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INDEX

TOPIC 1 "WMSDs"

TOPIC 2 "Machine Milking, Animal Welfare, Sustainable Livestock"

TOPIC 3 "Instrumentation, Equipment, Periodic Procedures and Tests"

TOPIC 4 "Noise, Vibration, Dust, Endotoxin, Microorganism "

TOPIC 7 "ROPS"

TOPIC 1
"WMSDs"

Agricultural Ergonomics Research and Outreach in California

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Abstract

Aims: The main aim of this paper is to give an overview of agricultural ergonomics research and outreach activities in California. Another aim is to introduce the California AgrAbility Program.

Methodology: A discussion about research publications on agricultural ergonomics is presented. In most countries, agriculture is recognized as one of the most hazardous industries, with musculoskeletal disorders (MSDs) being at the top of problems facing workers in labor-intensive agriculture. This talk gives an overview of the extent of MSDs in California agriculture, and a historical perspective on how ergonomics has been used to reduce the health effects of labor-intensive agriculture in California. The California AgrAbility Program is introduced and its main mission highlighted.

Results and Discussion: A summary of exposure to MSD physical risk factors within various classes of California crops is given. There are various administrative and engineering controls for abating MSDs in agriculture. These range from programmed rest breaks to mechanized or partially-mechanized operations. Worker-based approaches such as prone carts and platforms, and load transfer devices hold promise in combating the prevalent stooped work in agriculture. Although physical risk factors are major contributors to MSDs in agriculture, other psychosocial, organizational, cultural, and socio-economic factors could be important contributors to the development and prevention of these disorders. These factors may play a central role in the effective implementation and adoption of any intervention approach. Despite the advent progress in new technologies in agricultural practices, reliance on labor will always be a major cornerstone of agriculture for at least the foreseen future. An overview is given on how AgrAbility Programs in California and other US states have been assisting disable farmers and farm workers find solutions and other assistive technologies to maintain an active and productive work in agriculture.

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Keywords: MSDs, Ergonomics, AgrAbility, Labor-Intensive Agriculture

OWAS and REBA for the assessment of WMSDs in motor manual tree felling. Which is the best approach?

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Abstract

The risk to run into a Work-Related Musculoskeletal Disorder (WMSD) is very high when operating in the primary sector. As a matter of fact the number of professional illnesses related to the WMSD in Italy is high.

The study was carried out in the Autonomous Province of Bolzano (northeast of Italy), it consisted in the assessment of operator’s postures during felling operations, through the assignment of a WMSD’s index of exposure. This assessment was carried out with two different procedures: REBA and OWAS. A comparison of the results obtained from the two assessment tools was performed. In order to perform the assessment, every felling operation has been recorded with a digital camera, and it has been divided into three subtasks: pre-cutting operations, cutting operations and post-cutting operations. For each of them a frame capture every 10 second has been analysed.

The assessment of the OWAS and REBA’s score shows that the OWAS standard has a general tendency to assign a lower index to exposure in comparison to REBA. This is evident both for subtask operations and for the whole felling operation. Moreover, OWAS, due to its easier technique for the assessment has shown a greater capability to assess body posture also in not clear situation because the operator was partially hide by a tree or far from the camera.

In conclusion, from this study it is possible to determine that OWAS assessment is able to perform a faster and more precise and sensitive assessment than REBA.

Keywords: Body posture assessment, Forestry, Chainsaw, Cutting operations

Introduction

In occupational medicine the illnesses caused by any physical stress during the work period are cumulatively defined as Work Related Musculo-Skeletal Disorders (WMSDs) (Colombini et al. 2010). Several reasons might cause the arising of a WMSDs such as when joints are subjected to overloads for a long period of time, mechanical stress, vibrations, low temperatures, static muscle load and wrong body posture and when micro-traumas tend to reoccur in time (Colombini et al. 2010; Kee & Karwowski 2007; Zanuttini et al. 2005). All these causes are constantly present when working in forest environments (Calvo 2009; Ashby et al. 2001). Therefore the forestry work is considered one of the most physical works (Slappendel et al. 1993; Gallis 2006) and it is characterized by a high demand of physical efforts. For lumberjacks, these efforts are the principal cause of muscular stress (Zanuttini et al. 2005; Li & Buckle 1999). The muscular stress is mainly caused by the static muscular operations required for the control and use of a chainsaw (Slappendel et al. 1993). Indeed, during the felling tasks, the lumberjack must handle firmly the chainsaw in order to perform the cutting of the tree in the safest procedures. As a matter of fact, forestry-based work can be described by a series of tasks which force the operator to handle for long time a chainsaw which he drives with small and repetitive movements of the upper limbs while he maintains an uncomfortable and unstable body posture due to the environmental and logistics constraints. For all these reasons, the motor manually timber felling, is considered one of the heaviest, hardest, most uncomfortable and awkward jobs, which requires human strength (Gallis 2006; Gerasimov & Sokolov 2014). The operators employed in these tasks, together with the chokers setters (Gerasimov & Sokolov 2014), are the most affected by WMSDs (Gallis 2006).

In forest context the assessment of the body posture cannot be perform using dedicated sensors, because they can increase the risk of accidents as well as they limit the lumberjack's movements during the cutting. Therefore, the continuous monitoring with the use of instruments which permit the visual observation of the assessed person are techniques that are suitable to detect the level of discomfort due to the poor body posture assumed during working activities (Lasota 2013). Several visual techniques such as RULA (Rapid Upper-Limb Assessment), REBA (Rapid Entire Body Assessment), LUBA (Loading of the Upper Body Assessment), OCRA (Organizational Readiness to Change Assessment) and OWAS (Ovako Working Posture Analysis) are suggested in the literature for the body postural assessment (Li & Buckle 1999; David 2005; Lasota 2013). Among those, only REBA and OWAS assess the entire body (Karwowski & Marras 1998). Therefore those ergonomic tools will be tested for the WMSDs assessment during cutting operations, even if they have been developed for the ergonomic assessment in other sectors. While OWAS has been developed for the steel industry, REBA has been develop for health sector (Karhu et al. 1981; Hignett 1996; Hignett & McAtamney 2000; McAtamney & Hignett 2005; Zanuttini et al. 2005).

The goal of this research is to evaluate which is the best tool, between a low detailed assessment scoring system (OWAS) and a high detailed tool (REBA), to apply in the forest context in order to evaluate if the lumberjack works assuming good or poor body postures.

Material and methods

The study was carried out in the Autonomous Province of Bolzano (northeast of Italy), where the body postures assumed during 55 felling operations were assessed. The planned logging system foresee the use of a cable yarding, where the full tree system (FTS) is the logging system applied. This system consists in the harvesting of the entire tree via cable crane, without the processing of the branches and top. Sometimes could happen that the FTS is substituted by the cut-to-length logging system (CTL). At the contrary of the previous one, the operations of processing are performed in the felling area. Therefore, only the commercial assortment is exploited. Usually the CTL system is applied when is not possible to harvest the entire tree due to the overpassing of the payload of the logging system, or due to the difficulties encountered during the yarding as consequence of its big dimensions of the tree.

The ergonomic procedure consists in the assessment of operator's postures during the cutting operations, through the assignment of a WMSD's index of exposure. This assessment was carried out applying REBA and OWAS methods (Louhevaara et al. 1992; Hignett & McAtamney 2000). The methodology applied started with a video recording of each cutting thanks to the use of a GoPro® 3+. This camera was chosen because thanks to its 170° of wide-angle capture, the visibility of the entire operator's body at close distance was ensured. During each videotaping, the camera was placed in the lateral side with respect to the operator with a suitable angle that permitted the vision of his entire body. Therefore, the placement of the camera was very important in order to perform an accurate assessment. During the post-processing phases, thanks to the use of KINOVEA® software, every videos was divided in three main operations:

1. Pre-cutting operations: from when the operator starts to evaluate the felling direction and the presence of obstacles, to when the operator, gripped the turned on chainsaw, – lays the bar on the trunk;
2. Cutting: from when the operator lays the bar on the stump, to when the cut tree falls on the ground;
3. Post-cutting operations: from when the tree is completely laying on the ground, to when the operator moves to reach another tree. Stump grinding and cutting to length, if occurred, are considered in this operative phase.

For each one a frame capture every 10 seconds was taken using always the same software. These same pictures sets have been used for both REBA and OWAS assessments, in order to obtain the exposure index.

For the assessment of the REBA and OWAS score, the procedures already explained in literature have been followed (Karhu et al. 1981; Hignett 1996; Karwowski & Marras 1998; Li & Buckle 1999; Hignett & McAtamney 2000; McAtamney & Hignett 2005; Zanuttini et al. 2005; Jones & Kumar 2007). Both assessment are based on the visual evaluation of the body postures assumed by the subject during the tasks. OWAS and REBA are characterized to have a low detailed and high detailed assessment approach respectively due to the number of parameters assessed and the method of evaluation. The REBA method assesses both upper limbs separately and also because REBA evaluates 16 parameters against the 4 evaluated by OWAS method. While the OWAS performs a comparison among the postures assumed by the operator with predefined references, the REBA measures the angles that the joints assume during the work relatively to the neutral angles in resting position. For each parameter assessed, a score was defined. Thanks to the use of dedicated multi-entry tables and an equation, the calculation of the risk exposure can be performed. Anyhow the two system use two different scales of indexes, from those is possible to obtained the so called Action Class (AC), a scale which describes the urgency of an intervention in order to reduce the risk of WMSDs. While OWAS evaluates the AC from 1 to 4, REBA evaluates the AC from 1 to 5. Therefore, it is necessary an adaptation of the two methods in order to make a comparison between them. At this regards in specific literature (Kee & Karwowski 2007) are present works were in the REBA method the action classes 2 and 3 are clustered together in order to obtain a scale with 4 indexes (Table 1).

Table 1. Reclassification of the REBA scores according to OWAS.

Action classes	Scores		Risk level	Intervention required
	OWAS	REBA		
AC1	1	1	Negligible (1)	None necessary
AC2	2	2→7	Moderate (2)	May be necessary
AC3	3	8→10	High (3)	Necessary soon
AC4	4	11→15	Very high (4)	Necessary now

In the figure 1 the procedure followed during the study is summarized.

Figure 1. Description of the methodology followed during the research. The approach starts with the videotaping, than all the videos are divided into the main tasks (pre-cutting, cutting, post-cutting) and a capture frame with 10 seconds of interval was taken. Finally, each picture is assessed with OWAS and REBA tools respectively in order to have the final exposure index of the task.

Results

During the study about 10 hours of surveys were performed, where 55 felling operations have been recorded. For one of the recorded video the assessment was not possible due to a corruption of the video. From a first analysis of the videos, it appeared that for the 6% and 11% of the times the lumberjack did not perform the pre-cutting and/or the post-cutting operations respectively. This happened because some operations of pre-cutting or post-cutting were not necessary. In these cases, the operator, with the chainsaw turned on, starts the cutting as soon as he reaches the plant; otherwise the operator turns the equipment off and he moves to the next tree when the tree drops on the ground. Anyhow, the ergonomic assessment has been based on the evaluation of 852 body postures, divided in 142 pre-cutting, 549 cutting and 161 post-cutting respectively. Despite the care taken in the camera positioning not all the captures were assessable, due to a not easy detection of the parameters. Indeed, the operator moved around the tree to perform the cutting operations or due to his moving away from the camera in order to perform the CTL processing (Figure 2).

From this first consideration it is possible notice how the OWAS method, compared to REBA, has a greater capability to assess the cutting operations. Indeed the OWAS assessment, characterized to have a low detailed approach, is capable to assess body posture even if the target is partially covered by an obstacle (Figure 3). Therefore the OWAS tool permit to assign the scores in an easy way if compared with REBA.

Considering the three main tasks a comparison between them, considering the two ergonomics methods, was performed and it was reported in table 2. In the table 2 the results obtained considering the distributions of frequencies for each action class, recorded for each operative task, were reported.

Regarding REBA, slight differences were detected between the distributions about the action classes frequency for the two body sides. This happened as consequence of a different position of the upper limbs. In fact, sometimes happen that during the cutting the left shoulder and the left arm were raised or abducted, while the left wrist was bended to allow a firm gripping of the front handle of the chainsaw.

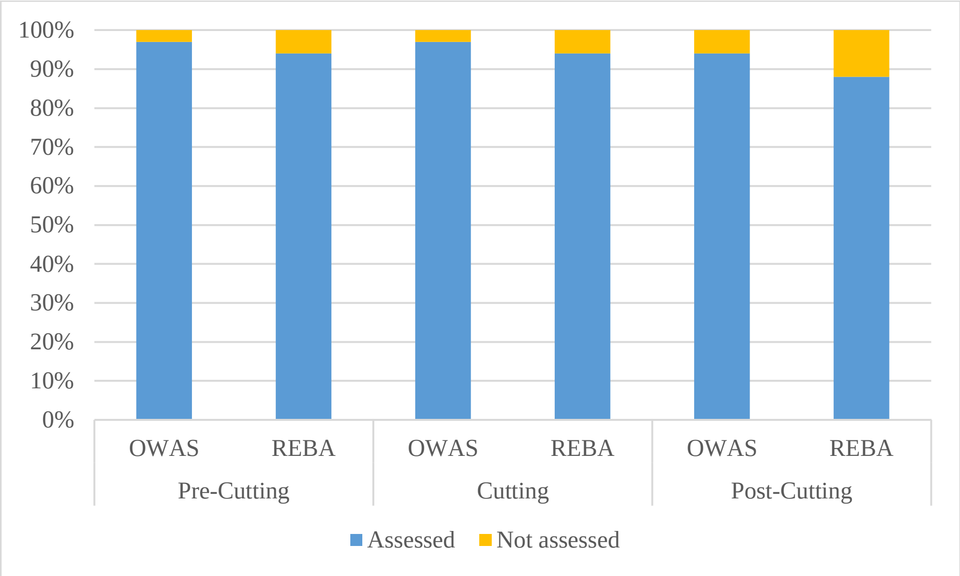

Figure 2. Distribution of the assessed and not assessed capture frames for OWAS and REBA methods respectively considering the three main operative tasks.

