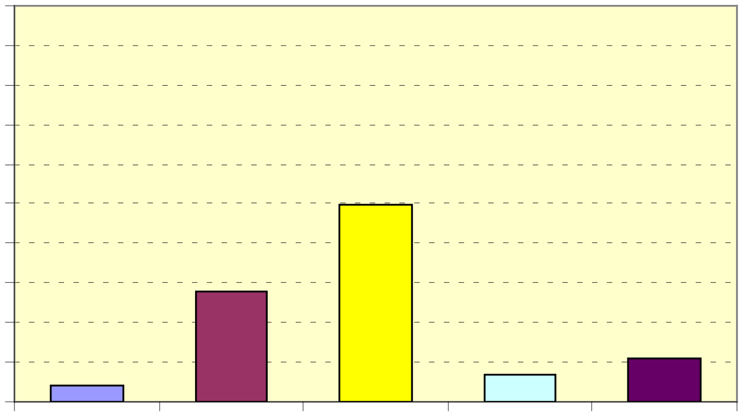


Figure 4 – Pressure used in the surveyed farms.

94% of farmers interviewed declared to clean regularly their spraying equipment at the end of each application (87% of cases) or when the type of pesticide is changed (7% of cases). Cleaning is mostly carried out employing just clear water (98% of cases), seldom adding cleaning agents or soda. The amount of water used for cleaning the sprayer is very variable depending on the accuracy of the cleaning and on the size of hoses. On average it amounted to 42 litres. Washings are often disposed directly in the ground (53% of cases) or on the crop (33% of cases), but sometimes they are also directly poured in the sewers (Fig. 5). 64% of farmers declared to have not any pesticide mixture residue at the end of the treatment, while 30% declared to apply it directly on the crop, 3% declared to pour it on the ground and 3% to leave it in the sprayer tank for reuse in the next application. When making the cleaning of PPP cans, 92% of farmers declared to add the washings to spray mixture. Emptied PPP cans were delivered to specialised disposal companies in 34% of cases, or put in the urban wastes containers (48% of cases), or they were stored in the farm (9% of cases) or even burned (9% of cases, Fig. 6).

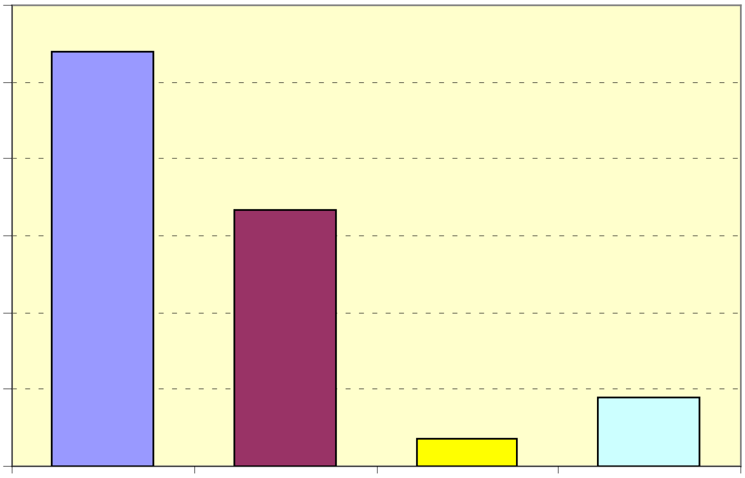


Figure 5 – Rinsing water destiny.

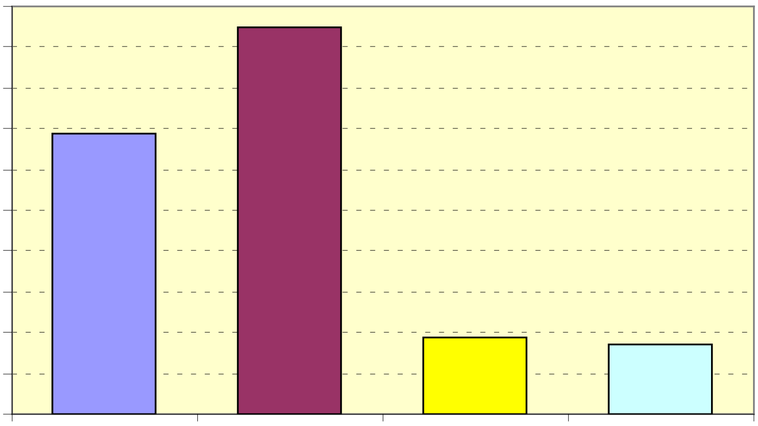


Figure 6 – Empty cans destiny.

94% of farmers interviewed declared that while making the PPP spray application they wear protective gloves: in 60% of cases gloves were impermeable but it was not possible to establish if they were impermeable to chemicals or only water proof. It is important to notice that the use of cotton or latex gloves, as registered in 40% of the farms surveyed, does not protect the hands against chemical agents. Protection from PPP inhalation was adopted in 97% of cases: 92% of farmers declared to wear a mask, fitted with active carbons filters (85%

of cases) or an integral helmet (7%). In the remaining cases, temporary solutions are adopted (e.g. anti-dust masks, handkerchiefs, textile masks, etc.) that are not effective in terms of operator safety. For the protection of the body (88% of the farmers interviewed declared to consider it) the most spread solution (52% of cases) is to wear impermeable overalls, even if, as already mentioned about the gloves, it was not possible to state their effectiveness in preventing from PPP contact. Also the disposable overalls, used in 23% of farms, do not represent a guarantee in terms of operator safety, as their effectiveness depends on the material they are made of (Fig 7 and Fig. 8). In any case it is recommended to avoid the use of textile overalls (that was still registered in 25% of farms) which can absorb the chemicals and therefore increase the PPP dermal exposure for the operator.

Figure 7 – Correct use of PPE during pesticide application.

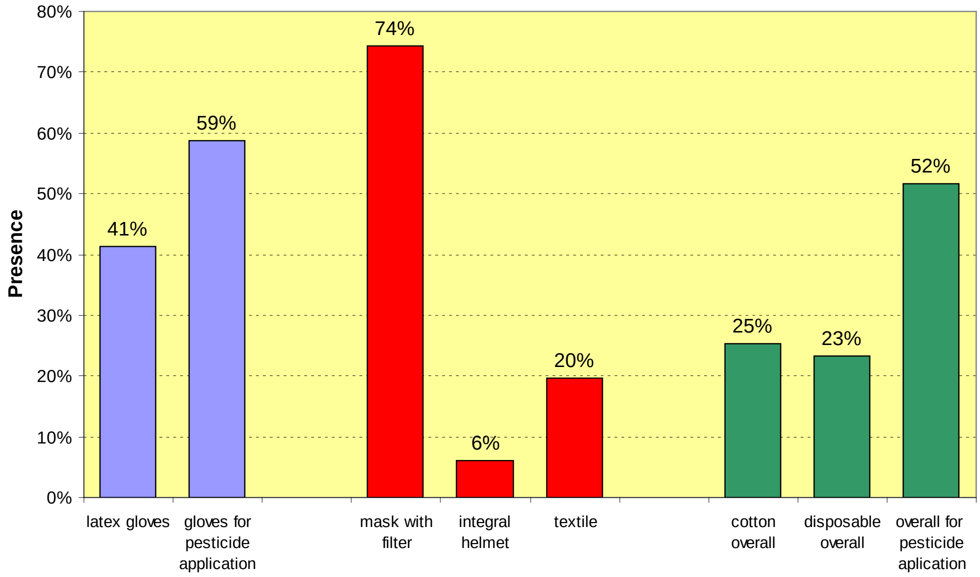


Figure 8 - Summary of the PPE use during pesticide application.