Figure 3. Examples of the body posture that must be assess. The picture on the left side is assessable by both methods, while the picture in the middle is not assessable, because the operator is coverade by the tree. The picture on the right is assessable only by OWAS, because the parameters necessary for REBA are not identifiable.

Table 2. Distribution of action category for the two ergonomic tools, in this only the assessable picture were considered.

		Action class			
		AC1	AC2	AC3	AC4
Pre-cutting	OWAS	33%	39%	22%	0%
	REBA (R)	0%	67%	26%	0%
	REBA (L)	2%	67%	24%	0%
Cutting	OWAS	4%	22%	70%	4%
	REBA (R)	0%	4%	91%	6%
	REBA (L)	0%	0%	91%	9%
Post-cutting	OWAS	31%	35%	22%	0%
	REBA (R)	4%	57%	28%	0%
	REBA (L)	4%	48%	37%	0%

Anyhow any statistical differences ($p<0,05$) were detected between the sample from the right body side and the left one. Therefore, the upper limbs have the same weight on the final assessment of the risk exposure, even if they perform different movements. When the results obtained for both methods are compared it is possible to assess that OWAS method has the tendency to assigns scores lower then REBA (Figure 4). Considering the index exposure assessed for the different tasks, both methods evaluate the cutting operations as the most dangerous even if with different levels. The evaluation of the index of exposure for the pre-cutting and post-cutting operations have shown to have the same results if the same assessment tool is used. The cutting operation is resulted to be the more dangerous than the pre-cutting and post-cutting operations because the operator assumed a posture where he had both legs bent, or he was kneeling, with bent and twisted back. These body postures are assessed with high level of risk exposure by both assessment tool. Indeed, considering the scale of the action classes (Table 1) the 70% and 91% of the cutting task, respectively for OWAS and REBA assessment, require a soon intervention in order to reduce the risk to run into a WMSD. Considering the pre-cutting and post-cutting tasks it is necessary to investigate more in deep which are the causes of the moderate risk exposure.

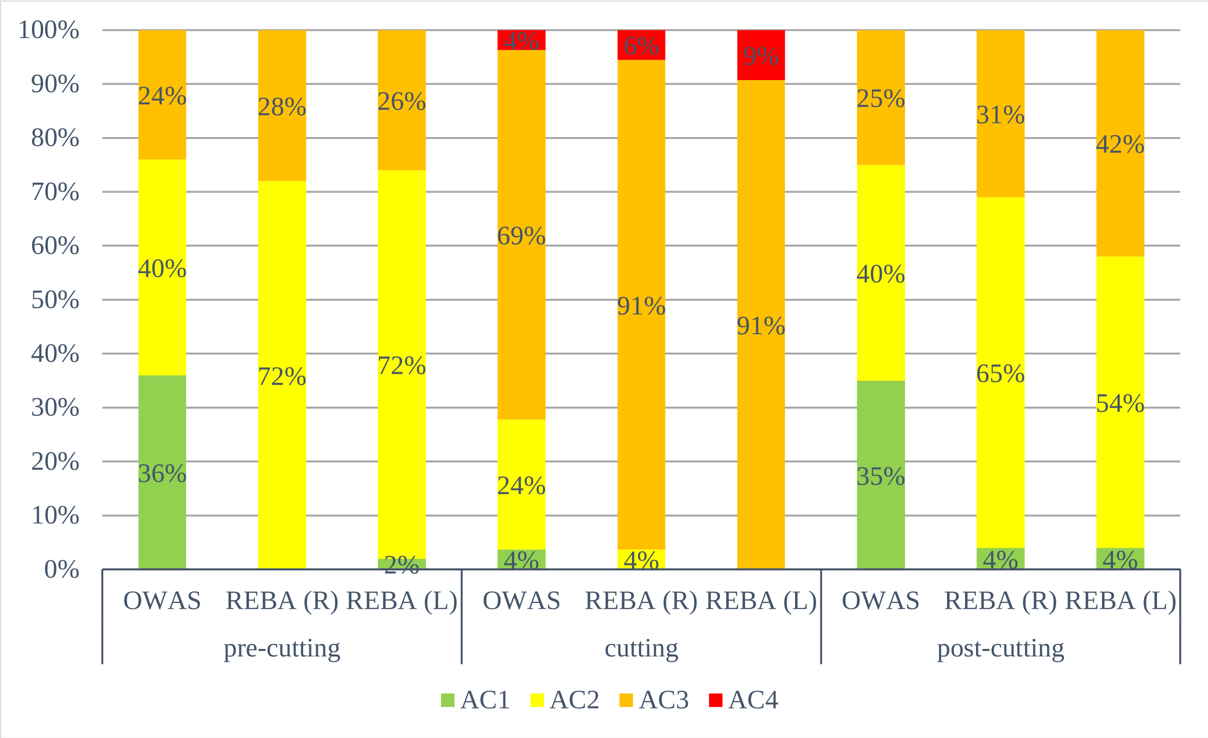

Figure 4. Distribution of the action level in relation to the main tasks.

Conclusion

Thanks to this research, it was possible to assess the body posture assumed by a lumberjack during felling operation, using two ergonomic tools: the OWAS and REBA. Considering the results obtained both methods have shown a good capability and reliability in the WMSDs assessment. In fact, the two methods have assessed 97% and 93% of the recorded pictures. The REBA tool assessed less body posture because the tool requires a high number of parameters, which sometimes are not detectable or they are detectable with difficult. For instance when the operator is covered by an obstacle or when it is too far from the camera. Besides this, the amount of details required by the REBA assessment cause the introduction of subjectivity, uncertainty, and errors in the final assessment. This happens mainly when a parameter is not easily identifiable. Another aspect that influenced the number of the assessable pictures was the absence of a zoom in the camera. The camera employed has been very powerful for the film recording at close range, but it has shown to have limitations when the subject was distant. As matter of fact, during the post-processing the details of his body postures were not properly assessable due to the bad resolution of those pictures where the lumberjack was far from the camera.

In conclusion, it is possible to affirm that OWAS has shown the best characteristics than REBA to be used for the body posture assessment during motor manually felling, in forest environment. OWAS has demonstrated to be a faster, less biased tool due to the fewer parameters required and their easier assessment compared to REBA. Moreover, OWAS has shown a more flexible application being able to assess the subject even if partially hidden behind a visual obstacle, such as a tree. Thanks to these characteristics, the OWAS methods can be used to perform an assessment in real time. Since OWAS was developed for different purpose (steel industry), it does not take into account several body postures typically and frequently assumed in forest operations, as well as the characteristics of the operation (such as vibrations or shocks or instable ground) which could be implemented in the approach. In the next step of the research an implementation of the traditional OWAS was taken into account in order to develop a tool more appropriate for the ergonomic assessment in forestry environment.

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Study of posture during plowing operations. Analysis of the pressures to the seat

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Abstract

With reference to the suspension system, the seats on the market are at the moment basically divided into three groups: mechanical, pneumatic suspended and active/semiactive seats. Since the end of the ‘60 studies on operator comfort to the tractor showed that the operation of the suspension of the seat is influenced not only by the design of the same, but also by the posture and dynamic behaviour of the driver. Many studies have been developed on the characterization of the stresses for the operator evaluating vibrations in different conditions, in agreement with the European Directives for the approval of seats. Interviews were conducted in the industry, which showed limb disorders whose cause could be related to the pressure against the seat.
It will be studied the interaction between the body and the seat of two operators recording the pressure values of 31 points in which were placed pressure sensors having a diameter of 100 mm². The recording of the data will be during the operations of plowing a field previously planted with corn. It will be recorded the pressure values in the two directions of plowing, alternately with the right and left wheel within the groove.
Processing of the data will allow the evaluation of the effect of stress on the seat to the two operators during plowing operations. Through geostatistical analysis will be realized a map could shows the barometric distribution of peaks. These maps could suggest the critical areas in which the body of the operator is affected by the higher stresses. The preparation of such maps, suggesting the critical areas in which the body undergoes the greatest stresses, can be a step for integration to the reading of the vibrations in the objective evaluation of the comfort of the seat.

Keywords: Comfort, Barometric maps, Agricultural tractor.

Introduction

Since the second half of twentieth century the agricultural machinery industry have realized that is necessary a system that can reduce strains to operator during his work-time. (Scarlett et Al., 2007). Seat has a very important role to reach this goal because it is the component of the strains transmission chain in intimate contact with the operator. Nowadays, in the market there are two main kind of seats: seats with mechanical suspension and seats with pneumatic suspension. In the first kind the elastic element is constituted by compression or tension springs, torsion bars or elastomer. The other kind of seat uses an air cushion to replace the spring function. There is also a new generation of seat that uses an active system of suspension that can reduce strains on operator reacting actively to excursion. Since the end of ’60 studies on operator comfort to the tractor showed as the suspension functioning is influenced not only by the design of the seat but also by the posture and dynamic behavior of the driver (Suggs et al. 1969). Several studies on strains to operator have been developed evaluating the vibration (Gomez-Gil J. et al. 2014) in different conditions of work. Other works were conducted, under the comfort of the seats of the cars, observing the pressure of the body on the seat (Gyi et al. 1998/99; Kyung et al 2008).These studies are made following the indications of European Directive about seats approval (Directive 78/764/CEE, revised by

83/190 and 88/465). The aim of this work is to study a system of investigation of the seat based primarily on the pressure exerted by the body of the operator on the surfaces of the seat and in particular if a system of pressure sensors could be able to differentiate different test conditions.

Methods

It has been studied the interaction between the body of operator and the seat. The study was conducted placing 31 pressure sensors on the contact area between seat and driver. The sensors are made by Tekscan (model WELF-system) and they have an area of 1 cm^2, on which they record the peak value of pressure with a frequency of 10 recordings per second.

It was used, in all test conditions, a pneumatic seat with adjustable sitting, backrest and headrest. The seat was mounted on a tractor with suspension on front axle and on cab, but these suspension have been kept off during the test to maximize the stresses on the seat.

The research was conducted with two operator with similar Body Mass Index (BMI) 23.7 ± 0.7 but with different experience to drive tractors.

The test protocol provided the recording of pressure value during a ploughing operation. Ploughing was made with an average depth of 0,30 m, on a field previously planted with corn.

The experimental plan provided to collect pressure values on the two directions, alternately with the left and right wheel within the furrow. Three replicates were performed.

Data was elaborated with geostatistical criteria using the software Surfer. This statistical elaboration permitted to observe the distribution of the stresses through maps of interpolated values.

Results

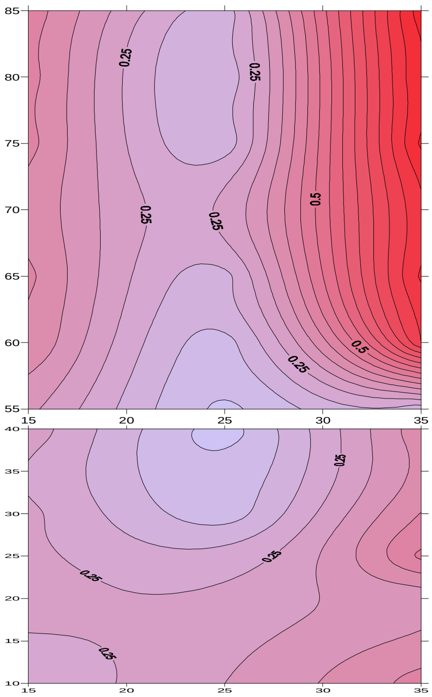
The data collected by the sensors 31 have resulted, through use of geostatistical software, maps of pressure distribution of the body on the seat. Figure 1-4 shows the map of the distributions of the beginner operator when the tractor is tilted to the right and figure y describes the same condition conducted by the experienced operator.

The peak values recorded in the contact area was 0,120 kg cm^{-2}, found on the right shoulder of the expert operator and the mean value obtained during the course was of 0,0282, collected looking backward, and 0,0473 looking forward. At the sitting the maximum values found was 0,045 for the beginner and 0,047for the expert.

In the course conducted with the tractor tilted to the left, the maximum values in the sitting was 0,045 and average was 0,0296 for the beginner and for the expert was, respectively 0,047 and 0,0199.

The results obtained from processing of the pressure data show how the worst working condition happens, in the case of an experienced operator, when the tractor works with the right side within the furrow. In this case in fact, the expert operator in addition to having the center of gravity shifted to the right due to the inclination of the tractor continuously rotates to the right the trunk to control the operations of plowing.