The operator, when applying the spray mixture, walks backward in 41% of cases, walks forward in 27% of cases and modifies the way of moving according to the crop type, to the features of the field/glasshouse or to the environmental conditions (38%). It is important to remind that the choice to walk in the forward direction is not recommended because it increases the risks for the operators of direct (from liquid sprayed) and indirect (from already treated leaves) PPP contamination. Especially in the most extreme conditions (very high spray volume rates and very developed vegetation), to pass from backward walking to forward walking while spraying may lead to an increment by 8 times of the operator PPP contamination (Cerruto et *al*., 2008, Fig. 13).

Conclusions

The survey carried out, that involved a significant number of farms, and therefore can be considered representative for the situation in Liguria region, pointed out that pesticide application in horticultural and floricultural farms is made in a not optimal way. More in details, spraying equipment used are very poor in terms of technology, they are often old, not safe and they are used not properly.

Operators generally have a lack of basic knowledge about the correct use of the sprayers and especially about their correct adjustment. Also the management of PPP wastes is often carried out not properly. If we consider that an average of 42 litres of clear water are employed for cleaning the equipment and that 40 treatments are made each year, then the farmers has to manage 2 m^3 of washings containing PPP, that, as pointed out by the survey, are usually poured on the ground, typically always in the same place of the farm, therefore generating PPP point sources.

Also the measures adopted to guarantee the operator safety while making pesticide application resulted in most cases not sufficient and therefore it was confirmed the need for a more appropriate training of the operators.

Acknowledgements

Survey has been carried out in collaboration with Riviera dei Fiori, L'Ortofrutticola, Le Riunite and Fratellanza Sarzanese Co-operatives in the ambit of a Project, financed by Liguria Regional Administration, aimed at realising a permanent service of inspections for hand held sprayers that are mainly used in horticultural and floricultural farms.

References

Bjugstad N., Torgrimsen T. 1996. Operator safety and plant deposit when using pesticide in greenhouse. Agricultural Engineering Research, 65, pag 205-212.

Cerruto E. Emma G., Manetto G. 2008 Operator contamination during pesticide application in tomato green house. Acta Horticulturae (801), 1515-1522.

Cerruto E., Balsari P., Oggero G., Friso D, Guarella P., Raffaelli M. 2008. Operator safety during pesticide application in greenhouse: a survey on italian situation. Acta Horticolture (801), 1507-1514.

Martin Rubi J.C., Yelamos Rodriguez F., Laynez Bretones F., Cordoba Escamez J., Diez Garcia F., Lardelli Claret A., Blanco Coronado J.L. Vicente Ruiz J,R. (1996). Intoxicaciones por insecticidas organofosforados : estudio de 506 casos. Revista clinica espanola n° 126, pag. 3-8.

Glass C. R., Mathers J.J., Martinez Vidal J.L., Egea Gonzalez F.J., Moreira J.F., Machera K., Kapetanakis E., Capri E. (1999). Potential operator exposure in southern european greenhouses and orchards. In: Human and environmental exposure to xenobiotics (AA. VV) La Goliardica Pavese, pag. 633-638.

Lotti G.(2001) Le malattie professionali del floricoltore. Oral comunication in Workshop "La corretta modalità di distribuzione dei fitofarmaci alle colture floricole" Sanremo, Sala Congressi UCFLOR, 1 dicembre 2001.

Definition of Unambiguous Criteria to Evaluate Tractor Rops Equivalence

Pessina D., Facchinetti D., Belli M.
Dipartimento di Ingegneria Agraria - Università degli Studi di Milano, Via Celoria 2, 20133 Milano Italy, ph. 02 50316876, fax 02 50316845, domenico.pessina@unimi.it

Abstract

The Roll Over Protective Structure (ROPS) is the most diffused means to reduce the operator's risk in case of agricultural and forestry tractor overturning. Many tractor models are nowadays available on the market; as a consequence, manufacturers are compelled to fit and submit for testing and approval a high number of ROPS very similar one another, in order to comply the relevant Regulations. The most popular dedicated Standards often do not provide clear and unambiguous criteria for evaluating the real strength equivalence of ROPS revealing only slight differences among old and new versions, frequently modified for a higher manufacturing uniformity. It could be useful to establish one maximum tolerance value(s), within a structural modification could be considered admissible without carrying out a new validation test. The probably most applied ROPS standard, issued by the OECD, the Code 4, provided for standard agricultural and forestry tractors, was taken into account. At the point 3.9.2.1 " ", is written "…The required energy shall not exceed the energy calculated for the original test by more than 5 %...". Some cases of protective structures for which a test was been repeated due to the introduction of slight structural modifications were examined, by comparing the rear and side loading curves, in order to correlate the structural modifications characteristics and the differences found. On the basis of the obtained data, a series of unambiguous criteria could so defined, to evaluate various ROPS modifications and their need to carry out (or not) a new validation test.

Keywords: ROPS, criteria, strength, equivalence

Introduction

Operators safety is one of the most important items to be considered in agriculture: despite the overall risk level has been recently decreased, the agricultural sector still suffers at present several serious and even fatal injuries. Agricultural machinery, especially tractors, represent important occupational hazard factors, causing very serious injuries. Statistics show that tractor drivers are exposed to grip and dragging from motion transmission elements, falls to the ground getting on or off from the driving place, crushing while hooking up or disconnecting tools, inhalation of exhaust gases, burns for hot surface contact, high levels of noise and vibrations and incongruous postures. But the most serious hazard is the **tractor overturning** (lateral, longitudinal or both, combined) due to vehicle overload and/or very high pull force and/or excessive ground slope.
ROPS (Roll Over Protective Structure) is still now the most diffused device to reduce the operator's risk in case of agricultural and forestry tractor overturning. ROPS became popular in the 50's, starting their application in Scandinavian Countries, where dedicated studies established the energy levels to be applied in order to simulate the mechanical stress produced in case of a rollover accident occurred in well-defined conditions. This information represented later the basis for the most popular International Standard (issued by OECD, EU, ISO and other international Organisations) currently in force to test ROPS strength. The first official Standard Code for the official testing of protective structures on agricultural tractors was approved on 21th April 1959 by the OEEC Council, then turned in OECD (Organisation

for Economic Co-operation Development). Since then, the various OECD codes were also applied to forestry tractors, to determine other performance characteristics of safety and noise. All ROPS testing methods are based on a rollover simulation through blows (with a mass equipped with pendular motion) or horizontal loadings (applied with a hydraulic cylinder) and crushing tests, to be quantified vs the mass of the tractor on which the protective structure is to be fitted.
In Italy, since 1st January 1974 each new standard wheeled tractor must be fitted with a ROPS (front or rear roll-bar, frame or cab), being it a structure of welded and bolted steel tubes, plates and sheets of various dimensions and thickness, fitted around the driving place, tested according to dedicated international Standards. In the following years, further specific standards were issued for specialized tractors (i.e. those narrow tracked, mainly used in vineyard and orchards); at a later time, also tracklaying tractors were equipped with tested ROPS. To comply with the technical legislation, ROPS manufacturers have to check their prototypes through strength to be carried out in officially qualified Testing Stations. To be considered positively, ROPS must ensure a safety volume (clearance zone) fitted around the seat in case of overturning.
The main purpose of the present study is:

- to determine clear and unambiguous criteria about the strength equivalence of two or more different versions of ROPS showing, due to homologation requirements, very slight differences among them;
- to study how ROPS minimum modifications affect their performances.

Materials and methods

Since 1973 the Dipartimento di Ingegneria Agraria of University of Milan - Italy (DIA-Unimi, formerly IIA-Unimi) is acting as a Testing Station officially recognized by the OECD for the assessment of the agricultural tractors performance and their components (particularly ROPS). For this purpose, from 1991 DIA-Unimi operates on its static test bench, and since 1994 an automatic data processing and arrangement of certificates has been activated, together with a file archive, for managing and sending approval reports.
Thanks to this file archive, 6 ROPS cases were found in which the tests were repeated twice or more, due to the introduction of slight structural modifications in respect to the first version. These structural modifications were then correlated to the rear and side loading curves, in terms of their trends and of the maximum force and deflection values obtained.

Results

The details of the 6 ROPS cases for which the tests were repeated due to the introduction of slight structural modifications are shown in **table 1**.

Case No.	DIA-Unimi ref.	ROPS make and model	Modifications detail
1	IIA 441 MI 1987	Landini TS 19	No spacer on rear mountings; M=3000 kg
	IIA 443 MI 1987	Landini TS 19/1	1 spacer th.30 mm on rear mountings; M=3000 kg
	IIA 444 MI 1987	Landini TS 19/2	2 spacers th.30 mm on rear mountings; M=3000 kg
	IIA 682 MI 1999	Landini TS 19/3	3 spacers th.30 mm on rear mountings; M=3400 kg
2	IIA 682 MI 1999	Landini TS 19/3	Different spacers on the rear axle and reinforcement

	IIA 733 MI 2002	Landini TS 19/3 ext	plates on the mudguards
3	IIA 744 MI 2004 IIA 758 MI 2004	Same Deutz-Fahr Italia AP 43A & AP 43A ext	Different bolts fitting direction; different length of some sections; M=4900 kg
4	IIA 602 MI 1994 IIA 759 MI 2004	Same Deutz-Fahr Italia C 36 & C 36 ext	Reference mass increase (3200 kg instead of 3000 kg); small shape modification of the front mounting; different length of some sections
5	IIA 611 MI 1995 IIA 772 MI 2005	Same Deutz-Fahr Italia T 69 & T 69 ext	Reference mass increase (3100 kg instead of 2850 kg); small shape modification of the front mounting
6	DIA 838 MI2010	Same Deutz-Fahr Italia C 56 & C 56 ext	Alternative rear mountings with different length

M = reference tractor mass; ext = extension

The differences of maximum force and deflection values recorded during the side and rear loadings of tests carried out on similar ROPS are shown in **tables 2 and 3**.

rear

Case No.	**ROPS versions involved**	**Rear loading**		**Notes**
		max deflection diff., %	**max force diff., %**	
1	TS 19 vs TS 19/1 TS 19 vs TS 19/2 TS 19 vs TS 19/3	0 5 15	-6,87 4,61 -4,46	TS 19, TS 19/1: M=3000 kg TS 19, TS 19/2: M=3000 kg TS 19: M=3000 kg TS 19/3: M=3400 kg
2	TS 19/3 vs TS 19/3 ext	-8,70	7,73	TS 19/3, TS 19/3 ext : M=3400 kg
3	AP43A vs AP43A ext	not applicable	not applicable	AP 43A, AP 43A ext: M=4900 kg
4	C36 vs C36 ext	6,90	10,66	C 36: M=3000 kg C 36 ext: M=3200 kg
5	T 69 vs T 69 ext	29,40	-24,60	T 69: M=2850 kg T 69 ext: M=3100 kg
6	C 56 vs C 56 ext	-0,53	-1,74	C 56, C 56 ext: M=4800 kg

side

Case No.	**ROPS versions involved**	**Side loading**		**Notes**
		max deflection diff., %	**max force diff., %**	
1	TS 19 vs TS 19/1 TS 19 vs TS 19/2 TS 19 vs TS 19/3	-1,25 -3,13 6,25	-7,06 0,73 2,41	TS 19, TS 19/1: M=3000 kg TS 19, TS 19/2: M=3000 kg TS 19: M=3000 kg TS 19/3: M=3400 kg
2	TS 19/3 vs TS 19/3 ext	-8,82	3,69	TS 19/3, TS 19/3 ext : M=3400 kg
3	AP43A vs AP43A ext	2,38	-7,83	AP 43A, AP 43A ext: M=4900 kg
4	C36 vs C36 ext	-6,53	37,74	C 36: M=3000 kg C 36 ext: M=3200 kg
5	T 69 vs T 69 ext	16	21,71	T 69: M=2850 kg T 69 ext: M=3100 kg
6	C 56 vs C 56 ext	-1,5	-2,75	C 56, C 56 ext: M=4800 kg

In general, if slight structural modifications are introduced, the differences for both rear and side loadings are not greater than 7-8 %. On the contrary, when also the reference mass is changed, logically the maximum force and deflection values variation become higher (as for example in Same Deutz-Fahr Italia C 36 and T 69 cases). In these last two cases (*Nos. 4 and 5*) the differences recorded were much greater than that of the reference mass: this is probably due also to not negligible structural modifications introduced. On the contrary, the *case No. 1* (Landini TS 19 and derived versions TS 19/1, TS 19/2, TS 19/3) is particularly interesting, because the reference mass remained constant (apart in one sub-case, see **Table 4**) and the structural modifications introduced were really very slight (**fig. 1**). The comparison among the relevant 4 force/deflection rear and side loading curves is shown in **fig. 2 and 3**.

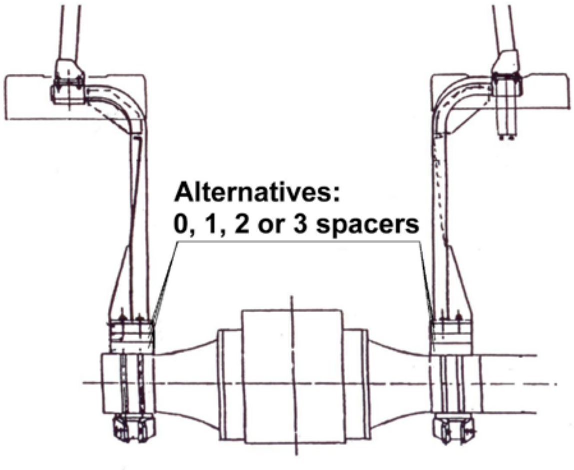


Figure 1. TS 19, TS19/1, TS 19/2 and TS 19/3 alternative spacers combinations.

If the reference mass is not changing, for Landini TS 19 ROPS series the difference in maximum force and deflection values remains within 6-7 %, evidencing higher figures for the force in respect to the deflection; on the other hand, considering a reference mass increase of 13.3 % (from 3000 to 3400 kg, sub-case TS 19 vs TS 19/3) and the relevant increase of energy to be absorbed, the max force and deflection values varied less, as an average.

Table 4. Energies to be absorbed and forces to be applied in the strength tests of the 4-posts frames Landini TS 19, and derived versions TS 19/1, TS 19/2, TS 19/3.