Figure 1. Beginner operator, tractor on a slope to the right



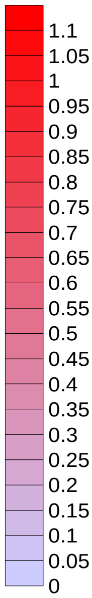


Figure 2. Expert operator, tractor on a slope to the right

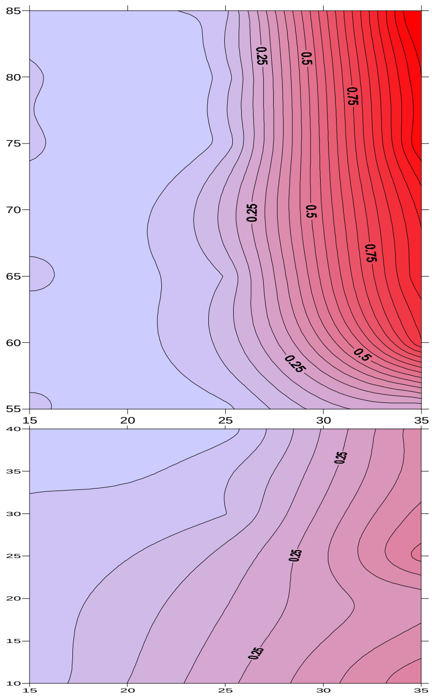


Figure 3. Beginner operator, tractor on a slope to the left

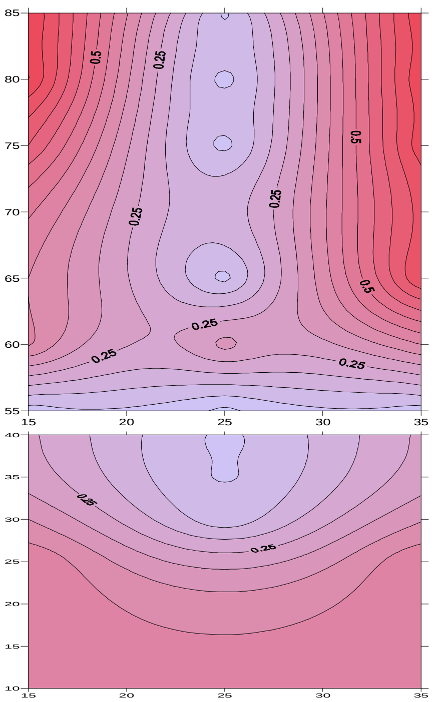
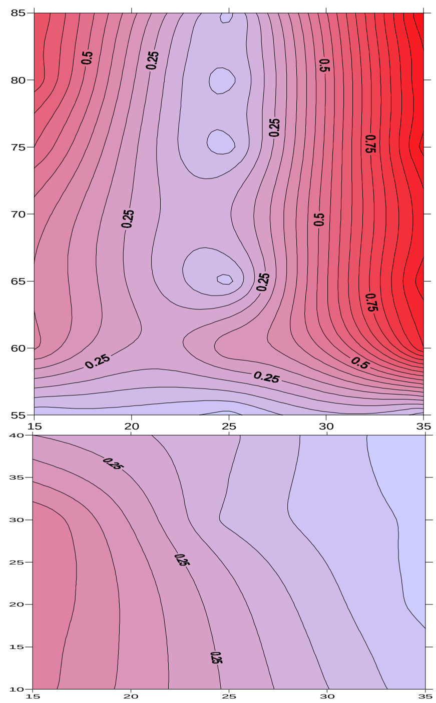


Figure 4. Expert operator, tractor on a slope to the left



Conclusions

This study of the pressures to the seat on the sitting and on the backrest of a tractor seat during ploughing operations have allowed to observe the distribution of the stresses through maps of interpolated values. The preparation of such maps, suggesting the critical areas in which the body undergoes the greatest stresses, may represent a step for integration to reading the vibrations in the objective evaluation of the comfort of the seat. The different experience of the operators has affected their posture: the first operator having little experience in plowing, drove with attentive look forward. The second operator, with well-founded experience in plowing, worked often with trunk reclined backwards in order to observe the behavior of the plough for the success of plowing. So the results of this study showed a heavy working condition, especially for expert operator that has been shown to use a posture with an effect more stressful the right shoulder. We should also consider that the experienced operator stays on tractor for an average time of 8 hour per day. So it is opportune make further studies about this topic, in order to evaluate other kind to working condition and to provide objective data to industry aimed at manufacture of more comfortable seats.

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A review of recent studies on the risk assessment from repetitive movements in agriculture

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Introduction

The aim of this paper is to carry out a review about recent studies concerning risks coming from repetitive movements in some agricultural activities (WMSDs, Work related Muscoloskeletal Disorders). In agriculture, as in other sectors, the ergonomic studies take into account numerous factors such as the interactions man - machine (hardware ergonomics), the interactions man-environment (environmental ergonomics), the interactions man-organization. Over the years, the aims of ergonomics have gradually changed moving from improving the working conditions to the most complete idea of improving the efficiency of the production system.

Agricultural mechanization involves work organization, safety and wellness aspects, human resources, and also machinery, equipment and materials utilized, as well as the characteristics of the workplace; consequently, we can consider agricultural mechanization as a sort of meeting point between rural activities and ergonomics.

As concerns agricultural activities, Ergonomics deals with the dimensional and functional design of the jobs, taking in account techniques and work time (working shifts, working hours), the analysis of posture, of the movements and the physical demands.

In Italy, risk assessment for biomechanical overload of the upper limbs due to repetitive movements is performed using the OCRA method (Occupational Repetitive Actions). The OCRA method, which has been updated and modified over the years, it is recommended by ISO 11228/3, EN 1005-5, and its application is mandatory in Italy in the assessment of such risks (Art. 28 D. Lgs. 81/08). The OCRA method on one hand involves a highly detailed description of the work process and on the other makes possible to summarize the data derived from the analyses and to present a global vision of the work. The force is usually estimated by means of the Borg CR10 scale, which is used to evaluate the subjective perception of the strain level involved from the work.

Studies presented in the paper involve viticulture, tomato growing, nurseries in greenhouses, She – ass milking. Involved aspects are the influence of the frequency concerning manual operations, the strength concerning the various part of the hand measured by instrumented scissors specifically assembled.

Manual Pruning in Vineyards

Vineyard winter pruning is still carried out manually even when preceded by mechanized pre-pruning. Although facilitating equipment is becoming more widespread, traditional manual secateurs and long handled shears remain the most often utilized tools.

During manual pruning cuts follow on from one another regularly and rapidly, particularly when the pruning is preceded by a pre-pruning machine. Manual operations, which is characterized by high frequency and a stereotypic load on the upper limbs, can in time put the muscular skeletal system at risk and cause WMSDs.

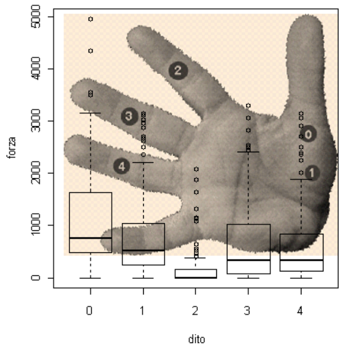
Preliminary studies were carried out by observing some agricultural jobs with the aim of enhancing risks indicators (repetitiveness, frequency, posture, strength), if they were. The results obtained led to focus on the level of risk due to repetitive movements of the upper limbs and trials were consequentially conducted. They involved most cultivars and the risk evaluation was conducted using the method OCRA.

So, seven vineyards sited in eastern Sicily were preliminarily studied, involving 30 workers and 12 hours of observation for each , 5 vine species (*Nerello mascalese, Nero d'Avola, Nerello cappuccio, Chardonnay, Merlot*) and 3 vine training systems (goblet cultivation, spurred cordon cultivation, guyot cultivation).

Vine species	vine training systems	Tool	Score Ocra Index	Risk
Nero d'Avola	Spurred cordon cultivation	Secateurs	5,56	**medium**
Nerello Cappuccio	Spurred cordon cultivation	Secateurs	6,22	**medium**
Nerello Mascalese	Spurred cordon cultivation	Long handled shears	5,52	**medium**
Nerello Mascalese	Sapling	Secateurs	5,55	**medium**
Nerello Mascalese	Sapling	Secateurs	4,92	**medium**
Merlot	Guyot cultivation	Secateurs	4,12	**borderline**
Chardonnay	Guyot cultivation	Secateurs	6,11	**medium**

The results have highlighted the presence of musculo - skeletal diseases factors related to manual pruning in viticulture. In addition, they led to investigate some aspects related to methodology OCRA. In particular, the experimental study involved two risk factors of primary importance, such as the strength and frequency.

As regards the strength, an instrumented scissor with sensors able to detect the stresses exerted by the hand during the cutting vine shoots has been developed in collaboration with the CRA-ING (Treviglio, Milan-EN) and utilized in laboratory. In according to the goals, the tool has proven useful to detect the stresses exerted by the different parts of the hand.

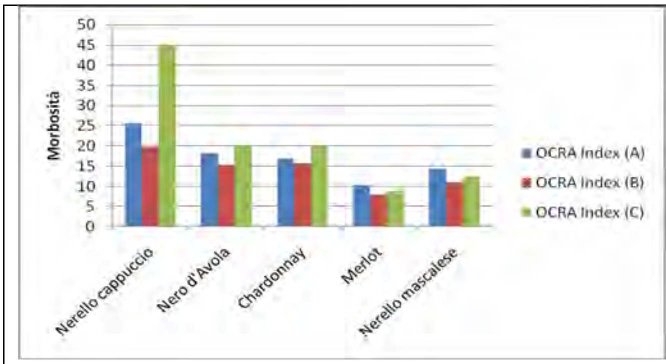


In parallel, a panel of operators was interviewed to verify the correspondence of the data provided by the scissors with the subjective evaluations of strength provided from each of the operators according to the Borg CR10 scale normally used for these kind of researches.

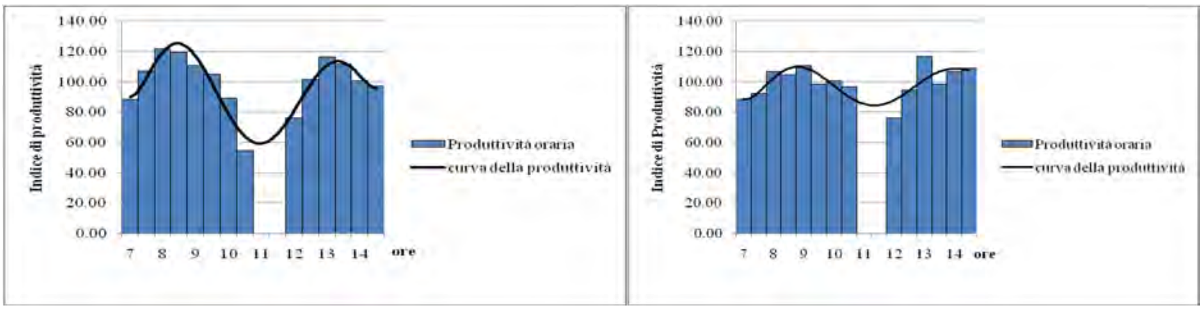
First of all, the instrument was able to reproduce measures consistent with the experimental plan; then, the interviews have allowed us to validate the instrument or, in other words, allowed us to correlate the values, obtained by the instrumented scissors, with the evaluations coming from the operators during the cutting operations.

The average values of the force derived from scissors tests, both those related to the entire hand and those concerning on the most stressed region of the hand, were converted in scores on the Borg scale using the procedure suggested by EN 1005-3.

The results of some simulations, conducted using those average values, confirm that during the cutting operation performed with common scissors some regions of the hand are more stressed than others. The methodology and the instrumentation used were able to highlight this phenomenon.

	(A) scores coming from workers during the interviews; (B) scores obtained from the average strenght exerted from the whole hand; (C) scores obtained from the average strenght exerted from the most stressed area of the hand;

Trials enhance the cutting frequency changes during the day, but by drawing a curve fairly regular and characterized by two peaks and a minimum before the lunch, that is very similar to the variability showed in manual citrus harvesting. It means that surveys about frequency have to be carry out along the whole day if we don’t want understimate or overstimate the connected risks.



Tying the tomatoes in greenhouse

Growing vegetables in greenhouse obliges to perform the operations manually with risks due to in manual handling of loads and repetitive movements. Greenhouse tomato growing involves specific cultivation operations, such as green pruning, tying the plants and distribution of pesticides and fertilizers, manual harvest. Although they do not require particular effort, they involve repetitive movements of the upper limbs and often they induce the operator to assume incorrect postures.

The preliminary survey has revealed the presence of indicators of muscle - skeletal risks, such as the repetitiveness and the high frequency of the movements. They led it to investigate in particular the binding operations and the tomato topping. The investigations involved tying the plants on vertical support wires, and green pruning that can be done at the same time. 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.

The risk assessment was conducted by OCRA index, showing a value of 4.1, and proving that operations commonly performed in greenhouses can lead to the employee a medium risk of exposure to biomechanical overload.

Tying the tomatoes

First evaluation of the risk from repetitive movements in greenhouse nurseries: annual cycle and multitask analysis

The aim of this study was to develop an appropriate methodology in the field of musculoskeletal risk in horticultural greenhouse nurseries. This study was the starting point of a national work group made up of doctors and experts in the field of work organization, whose aim is to put together simplified methods (database, software) permitting the monitoring and management of biomechanical overloading risk in such complex situations as cultivation in protected environments.

Measurements were carried out in different nurseries located in eastern Sicily. The first part of the work consisted of the identification of the main sectors and tasks characterizing the activities in the (plant) nursery. The measurements were conducted using the technique of breaking the work into its elementary phases. The tasks were later filmed. Subsequently, the use of the OCRA checklist made it possible to assess the postural requirement (shoulder, elbow, wrist, hand) for each task and to quantify the biomechanical overloading of the upper limbs.

There are several activities in the nurseries where there is a risk of biomechanical overload due to repetitive movements of upper limbs and the manual movement of loads. The observations confirmed that nursery activities show a considerable risk and should be considered throughout the annual cycle.



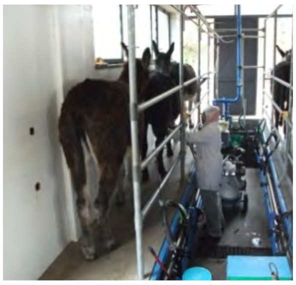
Manual sowing “operator seated”			Transplanting			Spraying		
Checklist OCRA	DX	20	Checklist OCRA	DX	14	Checklist OCRA	DX	16
	SX	20		SX	14		SX	4

Assesment of ergonomics studies concerning she-ass milking

In the farms in eastern Sicily the milking is either carried out manually or by means of a milking machine designed for sheep and goats but with some modifications made by adapting the type of milking liners.

As already demonstrated by research on cows milking is an activity characterized by repetitive movements, which in time can cause musculoskeletal stress. If the milker is at the same level as the cows, the back is bent and the trunk must bend for the udders to be reached; if the milker is in the milking pit the muscoloskeletal risk is mainly to the upper limbs. Workers involved in the care of animals are subject to musculoskeletal disorders because of their work.

Recent applications of the Ocra method have concerned the risks deriving from repetitive upper limb movements of the workers during the milking of she-asses, given the demand for she-asses milk is increasing because of its recognized anti-allergic qualities. The evaluation was carried out in three typical farms situated in Sicily, through the analysis of the positions taken by the milker, of the times of the work phases and the subsequent processing of the checklist OCRA.



Farm 1

Farm 2

Farm 3

	Heads	**In lactation**	**Type of milking**		**Duration**	**Checklist Score**
Farm 1	80	18 – 20	A trolley milking machine	A milking parlour with milking pit	30 min	7.50 (dx)
Farm 2	70	12 – 14	A bucket milking machine	A milking parlour	30 min	5.75 (sx) 2.25 (dx)
Farm 3	40	8 – 10	Manual milking	Outdoor	40 min	16,25 (sx) 18,50 (dx)

The research shows that in she-asses farming workers are exposed to musculoskeletal risks due to repetitive movements and incorrect postures. Those equipped with a milking parlour with pit parlour show the same problems observed in cow farming, but the small number of head per farm makes small the connected health problems. More than 8 -10 heads shouldn't be manually milked but only by a bucket machine. As concerns the case studied, great part of the inconvenient (maintaining grip and incorrect postures) are due to the use of cluster not suitable for she- ass, but for sheep and goats. A simulation has shown that, in the meantime, breeders with milking parlour with pit parlour and trolley machine can reach number of heads able to increase net profits (around 50 – 55 heads in lactation) maintain low the biomechanical overload risks.

Conclusion

In the agricultural sector, the WMSDs risk evaluation was hampered by many factors: the lack of attention by the employers in the evaluation of risk, the lack of sensibility against the ergonomics specifically concerning workstations. Moreover, there are some general difficulties in the application of the methods (OCRA and or another) in open field that, as is well known, it's a very different environment from industry and manufacturing.

In addition, season factors influences the risk and the exposure of workers to biomechanical overloading depending on the task carried out; moreover, the risk varies for the same task according to intensity and duration. For the assessment of the risk should be considered throughout the annual cycle.

Instrumented scissors allow to recognize the strength exerted on different parts of the hand. The strength intensity reported by the instrument was correlated to the strength evaluation coming from a group of people and when necessary it can be converted in the Borg CR10 scale normally used for these kind of researches. Physicians could now utilize the measured strength intensity exerted in different parts of the hand with the aim to foresee the development of disabilities involving workers' arm and hand.

Results obtained from surveys on vine cutting frequency suggest that the daily curve that represents the cuts per min has to be identify correctly, otherwise the risk could be wrongly evaluated.

Obtained results highlight how is important a multi-disciplinary approach, putting together the competences coming from agricultural mechanization (that includes work organisation), ergonomics and occupational medicine.

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TOPIC 2

"Machine Milking, Animal Welfare, Sustainable Livestock"

Ergonomic issues and musculoskeletal disorders among ewe dairy workers involved in mechanical milking

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Introduction

In comparison to the traditional practice of hand milking, the use of mechanical milking equipment has considerably improved worker comfort and work efficiency of milking operations on sheep farms. Nearly 50% of Italian dairy sheep are located on the island of Sardinia, where 3.2 million head are raised on approximately 12,700 farms. Over the past 20 years, the industrialization of sheep husbandry has led to a marked increase in average herd size per farm (from 121 to 250 head) and to a large increase in milking mechanization.

Milking operations are mainly performed in parlor milking systems (82% of farms, average 275 head/farm), while bucket and trolley systems are used in small herds with less than 190 head. The parlor design is usually parallel based on a single or double stanchion row mounted along a milking pit where the worker operates. As an alternative, the stalls can be assembled on an elevated platform, either static or movable, thus enabling the worker to operate at the same level of the parlor. Among the low milk line systems, the parlor type with 24 stalls and 12 milking units (2 stalls/unit) is the most common configuration, while the type with 24 stalls and 6 milking units (4 stalls/unit) is the prevalent choice in high milkline installations. Considering the short milk emission period of the Sardinian ewe, one operator can usually manage about 6-8 milking units without incurring the risk of udder overmilking.

Although mechanization has reduced the physical load imposed on the workers, some studies have reported an association between the cow milking tasks and symptoms of musculoskeletal disorders (MSD) in the upper extremities and back (Nevala-Puranen et al., 1996; Stal et al. 2001; Douphrate et al., 2009; Kolstrup et al. 2012). Several studies suggest that MSD risk factors are mainly associated to the physical work environment in relation to the worker's anthropometrics (Stal et al. 2003; Jakob et al. 2012; Cokburn et al., 2015). Most of the scientific literature refers to dairy cow milking operations, while only limited information is available on ergonomics of sheep milking parlor systems (Pazzona, 1985; Billon, 2005; Berger 2001). The purpose of our study was to investigate the ergonomic design of ewe milking parlors and the prevalence of MSD symptoms among ewe dairy workers.

Methods

The study involved 30 ewe dairy farms and 36 workers (33 males, 3 females). General farm data, design of milking parlors and dimensions of the workplace were recorded, as well as detailed information about work organization and milking routines. Anthropometric and demographic data were collected on all participants. Information about health status, individual perception of the physical workload and symptoms of MSD in different body areas were recorded using a modified version of the general standardized Nordic questionnaire administered by interview.

Results

The herd size of the investigated farms ranged between 200 and 1850 total heads, with an average of 450 lactating ewes per farm (Table. 1). The number of operators varied from 1 to 5 per milking installation, with an individual workload of 50 to 450 ewes per worker per shift.

Table 1. Farm and milking parlour characteristics

	Mean	*Range*		*Mean*	*Range*
Herd size (head/farm)	634	200-1850	Parlor Milking systems (n)	26	-
Herd size (ewes/farm)	450	100-1500	Stalls (n)	42	24-48
Farm land (hectares)	123.3	30-430	Milking units (n)	12,4	6-24
Workers (n/farm)	2.1	1-5	Ewes/Milking units	3.9	2-4
Workload (ewes/worker)	231	50-450	Milking units/worker	7	2.4-16

Milking operations were performed mainly in parlors (26 over 30 installations) by low milk-line (14) and high-line (13) systems. The most common parlor configuration was 2x24 stalls with an average of 12 milking units (4 stalls/unit). Each worker managed typically 7 milking units, without any automatic cluster removers. In 5 cases this number was greater than 12 units/worker. This value imposes a very fast work routine to avoid the risk of incurring in overmilking after the milk emission time (50-60 seconds). This means also a high number of the operator's movements along the stall rows to promptly remove the milking unit and reattach it to the adjacent ewe.

Figure 1. Milking operation in a swing-over high milkline system

In 22 over 27 parlors' the operators performed their work inside a milking pit, while in the other five they were standing in front of an elevated platform. Bucket milking systems, which force the operator to milk in a squat body posture, were used in only 4 farms. Work place dimensions varied largely among the farms: the mean pit depth was 92 cm, ranging from 78 to 110 cm. The pit width, which is important when two or more operators are simultaneously involved in the milking routine, was too narrow in three cases.

Anthropometrics of the operators that participated in the study (36 of 62) are shown in Table 2. Average male worker age was 44±10.4 years and the range of work history in dairy was 20-30 years. Body mass indexes indicated workers were generally overweight with 12 meeting a case definition of obese (BMI>30), which could increase the risk of MSD.

The physical design of the milking parlor was in many cases inconsistent with the anthropometrics of workers, especially for the women. Considering the neutral position corresponding to the waist height, it resulted that for about 30% of workers the pit was too high, and in three cases too low.

Average duration of farmer's workday was about 10 hours, but ranged between 12-16 hours in more than 30% of farms. During the lactation period (typically November through July) 42% of the worker's time was dedicated to milking tasks. Milking was performed twice a day, requiring on average 2.5 hours per shift including accessory operations. Longer milking sessions, more than 6 hours per day, were found in 7 farms with high numbers of ewes per worker. More than half of the workers perceived the milking task as "light" work in comparison to other farm operations as haymaking, soil tillage and animal care.

Table 2. Anthropometric data of dairy workers

	Male *(N=33)*		***Female*** *(N= 3)*	
	Mean	***Range***	***Mean***	***Range***
Age (years)	44	26-63	40	35-47
Height (cm)	171	186-158	157	152-165
Weight (kg)	85	60-110	65	52-72
BMI (kg/m^2)	28	22-40	26	22-30
Shoulder height (cm)	142	130-154	130	125-138
Waist height (cm)	108	90-123	108	101-121
Arm lenght (cm)	62	40-71	55	52-59

During the last year, 6 workers suffered work accidents in operations other than milking. Among all 36 operators that participated in the study, 27 reported MSD symptoms located in several regions of the body and 9 of them have been out from work at least one day for this reason. Pain was located mainly in the upper back (44% of workers), shoulder (17%) and neck (17%), upper (28%) and lower (22%) extremities. Five operators said of suffering a continuous wrist pain.

When the workers were asked to specify which factors contributed the most to their physical discomfort, they indicated principally: working in awkward positions, maintaining the same posture for long periods, working in cold/hot/humid environment, handling and lifting heavy objects. Critical points were also considered the lack of pauses during the workday and the necessity of working even when suffering physical pain.

Conclusions

This study investigated the work environment and the health among milking operators in dairy sheep farms. The findings reinforce the importance of the ergonomic design of dairy processes and milking parlor work areas to guarantee efficient and safe agricultural production methods.

Acknowledgments
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Manual Milking Ewes and the Risk of Carpal Tunnel Syndrome

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Introduction

The region of Sardinia, Italy is known internationally for the production of cheeses made from ewe's milk. Although most developed countries utilize automated milking equipment in ewe and cow dairies, the ancient task of manual milking is still performed in some countries and geographical locations (Kouyoumdjian and Machado de Araujo, 2006; Kutluhan et al., 2009). In Sardinia, Italy, manual milking of ewes is still performed on approximately 50% of ewe dairy farms. Both economic and cultural constraints have limited the adoption of modern dairy equipment by Sardinian ewe farmers. Automated milking equipment has been installed in 5,800 of the nearly 12,800 Sardinian ewe dairies. However, it is estimated that only 5,000 of the milking machines are currently in use The under utilization of automated milking equipment is primarily due the raise in milk production costs, which has driven the smaller farms to reduce energy and material expenditures. Additionally, ewe farmers have had to increase their flock size to stay competitive. Larger flocks result in longer periods of manual (hand) milking (Figures 1 & 2). Manual milking is a task that has been characterized as "a natural model for occupational carpal tunnel syndrome (CTS)" (Kouyoumdjian and Machado de Araujo, 2006). The purpose of this descriptive study was to evaluate the prevalence of CTS among Italian ewe farmers that manually milk sheep and compare them to a sample of cow dairy farmers that use mechanical milking equipment.

Methods

A random sample of 109 ewe farmers that manually milked was chosen from three regions in the north central part of Sardinia. Additionally a random sample of 75 cow dairy farmers that used mechanical milking equipment was chosen from two milk cooperatives also in the area near Sassari. Thus, the two groups came from similar social and territorial contexts. Demographics, hand symptoms, and electrophysiologic studies were obtained on 76 ewe farmers (70% response rate) and 56 cow farmers (75% response rate). A combination of hand symptoms and electrophysiologic studies were used in the case definition of CTS.

Interviews were conducted with both groups to determine age, height, weight, duration of time working in sheep / milk production activities, and a brief medical history checklist of systemic diseases (diabetes, rheumatoid arthritis, and hypothyroidism) that have been associated with CTS. The interviewers also addressed the presence of hand symptoms commonly associated with CTS. Participants were asked to indicate if they had any hand numbness, tingling, pain or burning within the past two weeks and instructed to rate hand symptoms on a 0-10 scale and describe the location of symptoms on a hand diagram. The hand diagram used in the present study was similar to other tools to assist in the evaluation of hand symptoms for the classification of CTS (Patil et al., 2012; Rosecrance et al., 2002; Anton et al., 2002). Hands were classified as having characteristic CTS symptoms if participants rated their symptom intensity at least 2 on the 0-10 scale and had numbness or tingling localized in two or more fingers corresponding to median nerve distribution. The CTS symptom classification was similar those employed in other epidemiological studies of CTS (Armstrong et al., 2008; Patil et al., 2012; Rempel et al., 1998; Silverstein et al., 2010; Werner et al., 2005).

Electrophysiologic studies or the medial and ulnar nerves were performed on both hands of each participant. Nerve studies were conducted using the Cadwell Sierra II Wedge nerve conduction equipment (Cadwell Laboratories, Inc, Kennewick, Washington, USA). Electrophysiologic studies were based on the recommendations by the American Association of Neuromuscular and Electrodiagnostic Medicine (Jablecki et al., 2002).

Figure 1. Ewe farmer milking sheep by hand sitting at the rear of the animal.

Results

Average age of ewe farmers was 47.3 (SD 13.2) years and for the cow farmers 38.5 (SD 11.1) years. The ewe farmers had a history of ewe work for a mean of 29.1 years (SD 15.6) while the cow farmers were slightly less experienced with a mean number of years worked with cows at 22.7 (SD 12.8). The mean number of hours worked per day for all farmers was 9.11 (SD 1.9).