Tests sequence	Formulae for required energies E (J) and forces F (N)	Energies E and forces F applied (M_{ref} = *3000 kg*)	Energies E and forces F applied (M_{ref} = *3400 kg*)
1. Rear longitudinal loading	E = 1.4 M	E = 4.20 kJ	E = 4.76 kJ
2. 1st vertical loading	F = 20 M	F = 60.0 kN	F = 68.0 kN
3. Side longitudinal loading	E = 1.75 M	E = 5.25 kJ	E = 5.95 kJ
4. 2nd vertical loading	F = 20 M	F = 60.0 kN	F = 68.0 kN

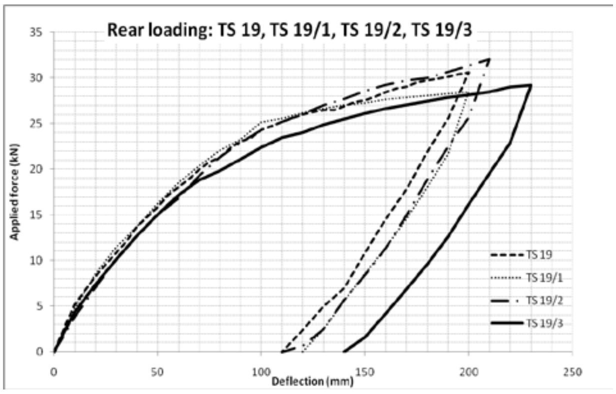


Figure 2. Comparison among the 4 loading curves of the protective structure Landini TS 19 and its slight modified versions TS 19/1, 19/2 and 19/3.

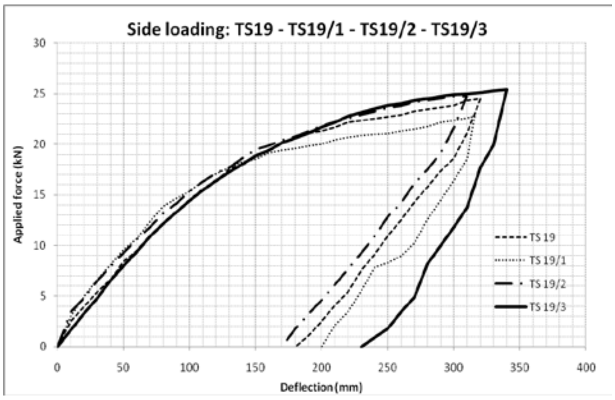


Figure 3. Comparison among the 4 loading curves of the protective structure Landini TS 19 and its slight modified versions TS 19/1, 19/2 and 19/3.

In **fig. 4** the comparison between the 2 force/deflection rear and side loading curves of the protective structure TS 19/3 and its modified version TS 19/3 ext. is shown. The same reference mass was considered in this case. To evaluate the behaviour of the two ROPS versions, the "elasticity ratio" could be calculated, being it the elastic/plastic deflections ratio, a useful indicator of the elasticity of the structure (**fig. 5**).
The frame TS 19/3 was characterized by a rear elasticity ratio of 100 mm/130 mm = 0.77, while for the TS 19/3 ext resulted a ratio of 0.91 (+ 18 %). TS 19/3 ext evidenced a lower stiffness, not depending on the spacers of different shape fitted on the rear axle, but probably due to the reinforcing plates fitted on the mudguards: The reinforcements compelled the upper part of the frame to absorb a greater amount of the applied energy. The side loading confirmed this trend, evidencing an elasticity ratio of 0.48 for the TS19/3 frame and a value of 0.55 (+15 %) for the TS 19/3 ext.

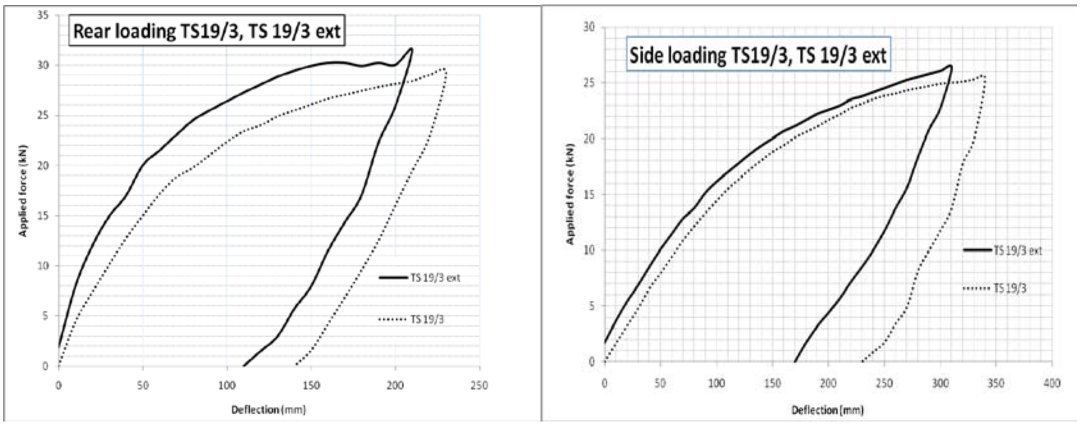


Figure 4. Comparison among the rear and side loading curves of the protective structures TS 19/3 and TS 19/3 ext.

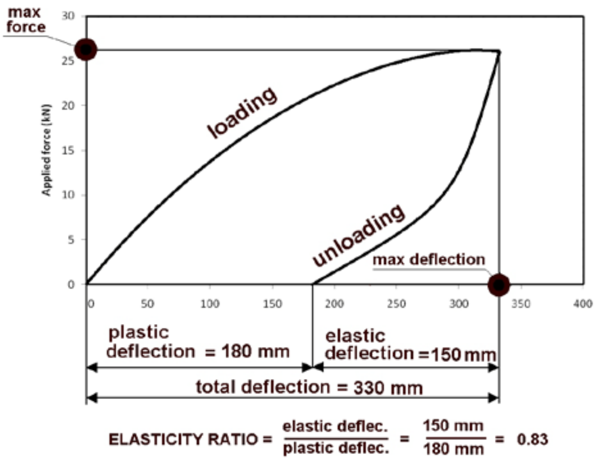


Figure 5. The "elasticity ratio" (elastic/plastic deflection values) is a useful indicator of the elasticity of a ROPS.

The *case No. 3* was relevant to the Same Deutz-Fahr Italia AP 43A frame, fitted on track-laying tractors, and therefore subjected to what prescribed by OECD Code 8. In this case, only the side loading is provided, and therefore no enough information was collected to draw a significant evaluation about the behaviour of the two ROPS versions.

The 2 force/deflection rear and side loading curves of the protective structures Same Deutz-Fahr Italia C 56 and C 56 ext are shown in **fig. 6 and 7** (*case No. 6*). These two ROPS versions were identical, apart the rear mountings that were showing a very slight different length. The trend of the rear loading curves are practically the same, and also the side loading curves are very similar. The differences of the maximum force and deflection values never exceed 3 %. This confirms that the structural modification introduced practically does not affect the ROPS strength.

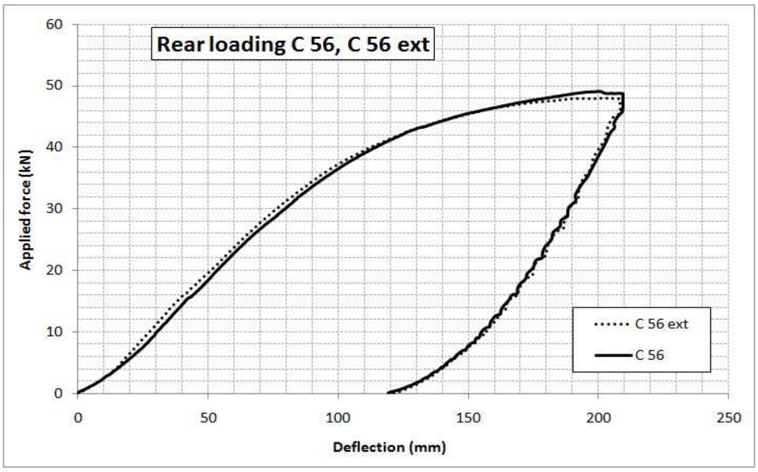


Figure 6. Comparison between the loading curves of the protective structures C 56 and C 56 ext.

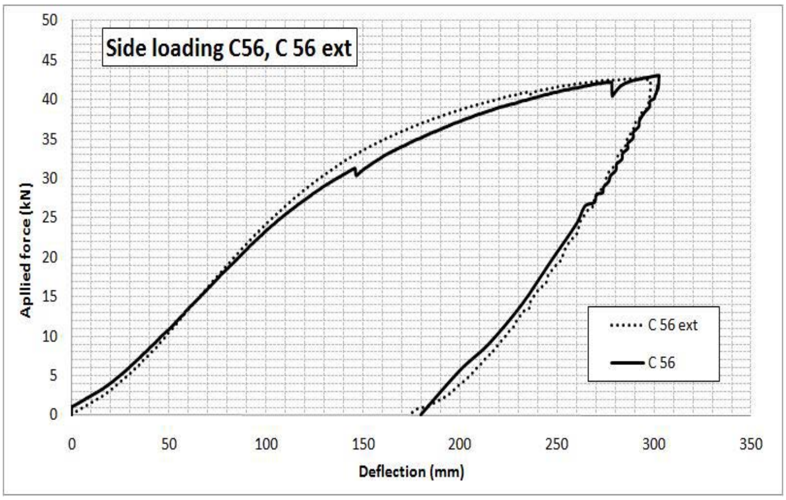


Figure 7. Comparison between the loading curves of the protective structures C 56 and C 56 ext.

Conclusions

The technical updating of the models included in a tractor series could lead to a mass slight increase, i.e. for the fitting of a new gearbox, or new larger tyres, or the air conditioner, and so on. If the cab already fitted has been tested for an insufficient reference mass to include these modifications, OECD Code 4, in paragraph 3.9.2.1, named "*Extension of the structural test results to other models of tractors*", says: "The loading and crushing tests need not be carried out on each model of tractor, provided that the protective structure and tractor comply (…omissis…) the required energy shall not exceed the energy calculated for the original test by more than 5 %."

On the other hand, in recent years tractor manufacturers establish their production on the basis of "families", being them series or groups of models on which the same cab is to be fitted, adapting it through little structural modifications. In these cases, OECD Code 4 provides that when technical modifications occur on the tractor, the protective structure or the method of attachment of the protective structure to the tractor, the Testing Station that has carried out the original test can issue a "technical extension report" based on the execution of a new test. As

a consequence, manufacturer are compelled to submit for testing all the ROPS including at least one slight structural modification. This situation is much time and money consuming.
Taking as a reference the figure of 5 % admitted for increased energy due to the increase of reference mass, it could be taken into account a similar limit in order to evaluate the possibility to avoid the execution of a new test in case of slightly structural modifications, such as the height of mountings, or their shape and thickness.
The tests repetition of the 6 cases analysed in this paper show encouraging possibilities for a positive consideration. In several situations, light structural modifications lead to little differences in maximum forces and deflection figures; in many cases they do not exceed 5 %. On the contrary the increase of reference mass caused a higher variance.
To evaluate the possible impact of structural modifications on the strength of a ROPS, and therefore their role in changing the rear and side force/deflection curves trends, the Finite Element analysis (FEA) technique can now profitably adopted, using as a reference the most popular software tools, such as Ansys, Nastran, Msc Pal 2, etc.

References

OECD Code 4, "OECD Standard Code for the official testing of protective structures on agricultural and forestry tractors (static test). OECD, Paris.

OECD Code 8, "OECD Standard Code for the official testing of protective structures on agricultural and forestry tracklaying tractors". OECD, Paris.

Evaluation of Noise Levels in Olive Mills

Porceddu P.R.[1], Dionigi M.[2]
[1]*University of Perugia. Dept. of Agricultural and Environmental Science*
Borgo XX Giugno, 74 – 06121 Perugia, ITALY.
Tel 0039 0755856079, Fax 0039 0755856440, pierriccardo.porceddu@unipg.it
[2]*University of Tuscia. Dept. of Geology, Mechanical and Hydraulic Engineering*
Via De Lellis – 01100 Viterbo, ITALY.
Tel 0039 0761357357, Fax 0039 0761357327, marcdionigi@gmail.com

Abstract

Generally in Italy mills are family-owned business, with two or three employees. Due to the seasonal work a lack of attention of workers' safety is present and few investments on this subject are made. Because the machines utilized noise one of the most important risk is considered. The paper noise level in nine mills of central Italy investigated. It emerges that continuous plants are more noisy than traditional ones. Moreover safety signs are not present and workers didn't wear the required PPE. It is important to do a correct vocational training also to promote the safety culture.

Keywords: workers' safety, noise exposures

Introduction

In Italy the olives are harvested from November to December. The production is about 3.4 x 10^9 kg. Oil production by 4.660 olive mills is made. Often they are family – owned business with two or three workers. Due to work pace very intense and the presence of old plants lead to think a lack of attention of workers' safety. Moreover due to the seasonal work of olive mills, few investments are made. Occasional workers are involved in the work therefore vocational training often is not done. Due to presence of various machines noise is one of the most important risk.

The aim of the paper is to investigate level of noise and to identify possible strategies for its reduction.

Material e methods

To evaluate the workers' noise exposure level, some investigations in nine olive mills in the central Italy were carried out. They are family-owned business, organized in traditional (8 and 9 olive mills) or continuous plants (from 1 to 7 olive mills). The machines involved in the production were arranged in a single room (1, 3, 6, 7 olive mills) or in two rooms (2, 4, 5, 8, 9 olive mills). In all cases the owner and one employee were involved in the production. In particular, in the mills an operator took care the initial phases, such as delivery, weighing, defoliation and washing while the other one the extraction and storage of oil phases supervised.

The noise measurements were carried out according to UNI 9432:2008. A Brüel & Kjaer 2260 Investigator phonometer fitted with overload indicator was utilized (Fig. 1). The instrument and its prepolarized free-field microphone satisfied the requirements of Class 1 according to the CEI EN 61672-1 . Thanks to a Class 1 (IEC 60942) calibrator (pistonphone) the phonometer to a regular calibration was subjected to verify that the deviation from the calibration value did not exceed the 0.5 dB.

Before any measurement were acquired informations about:

noise characteristics (e.g. constant, fluctuating, impulsive, cyclic noise);

workers' positions;

any period of rest.

The instrument was positioned at a height of 1.60 m above the ground, in the workers' positions. The microphone was pointed towards the direction of the prevailing noise source. Due to the workers' movements within the building, additional measurements at specified position were carried out. Such positions were really occupied by workers. The surveys were performed when all the machines were working.

Figure 1. Instruments utilized.

Three surveys for each measurement point were carried out, able to obtain a stable value of equivalent continuous sound level within ± 0.3 dB. Thanks to a spreadsheet the final value (L_{Aeq}) was obtained by the mean of the three values listed above. However, the lenght of each survey was never less than 60 s.