Forty-two of the 76 ewe farmers (55.3%) fit the case definition of CTS in at least one hand whereas 9 of the 56 (16.1%) of the cow farmers fit a case definition of CTS in at least one hand (OR 2.34 (95% C.I. 1.23-4.46)). All of the participating farmers continued to perform their regular dairy tasks despite having a case definition of CTS.

Figure 2. Ewe farmer milking sheep by hand standing over the animal. Note the hand milking of the ewe udder and teats.

Conclusions

The prevalence of CTS among the participating ewe farmers is among the highest occupation rates of this disorder for any type of work. Carpal tunnel syndrome is a significant occupational health issue for ewe farmers that continue the traditional methods of manual milking. Interestingly, the ewe farmers continued to perform their daily work despite the presence of CTS. The recent trend in automated ewe milking machines may help reduce the prevalence of CTS among the next generation of Italian ewe farmers. It is also interesting to note the relatively high (16%) prevalence of CTS among the cow dairy workers. The cow dairy farmers conducted a wide variety of tasks around the dairy including milking parlor activities involving intensive upper limb motions (Figure 3). Patil et al., (2012) compared 66 milking parlor workers with 58 non-parlor workers in large US dairies. Using similar methods, the researchers reported a prevalence of CTS among the dairy parlor workers of 16.6% and 3.6% among non-parlor dairy workers. Thus, the prevalence of CTS among the cow farmers in the present study was consistent with US dairy workers conduction milking activities.

Figure 3. Milking activity (attaching milking cluster to teats) in mechanized cow dairy.

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TOPIC 3

“Instrumentation, Equipment, Periodic Procedures and Tests”

A laboratory test bench to analyse nozzle sprays

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Abstract
Aim of this study is to propose a low cost laboratory test bench, suitably designed to analyse nozzle sprays according to the procedure described in ISO 5682-1. It consists of a transportable trolley carrying a tank, a two diaphragms pump driven by an electric motor, and a spray boom carrying one multiple nozzle holder. The spray boom may move, under the control of a DC motor, along two slides placed above the working plane of the trolley. Acceleration and deceleration ramps may be imposed by the speed controller. According to the procedure described in ISO 5682-1, the test liquid is sprayed above Petri dishes placed on the working plane and containing silicon oil: analysing the images of the drops captured inside the oil, it is possible to measure the spray drop diameters and then all the spray features. The image acquisition system is under development.
Moreover, the test bench will be used to correlate spray features to water sensitive paper (WSP) images. Spraying at the same time Petri dishes and WSPs, the image of drops inside Petri dishes will be correlated to images on WSPs, so allowing the calculation of unitary deposits from WSP.
Finally, the tests bench will be used to experimentally validate a model describing the WSP behaviour when sprayed with drops of assigned drop size distribution and volume median diameter. In this paper WSP images were produced by simulation, assuming some simplifying hypotheses: spherical drops and circular stains randomly placed on the images. Three types of spray were simulated (Fine, Medium and Coarse) with two drop size distributions (log-normal and Rosin-Rammler). The simulations showed that the unitary deposit can be derived from the measured percentage of covered surface on the WSP images, but the knowledge of the volume median diameter of the drops is necessary, independently of the probability distribution function of drop size.

Keywords: Pesticide Application, Image Analysis, Drop Pulverisation

Introduction
Spray deposit and superficial coverage are two of the main factors influencing the biological efficacy of a pesticide treatment as well as the environmental hazards. The correct deposit ensures the lethal dose on the target, while the coverage, for non systemic products, increases the probability of contact between pest and pesticide. Both aspects are influenced by many other factors, among which one of the most important is the spray spectrum (Hewitt, 1997; Matthews, 2004; Nuyttens *et al*., 2007). The ideal spectrum maximises spray efficiency as ensures the transfer of the required dose to the target and minimises off-target losses due to drift and run-off (Hewitt *et al*., 1998).

There are many drop size analysers available on the market nowadays, mostly based on optical imaging, laser diffraction, and phase doppler. Each analyser is best suited for specific types of testing; moreover, measurement techniques, type of drop size analyser, optical configuration, sampling methods, data analysis, and reporting techniques, all have a strong influence on the results, so that it is virtually impossible to compare data from different instruments without a clear understanding of the test conditions and methodology (Schick, 2008).

In this paper a low cost laboratory test bench is presented. It allows nozzle spray characterisation according to the procedure described in ISO 5682-1. Moreover, the test bench will be used to correlate the spray features (drop diameter population, coefficient of variation, volume median diameter, arithmetic mean diameter of drops) with data extracted from water sensitive paper images (superficial coverage, particle density). If the correlations will be statistically significant, the WSP image analysis will make it possible both to measure the unitary deposit and to characterise the sprays issuing from nozzles.

Finally, continuing the studies on the simulation of the WSP behaviour at varying spray features and superficial coverage (Cerruto *et al*., 2013), in this paper further results are presented regarding two drop size distributions (log-normal and Rosin-Rammler) and three types of spray (Fine, Medium and Coarse). The test bench will be used to validate the model and to confirm the results deriving from the simulations.

The laboratory test bench

The test bench under design consists of a transportable trolley with one working plane, carrying a 70 L tank, a two diaphragms pump "Annovi Reverberi AR 30 SP" with maximum flow rate of 36 L min^{-1} at pressure of 40 bar, driven by a 2.2 kW electric motor, and a spray boom carrying one multiple nozzle holder. This type of pump was chosen to be comparable with those installed in agricultural sprayers. Tank, motor and pump are positioned on the base of the trolley, near to the ground. The spray boom is applied to a mobile support that moves along two slides placed above and parallel to the working plane of the trolley, at a distance of about 0.5 m. The movement of the spray boom is realised by using anti-slip toothed belts connected to an axle powered by means of a DC motor with a speed controller. Maximum speed is about 1 m s^{-1}; acceleration and deceleration ramps may be imposed by the speed controller. A schematic view of the device is reported in Figure 1.

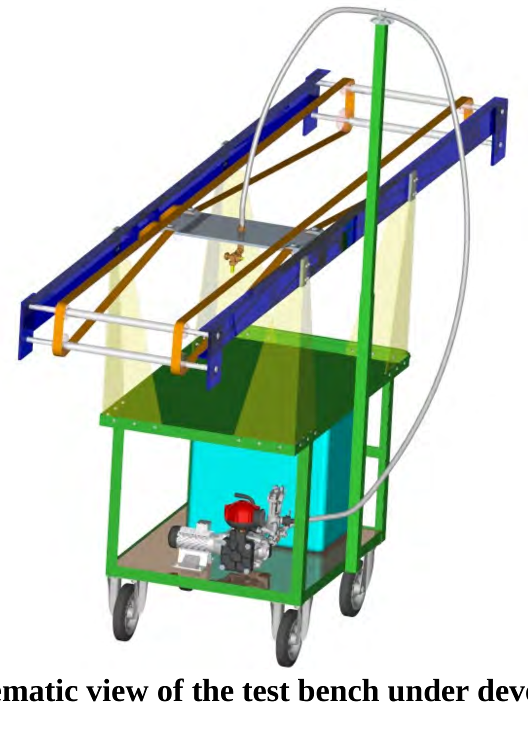

Figure 1. Schematic view of the test bench under development.

Following the procedure described in ISO 5682-1, the test liquid, a mixture with coloured dye tracer, will be sprayed above Petri dishes containing silicon oil of suitable viscosity placed on the working plane. The images of the drops captured inside the silicon oil will be acquired by means of a video system, at present under development, and will be analysed by means of an image processing software. The drop analysis will make it possible to measure all the spray features (probability distribution function of drop size PDF, volume median diameter VMD, arithmetic mean diameter AMD, coefficient of variation CV), as well as the calculation of the unitary deposit d_n (μL cm^{-2}). All data will be correlated with nozzle type and working parameters.

Placing water sensitive papers beside the Petri dishes, the data deriving from the analysis of their images will be correlated with those deriving from the analysis of the drops inside the Petri dishes: if the correlations will be statistically significant, the WSP image analysis will make it possible both to measure the unitary deposit and to characterise the sprays issuing from nozzles. Spraying in the same manner natural targets (fruits or leaves), it will be possible to correlate the unitary deposit on their surface, evaluated following well known procedures (Pascuzzi and Cerruto, 2015), to spray features and images of WSPs.

Finally, comparing effective and simulated water sensitive paper images, the test bench will allow the validation of the model (or will suggest appropriate corrections) and the assessment of the results obtained from the simulations.

Water sensitive paper simulation

WSP images were simulated using two drop diameter probability distribution functions, log-normal and Rosin-Rammler, widely used for describing drop pulverisation (Babinsky and Sojka, 2002; Schick, 2008). The PDF of the number of drops are:

Log-normal: $$f_0(D) = \frac{1}{\sqrt{2\pi}\,\sigma D} e^{-\frac{(\ln D - \ln \mu)^2}{2\sigma^2}}; \qquad (1)$$

Rosin-Rammler: $$f_0(D) = \frac{k D^{k-4}}{\lambda^{k-3}\Gamma\left(1-\frac{3}{k}\right)} e^{-\left(\frac{D}{\lambda}\right)^k}, \qquad (2)$$

being D the drop diameter and $\Gamma(x)$ the gamma function. The scale (σ and λ) and location (μ and k) parameters are analytically correlated to CV, AMD and VMD of the drop diameters.

For each PDF three spray types were simulated, classified as Fine, Medium and Coarse (Hewitt *et al*., 1998). They were obtained by changing the scale and location parameters of the two PDFs. The values chosen for the simulations are reported in Table 1.

Images of water sensitive papers (2 cm × 7 cm) were produced by simulation with a resolution of 1200 dpi, randomly allocating the stains, circular shaped. Given the drop diameter D (μm), the corresponding stain diameter D_s (μm) was calculated by using the Equation 3 (QInstruments):

$$D_s = 0.938 \cdot D^{1.143} \qquad (3)$$

These simulated WSP images were treated as effective WSP images and then they were analysed by means of an image processing software, the *ImageJ* (Abramoff *et al*., 2004). All data provided by the *ImageJ* were correlated with the reference ones used to produce the images so to analyse their trend at varying spray and image features. In this study the possibility of assessing the unitary spray deposition (μL cm^{-2}) at varying superficial coverage on WSP images and spray features was exploited.

All simulations, statistical analyses and graphical representations were carried out by using the R software (R Development Core Team, 2012).

Table 1. Parameters used for the simulations of the sprays

			Rosin-Rammler			Log-normal		
Spray type	VMD (μm)	CV (%)	AMD (μm)	*k*	λ (μm)	AMD (μm)	μ (μm)	σ
	141	70	70	3.874	155	52	43	0.631
Fine	160	80	70	3.702	177	46	36	0.703
	181	90	70	3.576	201	41	31	0.770
	261	70	130	3.874	287	96	79	0.631
Medium	296	80	130	3.702	327	86	67	0.703
	334	90	130	3.576	370	76	56	0.770
	362	70	180	3.874	398	134	109	0.631
Coarse	410	80	180	3.702	453	119	93	0.703
	466	90	180	3.576	516	106	79	0.770

Results and discussion

The reference percentage of covered surface S^* (%), fixed without considering overlaps between stains, and that S_m (%) provided by *ImageJ*, measured with overlaps, were related as reported in Figure 2.

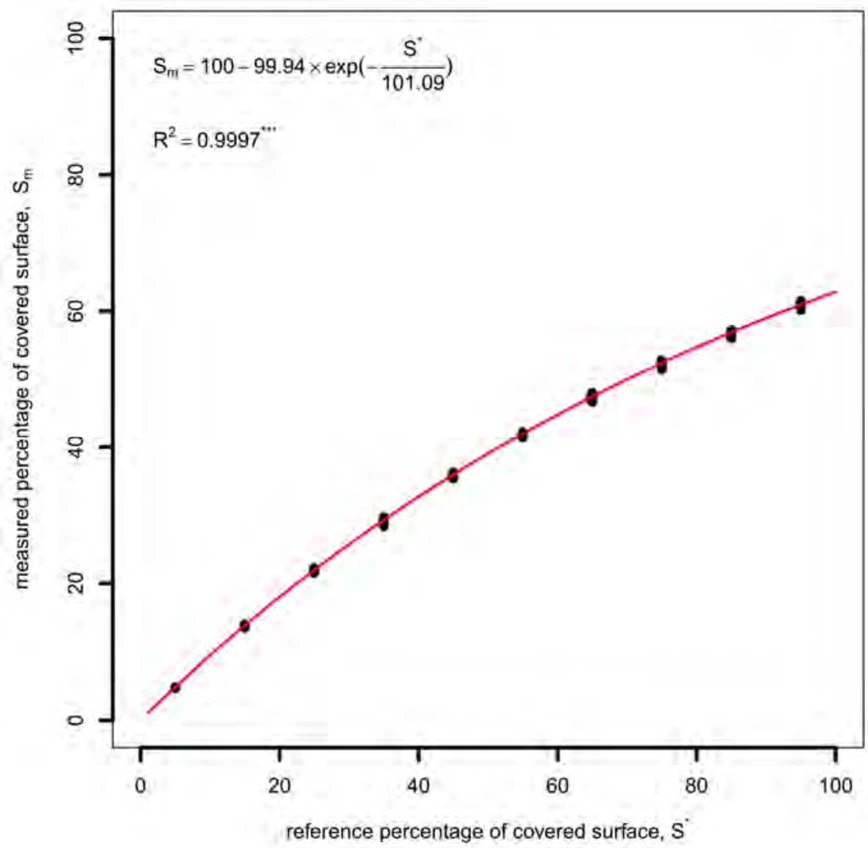

Figure 2. Correlation between reference S^* and measured S_m percentage of covered surface.