In order to ensure reproducibility of measurements were taken into account the most important contributions of the uncertainties, such as:

uncertainty of sampling (environmental uncertainty) (u_a), determined by a spreadsheet;

uncertainty on the instrument positioning (u_L), generally the value attributed is 1 dB;

instrumental uncertainty (u_s), generally using class 1 instruments the uncertainty is 0.5 dB.

To know the time spent by workers in different locations inside the building, audio visual material was utilized. Thanks to a spreadsheet it was possible to calculate the equivalent continuous sound level (L_{Aeq}), the workers' daily noise exposure ($L_{EX,8h}$) and their related uncertainties.

Results

The collected data some differences between continuous and traditional mills show (Tab.1). Noise levels are higher in continuous olive mills than in traditional ones. The high noise levels in the defoliant/washing machines depend on both the noise generated by the machine and the impact of the product on the hopper surfaces.

The high L_{Aeq} value related to the washing machine of the mill number 9, is probably due to the restricted area in which the machine was positioned and to the reverb by walls.

Differences in the olive pressing phase between continuous and traditional plant are evident. They depend on the different machine utilized (crusher with hammers, millstone).

Due to the high rotatory speed the noise level values of decanters are 10 dB(A) ahead of presses. Due to the presence of the office inside the production area without any walls, high sound levels were recorded in some mills (e.g. number 1 and 6).

Generally the sound sources separation in two different rooms leads to a noise reduction (e.g. single room mills 1, 3 – double room mills 2, 4). Analyzing $L_{EX,8h}$ data (Tab. 2) it emerges that the workers "A" were subjected to levels of daily noise exposure range from 80 dB(A) to 85 dB(A).

Workers "B" were exposed to high noise levels, especially in the continuous mills, where in some cases the 87 dB(A) was exceeded.

Table 1. L_{Aeq} values referred to the phases and mills.

Work area	Continuous olive mills							Traditional olive mills	
	1	2	3	4	5	6	7	8	9
Delivery	64, 8	70,0	65,9	60,7	62,4	66,0	56,0	57,7	51,3
Weighing	80,4	83,1	70,0	83,5	81,5	-	65,5	-	77,1
External defoliator	-	74,9	84,8	81,3	83,8	-	-	-	-
Hopper	80,4	83,3	89,6	85,0	-	85,5	85,2	84,6	85,8
Defoliant/washing machine	90,7	86,1	90,5	88,8	90.8	88,7	86,9	83,3	92,5
Crusher/millstone	91,2	89,5	92,2	90,6	90,0	88,5	86,5	80,7	83,1
Kneader	90,2	88,3	84,5	88,6	90,0	88,5	84,2	82,1	83,1
Stacking machine	-	-	-	-	-	-	-	83,9	83,1
Presses/decanter	92,1	88,5	90,9	91,5	91,5	89,1	86,2	81,8	81,7
Centrifugal separator	91,8	90,8	88,6	84,4	91,1	88,8	85,4	83,8	81,7
Oil storage	90,4	67,7	78,5	67,7	79,5	89,1	77,5	66,3	-
Office/desk	88,2	70,0	70,0	83,5	78,1	86,7	65,1	66,3	81,6

The uncertainty values range from 1.1 to 1.5 dB.

Table 2. Daily noise exposure $L_{EX, 8h}$.

Mills	$L_{EX,8h}$ [dB(A)]	
	A*	B**
1	83,0 ± 0,8	91,1 ± 0,8
2	81,5 ± 0,8	88,8 ± 0,9
3	82,6 ± 0,9	89,1 ± 0,7
4	83,1 ± 0,7	86,5 ± 0,7
5	81,6 ± 0,9	90,4 ± 0,7
6	84,3 ± 1,0	88,2 ± 0,6
7	79,3 ± 1,1	84,1 ± 0,7
8	81,5 ± 0,9	83,3 ± 1,0
9	83,6 ± 0,9	82,3 ± 0,9

*A: worker assigned to the delivery of the product.
**B: worker assigned to the phase of extraction (continuous mills) and to the stacking machine (traditional mills).

Conclusions

The Italian law on noise rules that owners must evaluate the noise risks and take measures to reduce it. The same law provides three limit values:

$80 < L_{EX,8h} < 85$ it is necessary to do vocational training, to equip workers with PPE (Personal Protective Equipment);

$85 \leq L_{EX,8h} < 87$ it is necessary to place safety signs, to impose the PPE use and to undergo annual medical tests;

$L_{EX,8h} \geq 87$ it is necessary to stop any kind of work, to identify the causes of excessive noise and to take measures to lower the exposure below the limit value.

Unfortunately vocational training was inadequate in all analyzed mills. Safety signs were not present and workers didn't wear the required PPE (Personal Protective Equipment), because they were not present or in poor use conditions (e.g. lack of brand or model needed to verify their efficacy).

It is important to plan a correct machines maintenance, especially for those who have rotatory movements. In such case the perfect working of ball bearings is very important.

Beyond the noise analysis to know the real conditions of workers at work it is important to take into account other risks such as: microclimate, manual material handling, repetitive manual operations.

References

Biondi P., Monarca D., Panaro V., Pasqualone S. B. 1997. Indagine sui livelli di rumorosità nei frantoi oleari. Rivista di Ingegneria Agraria, 3, 150–159.

Panaro V., Pascuzzi S., Santoro F. 2004. Analisi delle esposizioni al rumore nella filiera olivicola: rilievi nelle fasi di raccolta meccanica e spremitura delle olive. Rivista di Ingegneria Agraria, 2, 43–50.

Porceddu P.R., Babucci V., Panaro A. 2005. Verifiche di sicurezza in piccoli frantoi oleari in Umbria – Proceeding of L'ingegneria agraria per lo sviluppo sostenibile dell'area mediterranea, Catania 27-30 June 2005.

D. Lgs. 106/09. 2009. Disposizioni integrative e correttive del D. Lgs. 81/08, in materia di tutela della salute e della sicurezza nei luoghi di lavoro.

D. Lgs. 81/08. 2008. Attuazione dell'articolo 1 della legge 3 agosto 2007 n. 123, in materia di tutela della salute e della sicurezza nei luoghi di lavoro.

UNI 9432:2008. 2008. Acustica – Determinazione del livello di esposizione personale al rumore nell'ambiente di lavoro.

Evaluation of Hand Forces During Manual Vine Branches Cutting

Romano E.[1], Bonsignore R.[2], Camillieri D.[2], Caruso L. [2], Conti A.[2], Schillaci G.[2]
[1]Agriculture Research Council- Agricultural Engineering Research Unit (CRA-ING); Laboratory of Treviglio, via Milano 43, 24047 Treviglio BG, Italy-Tel.-Fax +39 0363 49603 elio.romano@entecra.it
[2]Università di Catania – DIA, Sezione Meccanica, Via S. Sofia 100, 95123 Catania, Italy-Tel. +39 095 7147512, Fax +39 095 7147600 giampaolo.schillaci@unict.it

Abstract
As we know, winter pruning is one of the critical points in the management of the vineyard. In small farms, often located in slope areas, winter pruning is mainly performed manually. From studies carried out on vineyards from Sicily and Lombardy region, pruning operated with conventional scissors remain the most widely used method. The use of pre-pruning machine is a very good solution to facilitate the subsequent manual intervention. In every case, winter pruning require manual operations carried out by secateurs or, less commonly, by long handle shears. Recent works, conducted to assess through OCRA Index the muscle – skeletal risk due to manual pruning of the vineyard, showed a variability in the forces applied on the scissors. The purpose of this work is to verify the forces exerted on the scissors by different regions of the hand during the pruning of the vineyard. So we used a conventional scissors equipped with sensors able to detect the force exerted and the duration of the effort. The tests were conducted in the laboratory and the results were processed with the aim to show if the hand forces during manual cutting are function of diameters and cultivated varieties.