The correlation between S^* (%) and S_m (%) was described by Equation (4), independently of spray features:

$$S_m = 100 - 99.94 \cdot e^{-\frac{S^*}{101.09}} \tag{4}$$

This result confirms those of previous researches (Cerruto and Aglieco, 2013; Cerruto *et al.*, 2013), obtained considering sprays with log-normal PDF only. Probably it is independent of spray features, but could be affected by other factors (circularity of the stains, for example) that will be investigated in further researches. According to the Equation (4), the measured percentage of covered surface increases exponentially towards 100% when the reference one tends to infinity. This means that high values of percentage of covered surface are obtained with very high overlaps between stains.

The unitary spray deposit was related to the superficial coverage as reported in Figure 3 at varying spray type, PDF and CV of drop diameters. The graph shows that the spray deposit is primarily affected by spray type, then by CV and finally by PDF.

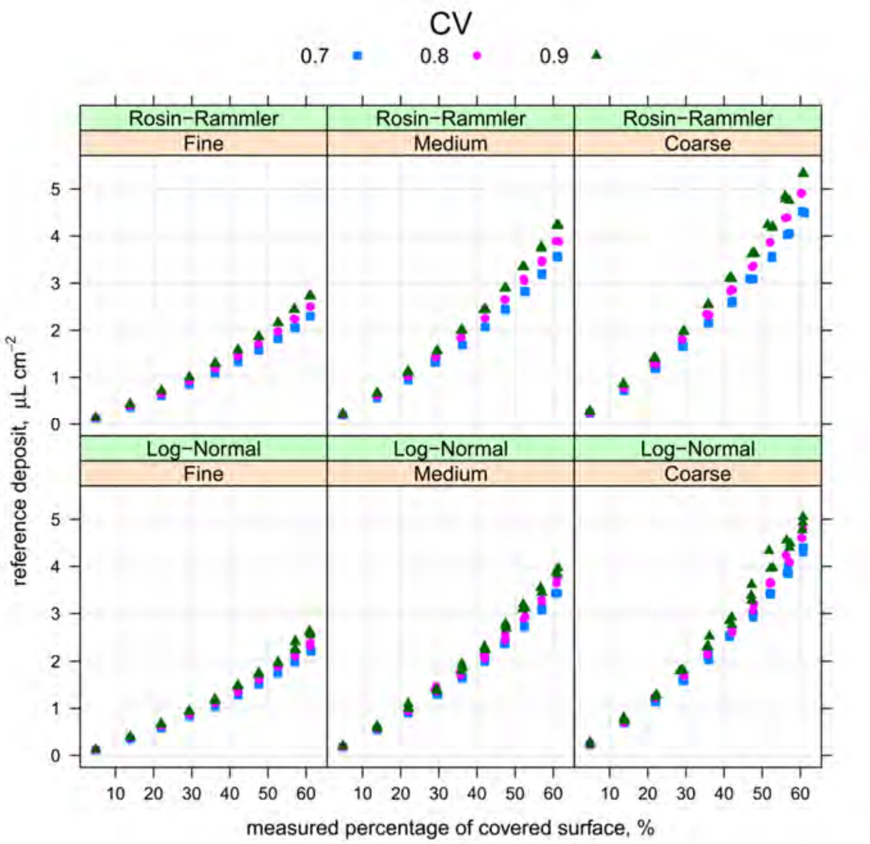

Figure 3. Correlation between unitary spray deposit and measured percentage of covered surface at varying spray type, CV and PDF.

Fixing spray type, CV and PDF, the trends of unitary deposit vs. superficial coverage were well explained by quadratic relations, with coefficients of determination ranging from 0.9949 up to 0.9996, highly significant. This result confirms the possibility of calculating the unitary spray deposit by known spray features and percentage of covered surface on WSP images.

Making explicit the effect of spray type in terms of volume median diameter VMD, the graph of Figure 4 was obtained. As expected, it shows a strong effect of VMD and a negligible effect of PDF.

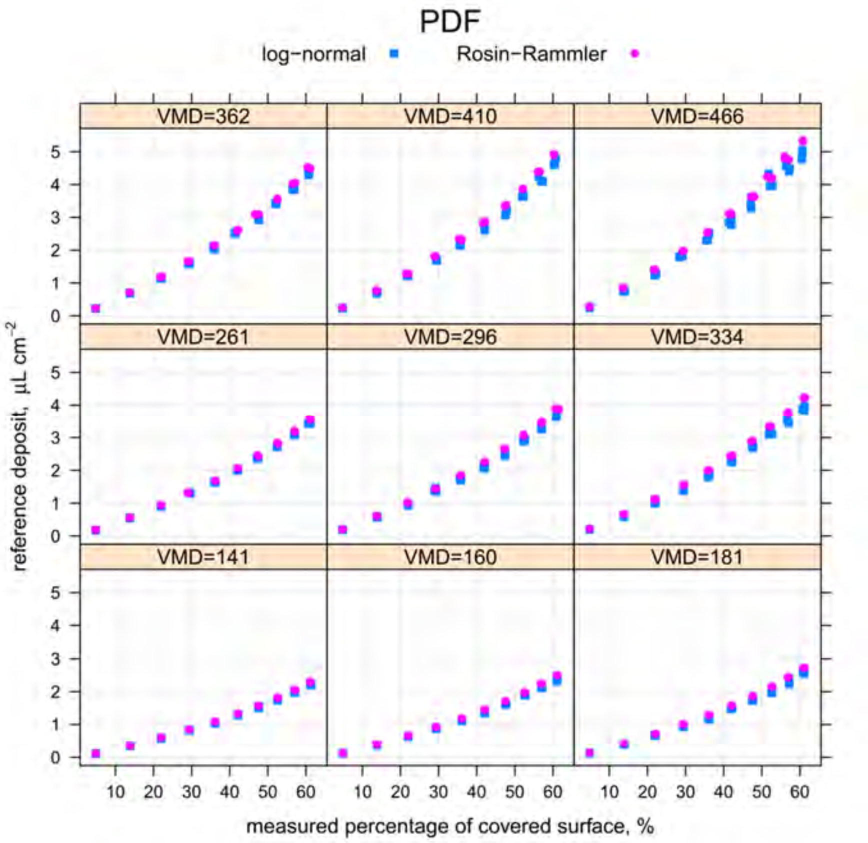

Figure 4. Correlation between unitary spray deposit and measured percentage of covered surface at varying volume median diameter VMD and PDF.

Taking into account only the volume median diameter VMD (µm) and using a multiple regression approach, the unitary deposit $\hat{d}_n$ (µL cm^{-2}) can be calculated according to the Equation 5:

$$\hat{d}_n = 10^{-6}[12770 + 8169 \cdot S_m + 124.7 \cdot S_m^2 + \mathrm{VMD} \cdot (189.7 + 72.26 \cdot S_m + 1.242 \cdot S_m^2)] \tag{5}$$

The regression equation had determination coefficient R^2 equal to 0.9952, highly significant. The relative error between reference d_n^* and computed $\hat{d}_n$ unitary deposit, calculated according to Equation 6:

$$e = \frac{d_n^* - \hat{d}_n}{d_n^*}, \tag{6}$$

ranged from -23% up to 8%. The highest relative errors were detected estimating low unitary deposits (less than 0.05 µL cm^{-2}), whereas in other cases the error was less than 10% (Figure 5). A better estimation can be obtained by including in Equation 5 the effect of PDF.

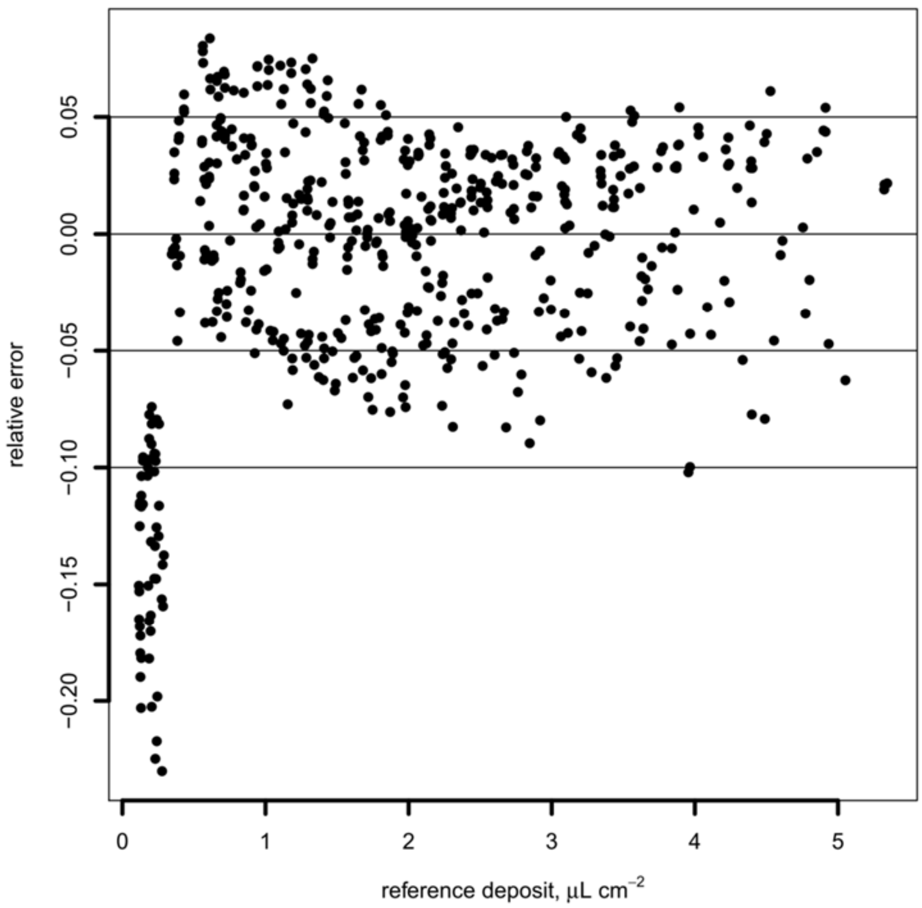

Figure 5. Relative error on unitary spray deposit when computed by using Equation (5).

Conclusions

The results of this research provided some important hints for further developments of the study. In particular:

- Reference and measured percentage of covered surface on water sensitive paper images were related by a simple relation (Equation 4), independently of the spray features. This allows a quick estimate of the overlap between stains by measuring the percentage of covered surface, the easiest parameter to measure during the analysis of WSPs.
- The spray unitary deposit can be estimated from the percentage of covered surface, but the knowledge of the spray features is necessary (spray type and CV of drop diameters). As a first approach, the unitary deposit was estimated, with a relative error in most cases less than 10%, knowing the volume median diameter only (Equation 5).
- The test bench under development should be suitable to validate (or suggest corrections to) the model used to simulate the behaviour of water sensitive papers. When it will be completed and available for experimental activities, it will be possible to correlate the data extracted from the WSP analysis (superficial coverage) to spray features and unitary deposit on natural targets, parameters strictly correlated to the efficacy of a pesticide application.

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Evaluation of pump-over thermal effect during red grapes fermentation: preliminary results

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Abstract

In oenology, pump-over is a mechanical technique used to enhance the fermentative maceration. Pump-overs are conducted, with or without air contact, by taking the must from the bottom of the fermentation tank, and using it to spray the cap. The aim of this practice is the enhancing the phenolic and volatile compounds extraction from grape skins. Consequently, wine quality is improved in this way.

During some temperature monitoring tests a "secondary" effect of pump-over has been highlighted. Temperature affects volatile and phenolic compounds concentration too. Particularly, low temperatures may be used to improve volatile production by yeasts during fermentation, and regulate the extraction of polyphenols compounds from the solid to the liquid phase.

The aim of the work is to describe the thermal effect of pump-overs with and without air contact during a red fermentation.

Tests have been performed during the September 2014 Tenuta Argentiera (Bolgheri (LI), Italy) in a tank of 20 m3 capacity. Six probes were placed into the fermentation tank, for temperature monitoring in different zones during pump-overs.

Both kinds of pump-overs produce two main effects during fermentation: a temperature homogenization, reducing the differences among the zones of the tank, and a cooling effect, reducing the average temperature of the must. Hence, in addition to their effect on compounds extraction, pump-overs could be useful to reduce and control the temperature during red fermentation.

Keywords: Quality, Temperature, Wine.

Introduction

During alcoholic fermentation of red grape berries for wine production an ascending flux of carbon dioxide is produced. Gas bubbles carry up the solid parts (i.e. grape skins) to the liquid-air inter-phase, arranging the marc cap. The cap releases to the must compounds important for wine quality such as anthocianyns and tannins. Furthermore, it contains a large number of yeasts: about 150-200 $*10^6$ colony forming units per ml, while on the bottom of the tank this numbers is reduced 3 times (Riberau-Gayon et al., 2004).

In order to improve the extraction process from the marc cap some methods of different nature have been developed. Among these the most common are physical (maceration length, temperature, carbon dioxide pressure), chemical (sulphur dioxide addition), biochemical (maceration enzymes), and mechanical (pump-overs, delestage, and cap punchings) (Bosso et al., 2009).

In pump-overs the juice is drawn from the base of the fermentor and pumped to the top. Then it is sprayed onto the skin cap. Depending on the desired level of juice air exposure, pump overs could be done in closed conditions (almost without air contact), open conditions (must is splashed in a vat before its reintroduction in the fermentor), or with an in-line Venturi (Moenne et al., 2014). Pump-overs promote color and flavor extraction, incorporate oxygen into the must, and homogenize sugar and yeast concentration as well as temperature (Riberau-Gayon et al., 2004). Furthermore, some wineries use pump-overs for juice cooling. In this case the must passes trough an heat exchanger during the operation (Boulton et al., 1996).

In literature, there are few works focusing on the effects of pump-overs on wine temperature. In 1951, Ribereau-Gayon and co-workers demonstrate that pump-overs could decrease the fermentation time, by increasing the temperature through the increase of yeasts activity. Boulton and co-workers (1996), on the other hand, focused on the temperature homogenization provided by pump-overs. Furthermore, Boulton et al. (1996) describe a procedure to remove the fermentation metabolic heat during a pump-over. Particularly, the juice cooling is obtained by passing it trough an external heat exchanger before its re-insertion into the tank. Despite the importance of the fermentation temperature, in literature, a detailed picture of the effect of pump-overs on the thermal homogenization, and the removal of metabolic heat is not provided.

Materials and Methods

Test were carried out during the vintage (September and October) 2014 at Tenuta Argentiera (Castagneto Carducci (LI), Italy). The experimental tank had 200 Hl of nominal capacity, and was provided with an automatic pump-overs with a hydraulic pump controlled by an electronic control panel. Furthermore, the tank was equipped with two heating/cooling jacket: the first was arranged from the bottom (0 cm) to 60 cm height, and the second from 130 cm to 190 cm height. The tank's internal diameter was 2.9 m and the steel thickness was 1 cm. Two poles were put into the tank, bringing 3 temperature probes each (WatchDog DataLogger, Spectrum, US). The first pole was put at 60 cm height, and the second pole at 124 cm height. The probes was put at 20 cm from each borders, and in the middle of the pole. The temperature acquisition frequency was 1 data every 5 minutes.

The tank was filled with 170 Hl of red juice and berries (cv. Merlot), with the chemical analyses reported in table 1.

Table 1. Chemical parameters of the grape must used during the tests.

Parameter	Value
Relative Density at 20 °C (kg/dm3)	1.09446
Total acidity (g/l of tartaric acid)	5.72
pH	3.58
Malic Acid (g/l)	2.15
Glucose-Fructose (g/l)	219
Assimilable Nitrogen (mg/l)	99
BABO at 15°C	18.6
Potential ethanol (% vol)	12.7

In the study, 8 pump-overs were analysed: 2 with air contact, and 6 with-out. Among the 6 pump-overs without air contact 3 have 4 minutes length, and 3 have 6 minutes length. The pump-overs were performed as scheduled in table 2.

Table 2. Scheduling of the monitored pump-overs.

Day	Opened/Closed	Length
3	Opened	40 min
3	Closed	4 min
3	Closed	4 min
4	Closed	4 min
4	Opened	15 min
4	Closed	6 min
4	Closed	6 min
5	Closed	6 min

Results and Discussion

The alcoholic fermentation trend is shown in figure 1, and the monitored pump-overs are displayed in the plot whit eight lines.

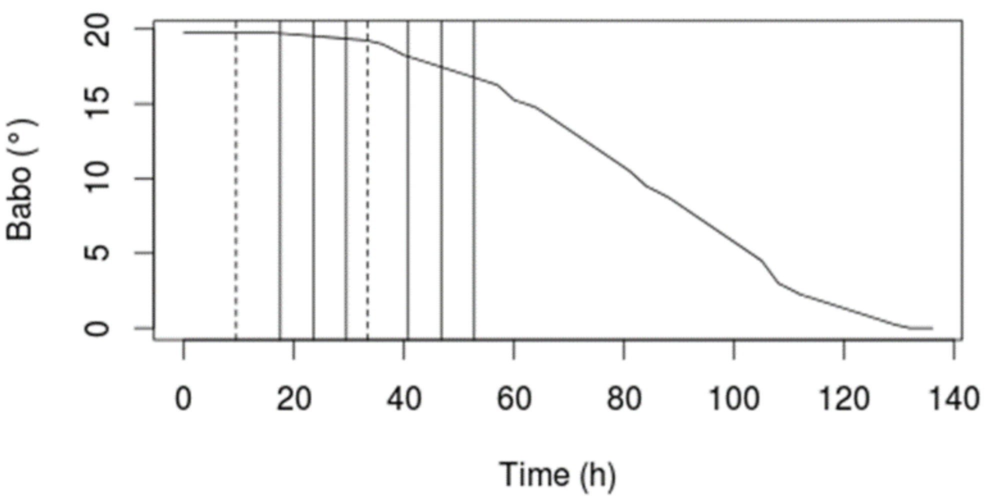

Figure 1. Alcoholic fermentation trend. The pump-overs are reported with dotted lines (with air contact) and with continuous lines (without air contact).

The eight pump-overs were performed during the tumultuous phase of the alcoholic fermentation and, particularly, during the day 2 and 3. During the considered time, the temperature increase from 22.5 °C, to roughly 25.0 °C.

Figure 2 shows the average temperature of the six probes on the fermentation tank.

With a continuous monitoring it is easy to see the cooling effect of pump-overs, which are clearly recognizable by the drops in temperature.

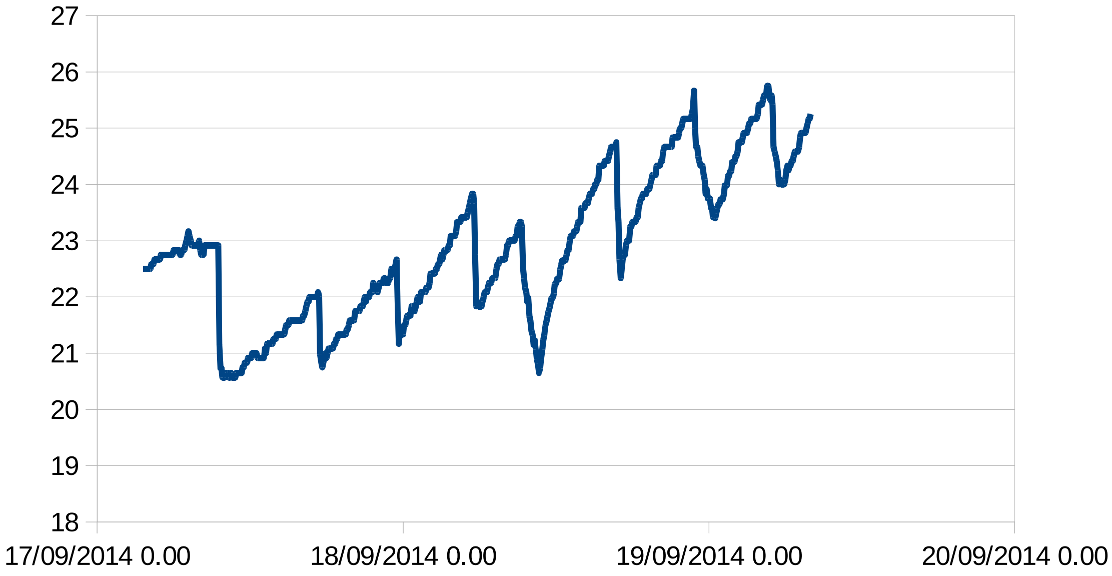

Figure 2. Mean temperature recorded in the tank during the fermentation

On the average, pump-overs were able to remove 2.0 ± 0.5 °C. The two with air contact remove 2.3 °C, and 2.6 °C, while the six closed pump-overs remove, on the average, 1.9 ± 0.5 °C. The closed pump-overs remove in 4 minutes 1.6 ± 0.4 °C, while they remove 2.2 ± 0.4 °C in 6 minutes. At a t-test the probability related with the equality of the two population is 0.1. However, they remove almost the same amount of fermentation metabolic heat per minute: 0.39 °C/min for the 4 min length, and 0.37 °C/min for the 6 min ones.

The cooling effect, in a open-system, could be easily explained with the must contact with the environment. In fact, during both open pump-overs air temperature was 18 °C, while the must temperatures were about 23 °C. Hence, the contact between must and air produces, in these pump-overs a cool down effect. On the other hand, this effect is also exhibited when the system is not in contact with environment, or rather, during the closed pump-overs.

A possible explanation of this phenomenon could results from an analysis of the heat transmission in to the tank. The must, as well as all the fluids, when it is not at the thermal equilibrium state, transports mass and heat with the convection mechanism from the hottest to the coldest zones. Since during the winemaking process, the metabolic heat produced by yeasts on one side, and the heat removal due to the cooling jacket on the other side, produce high temperature difference in the tank (Guerrini et al., 2015) it is possible to assess that a convection transport is established. In these conditions, a thin layer of flow (wall layer), close-fitting the wall of the fermentor that, moves very slow, is formed. This thin wall layer, partially blocks the heat transmission by convection, providing an insulation, slowing down the heat transfer, and thus reducing the exchanging efficiency of the cooling jacket (Knudsen et al.,1999)

It could be supposed that pump-overs, increasing the recirculation speed of must in the tank, break this wall-layer. Thus, they could produce an improvement of the thermal exchange efficiency, which lead to a significant decrease of the temperature in the tank.

Finally, the pump-over homogenizing effect has been assessed with the measurement of the standard deviation among the six probes, before and after the treatment (Table 3). The values of standard deviation decrease after the treatment, confirming the known homogenizing effect of pump-overs (Boulton et al., 1996).

Table 3. Homogenizing effect of pump-overs. SD is the standard deviation among the probes

Day	Opened/Closed	Length	SD Before	SD After
3	Opened	40 min	0.80	0.25
3	Closed	4 min	1.54	0.39
3	Closed	4 min	0.87	0.69
4	Closed	4 min	1.39	0.59
4	Opened	15 min	1.86	0.45
4	Closed	6 min	2.13	1.70
4	Closed	6 min	2.17	2.78
5	Closed	6 min	2.97	1.24
	mean		1.72	1.01

Conclusions

The main thermal effects reported from the use of the pumps-over are homogenization of temperature, and cooling. The cooling has been recorded in both pump-overs: with and without air contact. Cooling is due to the thermal exchange with the air, and to the increase of the exchange efficiency. The latter phenomenon needs to be clarified with further tests. However, pump-overs (open and closed) could be useful to help the cooling system to keep the desired temperature during the alcoholic fermentation.

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Hose reel vs dripline irrigation systems: which is better from Carbon Footprint standpoint?

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Abstract

Irrigation plays an essential role in the cultivation of crops but it also has a relevant contribution to the environmental impact of agriculture. The present work analyzes the Life Cycle of hose reel and dripline irrigation systems, with the aim of evaluating and comparing their carbon footprint. LC analysis was carried out using the software Simapro, with the support of the Ecoinvent Database. Although water consumption is the main indicator used to assess efficiency of irrigation, it is not sufficient to evaluate its overall sustainability. Indeed the use of irrigation equipment and machines cause a large amount of GHG. The GHG of the irrigation systems have been assessed by analyzing two stages of their life cycle: production and use phases. Production phase encompasses all the impacts due to the machine industrial manufacturing from raw material extraction and processing, to production and assembly of the various components. Use phase considers the impact due to energy consumption for water distribution to the field. The functional unit is the m3 of water distributed under average technical and climatic conditions of central and northern Italy. Results show that dripline systems give rise to the highest GWP. Their high impact is due to their short lifetime, since they have to be replaced annually. On the other side, the lifetime of the travelling rain gun span for over 15 years and therefore their production impact has a lower contribution able to compensate the higher impact of the use phase due the high water working pressures.

Keywords: Irrigation; Carbon Footprint; LCA.

Introduction

Agriculture manipulates ecosystems to produce food and fiber. This principle is common both to early and modern agriculture. However, modern agriculture went through a massive increase of food production, which doubled in the last 35 years (Pimentel, 1992). This increase in productivity has been achieved thorough the introduction of new cultivation technologies and techniques, to respond the continuous global increase of food demand. The increase of agriculture production requires a vast amount of resources and it causes a vast series of environmental impacts, which represent a threat to the natural ecosystems of the world. Some of these are related to resources depletion, Eutrophication of marine ecosystems and, last but not least, contribution to global warming (IPCC, 2007). Therefore, to maintain agricultural sector and food production sustainable, it is necessary to identify the technologies and techniques with lower environmental impacts. Irrigation plays an essential role in crop cultivation and yield rates boost, and at the same time, it is one of the agricultural techniques with the highest environmental impacts. This study assesses the contribution of irrigation technologies to climate change. Although poorly understood, climate change is an urgent threat to agriculture and food security. The irrigation sector will be strongly affected by climate change, as well as by changes in the effectiveness of irrigation methods (Tilman, 1999). Therefore, it is necessary to identify irrigation techniques, which make an efficient use of water and have a low environmental impact in terms of climate change contribution. Efficiency of water system is extensively studied in literature but very few works assess the impact of irrigation in terms of contribution to climate change.

This study assesses the carbon footprint (CF) of two widely used irrigation technologies: a hose reel machine equipped with a travelling rain gun and dripline systems. CF measures the total amount of Greenhouse gas emissions of a defined population, system or activity, considering all relevant sources, sinks and storage and therefore their Global Warming potential, measured in Kg of CO2 equivalent (Wright et al., 2011).

Materials and Methods

The methodological framework adopted in this study is based on a life cycle assessment (LCA) of the two irrigation systems, in accordance with the standards ISO 14040 and ISO 14044. The aim is to provide a cradle to field analysis, which comprises the environmental burdens of the systems' production and use phases. Production phase encompasses all the impacts due to machines industrial manufacturing from raw material extraction and processing, to production and assembly of the various components. Use phase considers the impact due to the energy flows during water distribution to the field. System boundaries are presented in figure 1.