Keywords: cutting force, vineyard, dynamometric scissors

Introduction
In winter pruning of vines, manual shears are the most used both in case of manual intervention and in the case of finishing after mechanic pruning (Balloni et al. 2008, Schillaci et al, 2009), although there is a progressive replacement of such equipment with electric shear with electronic control. The intervention of the vine pruning is done with cuts that follow one another quickly thanks to a constant regularity in the morphology of the plant and pruning system. This activity, carried out for 4-5 consecutive months, may result in the worker musculoskeletal disorders of the upper limbs due to physical effort required to cut wood and from repetitive actions.

Regional guidelines for the prevention of musculoskeletal disorders related to repetitive movements and efforts of the upper limbs (DG Health All.1 3958/2009) lists among workers exposed to risk of biomechanical overload even the employees working continuously to some agricultural including pruning. Pruning may be associated with musculoskeletal disorders of the hand, especially paresthesias of the hand (Roquelaure et al. 2001), and wrist, combined with static work done by the shoulder-arm system (Wakula et al. 2000). The risk factors vary according to the working arrangements (just cutting and cutting and simultaneous removal of cut branches), the type of pruning, the distribution of work and the vineyard (vine, slope, height strains) (Wakula J, K Landau). The bibliography about it does not provide sufficient information to evaluate the strain and biomechanical stress to which the worker is subjected during pruning. Studies to evaluate, through OCRA index (Colombini et al. 2005), skeletal muscle, the risk from exposure to repetitive movements of upper limbs in manual pruning of the vineyard (Schillaci et al. 2009), found a variation in the forces developed by hand trimmer. Work ergonomics and design tools for pruning (Wakula et al. 2000; Paivinen et al.

2000; Haapalainen et al., 2000) were aimed observation of the accumulation of stress operator. Recent research (Spare et al. 2009) evaluating the shear strength of the shoots in the laboratory penetrometer using texture analyzer TA-HDi with load cell, showed differences between the varieties tested.

The purpose of this study was therefore to assess, through cuts made by a scissors equipped with sensors, the forces exerted by different regions of the hand during cutting of branches of different cultivars and different diameters, from eleven vineyards cultivated in two different Italian regions.

Materials and method

With this aim was used a traditional pruning scissors on which were placed 5 sensors capable of detecting the force applied and duration of these forces.

Fig.1: Shear with sensors connected to wireless transmitters

Samples collected during the pruning were immediately tested to evaluate the resistance in terms of reaction to the penetration of a blade thickness of 2 mm, with triangular section, maximum width 6 cm and maximum length 3 cm (Stoker Profil 21), weighing 240 g and length of 21 cm, chosen as the type of shear with media interaction against muscle activity (Haapalainen et al, 2000). For the measurements have been used force sensors Flexi Force Sensors ® A201 of Tekscan based on printed circuit boards, flexible and ultra-thin substrate made of two layers of film (polyester / polyamide).

Each layer is a conductive material (silver) and a layer of pressure sensitive ink. The sensitive area is formed by a circle of silver ink overlay sensitive. These sensors have the ability to detect signals of strength from 0 to 440 N, a response time of < 5microseconds on an area of detection with a diameter of 9,53 mm. The resistance of the sensor is then transferred to a computer by wireless signal. The end of such sensors is positioned so as to coincide with the point of contact of the fingers of the operator with the handles of the pruning shears during the operation in order to investigate the efforts related to the contact point with the handle of the index, middle and ring fingers and the palm corresponding to two zones closet o the thumb. Tests were conducted in laboratory and were intended to record the forces exerted by hand of the pruner and their distributions in the regions of the hand under investigation according to the diameters of the branches and the vineyard. The cuts were made in correspondence of 4 diameters: 5, 7, 10 and 12 mm. To conduct statistical analysis were performed 2 cuts for every diameter and 3 repetitions foe each cultivar. From each cut, each sensor gave the force in N and length in seconds. The samples tested were collected in February and March 2010 during the pruning from 5 farms in Sicily, and from 3 farms in Lombardy Region in order to differentiate the area sampling. The vineyards observed and the farms from which they were taken are shown in table 1.

Table 1. Characteristics of observed vineyards

Cultivar	*Pl.year*	*Form pruning*	*Site*
Cabernet	2005	Spurred	Viagrande (CT)
Sauvignon A	2003	cordon	Torre de' Roveri (BG)
Cabernet		gdc	
Sauvignon B			
Chardonnay	1992	Guyot	Castiglione di Sicilia
Franconia	2001	Spurred	(CT)
Frappato	2002	cordon	Almenno S.Salvatore
		Spurred	(BG)
		cordon	Vittoria (RG)
Marzemino	2002	Spurred	Adro (BS)
Merlot A	2006	cordon	Viagrande (CT)
Merlot B	2000	Guyot	Torre dei Roveri (BG)
		Spurred	
		cordon	
Moscato di	1993	casarsa	Torre de' Roveri (BG)
Scanzo	1992	Spurred	Torre de' Roveri (BG)
Moscato giallo	2006	cordon	Linguaglossa (CT)
Nerello cappuccio	1984	Spurred	Castiglione di Sicilia
Nerello mascalese	2001	cordon	(CT)
Nero d'Avola		Spurred	Pachino (SR)
		cordon	
		Spurred	
		cordon	

Results

The samples collected in fields during pruning operations were tested with the sensorized scissors and then placed in an oven to measure moisture percentage (table 2).

Table 2. Moisture of samples

Cultivar from Sicily	*Moisture %*	*Cultivar from Lombardy*	*Moisture %*
Cabernet Sauvignon A	42,39	Cabernet Sauvignon B	48,73
Chardonnay	47,32	Franconia	40,60
Frappato	51,50	Marzemino	45,70
Merlot A	45,17	Merlot B	40,50
Nerello cappuccio	45,34	Moscato di Scanzo	45,43
Nerello mascalese	49,78	Moscato Giallo	47,11
Nero d'Avola	46,37		

Obtained results were processed using the software R for statistical variability to distribute data and to investigate the influence of independent variables considered. Were considered the factors cultivar (CV), branch diameter (DIA), date of sampling (DATA), region of the hand (FINGER), the repetition of the cut (RIP). Were investigated response variables related to maximum force implemented for each cut (FORZA) and the length of cut (TIME). The influence of these factors has been extracted, through the analysis of variance (ANOVA). As for the forced response variable, showed significant effects by the cultivar (CV), diameter (DIA) (Fig.1) and the region of the hand (FINGER) with a p-value less than 0.001. In Fig. 2 is a clear distribution of power between the regions of the hand (0: index, 1: medium, 2: ring finger, 3: region of the palm next to the thumb, 4: region of the palm distal to the thumb). Elaborations of the first order for the response variable DURATION, showed statistical significance for the factors cultivar (CV), branch diameter (DIA), with a p-value less than 0.001. Did not show significance for the factors repetition (RIP) and region of the hand (FINGER).

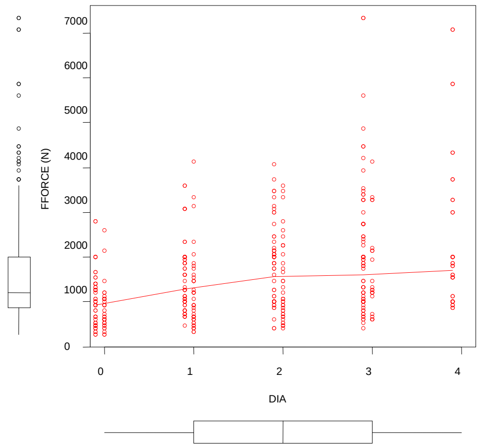


Fig. 1: Distribution of forces in the observed diameters

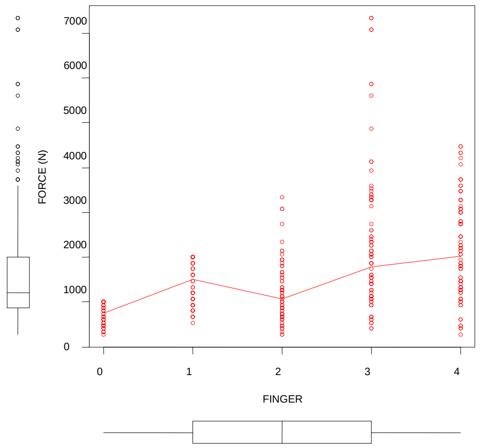


Fig. 2: Distribution of forces in the observed regions of the hand

Overall, tests gained an average strength of 14,03 N with a standard deviation of 5,50 and an average length of the cuts of 0,75 seconds with standard deviation of 0,47. Fig. 3 and fig. 4 show strengths and durations required in the cutting of branches.

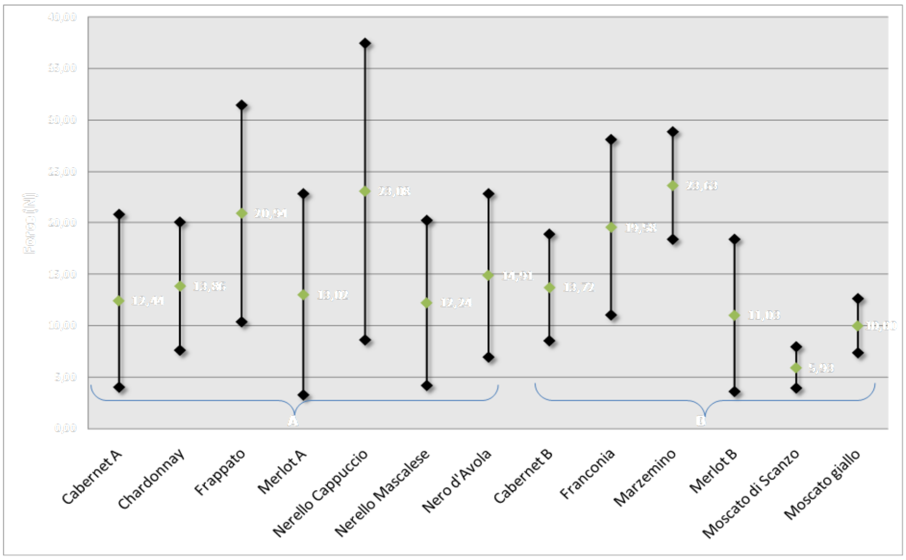


Fig.3: Mean force in studied cultivars (A= Sicily, B= Lombardy)

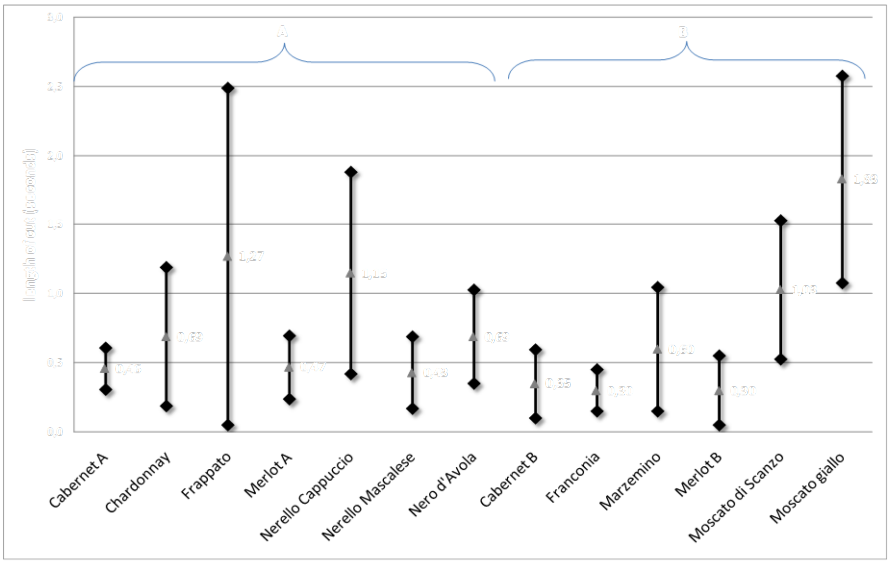


Fig.4: Mean of length of cuts (A= Sicily, B= Lombardy)

The cv that showed major forces during the cuts were Marzemino (23.63 ± 5.20) and Nerello Cappuccio (23.08 ± 14.42) while the minimum was from Moscato di Scanzo (5, 93 ± 1.99). Regarding the duration of the cut, the largest value was found for Moscato Giallo (1.83 ± 0.75) while the minimum was found for Franconia (0.3 ± 0.15) and Merlot (0.3 ± 0.25).

Conclusions and prospects

The aim of this study was to evaluate, through cuts made by scissors equipped with sensors, the forces exerted by different regions of the hand during cutting of branches from eleven cultivars during winter pruning of vines from two different region in Italy. The acquisition system has permitted to obtain values of maximum force and duration of the cut from five different regions of the hand. The statistical analysis of data has given the significance of the various factors in the study. Factors that showed influence on the force needed to make the cut were: different cultivars from the sample, the different regions of the hand, the diameters of the branches. This research suggests some considerations about the possible factors influencing repeated efforts during the operations of pruning that can be a support for studies on risks and skeletal muscle requires further confirmation by tests conducted on a larger number of cultivars and studies on optimization of the sensors on the scissors or on the hand.

References

Haapalainen M., Kivisto-Rahnasto, Mattila M. 2000. Ergonomic design of non-powered hand tools: An application of quality function deployment (QFD). Occupational Ergonomics 2(3) (1999/2000) 179–189

Paivinen M., Haapalainen M., Mattila M. 2000. Ergonomic design criteria for pruning shears. Occupational Ergonomics 2(3) (1999/2000) 163–177 163

Pezzi F., ADE G., Bordini F., Giunchi A., 2009. Evaluation of the cutting force on vine branches in winter pruning. J. of Ag. Eng. – Riv. Di Ing. Agr. (2009), 1, 33-36

Schillaci G., Balloni S., Rapisarda V., Romano E., Bonsignore R., Camillieri D. 2009. Valutazione del rischio da esposizione a movimenti ripetitivi degli arti superiori nella potatura manuale del vigneto. Atti del IX Convegno Nazionale dell'Associazione Italiana di ingegneria Agraria, Ischia Porto, 12-16 settembre 2009, mem. n.170

Wakula J., Beckmann T., Hett M., Landau K., 2000. Ergonomic analysis of grapevine pruning and wine harvesting to define work and hand tools design requirements. Occupational Ergonomics 2(3) (1999/2000) 151–161