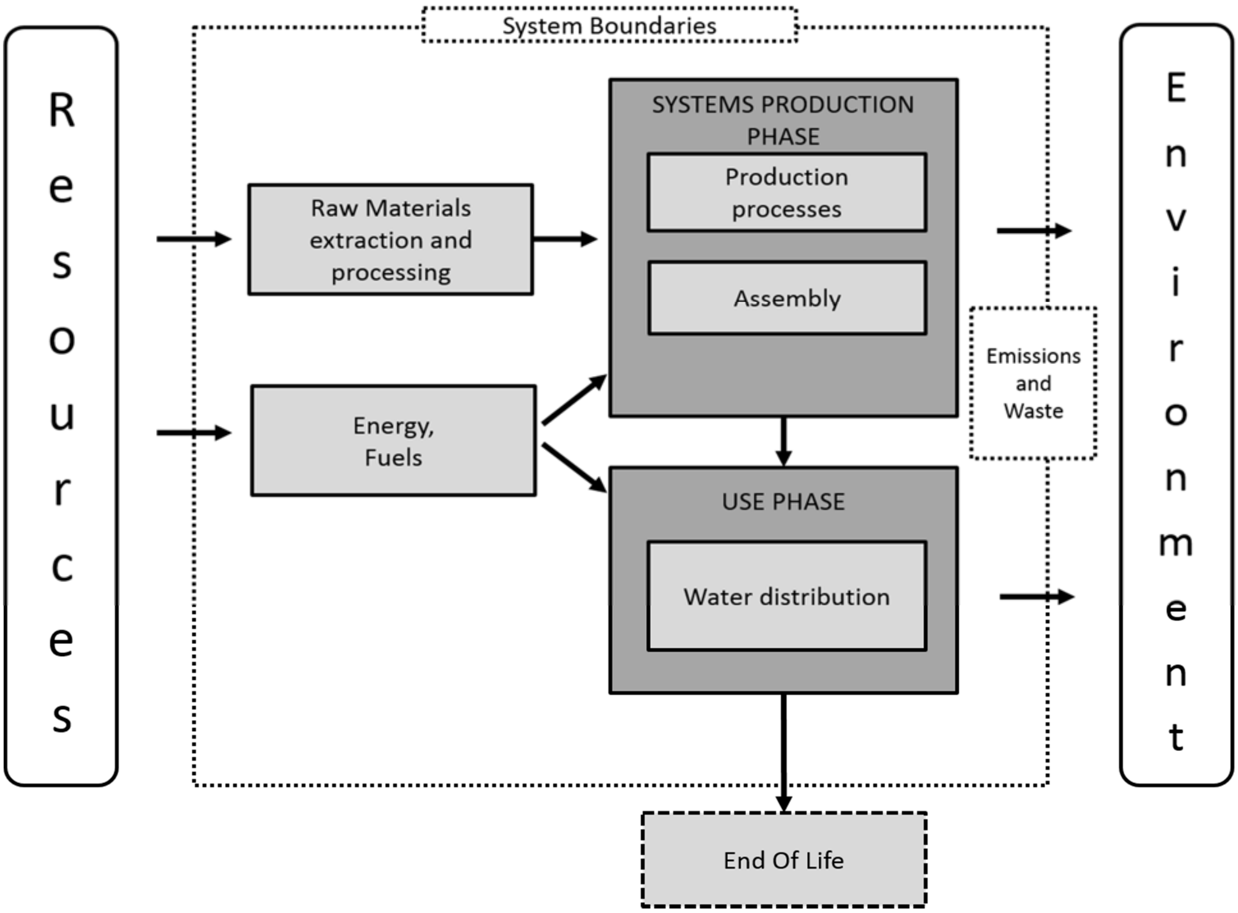

Figure 3. System Boundaries.

The disposal scenario of the two irrigation systems is out of the scope of this study. This is because it has been difficult to source consistent data about the disposal of the systems once they complete their economic life.
As previously underlined, the goal of the study is to compare the environmental impact of a sprinkling irrigation machine and dripline system, considering the impact category of Global warming Potential, measured in Kg CO2 eq. The functional unit chosen, to which all results have been reported, is the m^3 of water distributed to the field.

Description of irrigation systems
a) Hose reel machine equipped with a travelling rain gun.
The hose reel machine has four main components: a large reel mounted on a four-wheel cart, a large semi-rigid polyethylene hose that is wounded on the reel, a gun cart and a large volume gun-type sprinkler mounted on the gun cart. The gun cart is trailed at the end of a travel line along with the rigid hose. During operation, the hose pulls the gun cart back as the hose is wound onto the hose reel. The hose reel is powered by a water turbine. The machine chosen for comparison is equipped with a 400m length hose of 125 mm of external diameter. The gun cart is equipped with a big gun sprinkler, named Explorer, with a 30 mm Ø snorkel nozzle.
b) Dripline system:
Drip irrigation involves dripping water onto the soil at very low rates from a system of small diameter plastic pipes fitted with outlets called emitters or drippers. Pipes are usually grounded to apply water close to plant roots. The dripline system chosen for comparison is flat emitter dripline, pitch 30 cm, in two versions:

- 16 mm external diameter, 8 mills thickness
- 22 mm external diameter, 10 mills thickness

Life Cycle Inventories
Life Cycle inventories (LCI) of the analyzed systems are presented below. The LCI are lists of the flows from and to the systems, such as inputs of water, energy, and raw materials and emissions or waste release to air, land, and water. For each of the analyzed systems the inventory has been divided in two sections, relating to production and use phase, to make easier a reallocation of their impacts to the chosen functional unit. The Members of AMIS, Italian association of self-propelled irrigation machine producer, have provided data regarding the production phase of hose reel machines and rain guns. Data on dripline have been gathered from technical sheets and catalogues of producers.

Production Phase
Following the LCI for production phase of the two systems. First the LCI of the 125/400 hose reel machine is presented in Table 1, then sprinkler cart and Explorer gun sprinkler in table 2 and table 3, and lastly the LCI of the dripline system in table 4.

Table 1. LCI hose reel production phase.

LCI Hose reel 124/400		
Material/Process	Unit	Quantity
Steel (low alloyed)	Kg	1834,44
Paints	Kg	18,872
ABS (Acrylonitrile butadiene styrene)	Kg	6,652
Aluminum Milling-turning	Km removed all.	1,75
Aluminum	Kg	28
Cast Iron	Kg	32,2
Cast Iron Milling-Turning	Km removed iron	1,38
Plastic pipes Extrusion	Kg ext. material	1370
Steel sheet rolling	Kg rolled material	314,2
Aluminum extrusion	Kg ext. material	0,24
Laser cut	seconds	993
Lubricant oil	Kg	11,48
Polyethylene	Kg	1370
Steel bar rolling	Kg rolled material	690
Milling-turning steel	Kg removed material	7,785
Synthetic rubber	Kg	1,29
Injection moulding	Kg moulded material	7,942
Arc welding	m	62,39
Zinc coating	Kg coated material	1015

Table 2. LCI gun cart production phase

LCI gun cart		
Material/Process	Unit	Quantity
Steel (low alloyed)	Kg	245
Synthetic rubber	Kg	35,2
Injection moulding	Kg moulded material	35,2
Paints	Kg	0,807
Laser cut	seconds	100
Arc Welding	m	8

Table 3. LCI Explorer production phase

LCi Explorer sprinkler		
Material/Process	Unit	Quantity
Aluminum	Kg	5,5
Chromium steel	Kg	2,6
Milling Turning	Kg removed material	7,785
Polyethylene	Kg	1,43
Injection moulding	Kg moulded material	1,43
Brass	Kg	0,4
ABS	Kg	0,409
Calendering	Kg treated material	0,409
Heat (from Natural Gas)	MJ	226

Table 4. LCI Dripline production phase

LCI Dripline System (per hectare)			
Material/Process	Unit	Quantity	
		Ø 16	Ø 22
Polietilene	Kg	87,1	120
Injection moulding and extrusion	Kg treated material	87,1	120

Use Phase

Life Cycle inventories regarding the use phase have been modelled considering average working conditions for the two systems (Table 4). As previously mentioned, impact of use phase is mainly due to the production and combustion of diesel burned in combustion engine, which generate the power needed to feed with pressured water the irrigation systems.

Table 5. Systems working conditions

Working Conditions			
	Unit	Hose Reel	Dripline
Economic life	Years	15	1
Seasona Irrigation volumes	m3/ha	2500	2500
Max irrigable area	ha	35	1
Pressure at pump	m.w.c	70	3
Working pressure Pressure (output)	m.w.c	50	15
Flow rate	l/min	1260	363

The consumption of diesel has been calculated with the following formulas:

$$C = W * CS$$

C = Diesel consumption of the pump (g/h);

W = Power absorbed by the pump (kW)

CS = Specific consumption of the endothermic engine (g/kWh)

And

$$W = \gamma * Q * H / 102 * \eta$$

γ = Specific weight of water at 4 °C in Kg/m^3
Q = pump flow rate in m^3/s;
H = Hydraulic head in m H_2O;
η = Pump efficiency (70%).

Following the LCI of the use phase:

Table 6. LCI Use phase (Diesel Consumption)

LCI Use Phase			
		Hose reel	Dripline
Hourly consumption	l/h	4,26	0,84
Seasonal consumption	l/ha	125,99	101,64

The CF has been assessed multiplying inventory flows by the emission factor corresponding to that activity, material or process. Emission factors are form the EcoInvent database version 3 of the Swiss Centre for Life Cycle assessment. The LCIs have been analyzed with the software Simapro (8.0.2, pre-sustainability-2014, UK).

Results
The results of the inventories analysis is presented below, starting with the production phase, use phase, and finishing with the allocation impacts to the Functional Unit. CF has been assessed using the IPCC 2013 GWP 100a method.

Impact of production phase
The total impact due to the production of the Hose Reel system is 7520 Kg CO2 eq. Figure 2 presents the contribution of the components to system impact.

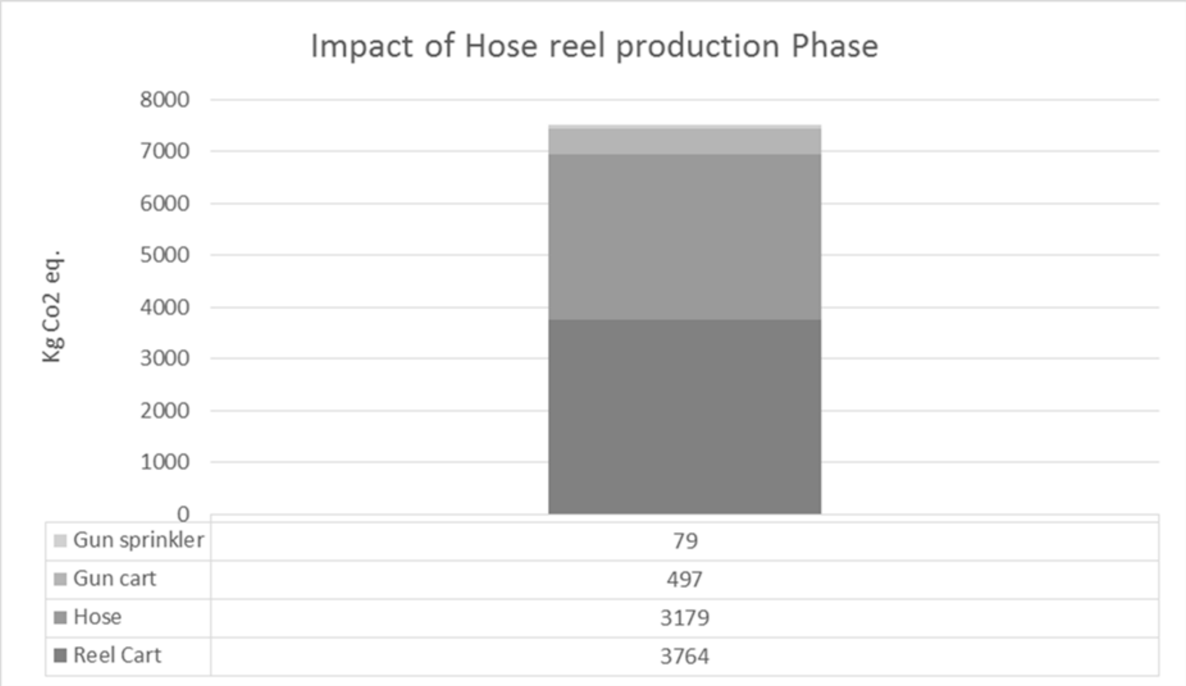

Figure 4. Impact of production phase of the hose reel system

The reel cart is the component with a higher contribution to the system CF (50%), followed by the hose (42%).
As previously underlined, two dripline models have been assessed in this study. Impact has been evaluated considering the quantity of material necessary to cover a hectare of cultivated surface. Dripline diameter is usually chosen in function of filed length and therefore two models of dripline have been analyzed to partially assess this variability. Impacts due to production phase of 16 mm Ø and 22 mm Ø dripline are presented in table 3.

Table 7. Impact of production phase of the dripline system

Impact dripline production (per ha)		
Materials/Processes	Kg CO2 eq.	
	Ø 16	Ø 22
Polyethylene	192,67	266,4
Injection moulding and extrusion	30,15	41,68
TOTAL	222,82	308,08

<u>*Impact of use phase*</u>
CF of use phase is mainly due to diesel production process and combustion, which is necessary to power the hydraulic pumps for feeding the systems with water at a required pressure and flow rate. Following the impact of use phase, due to the season volume distributed on 1 hectare.

Table 8. Impact of use phase, per m3 of distributed water

Impact Use phase (per ha)	
System	Kg CO2 eq.
Hose reel	401
Dripline	324

CF of the systems
The functional unit of this study is the m3 of distributed water, therefore all the impact of production and use phases have been reallocated, based on system lifetime, seasonal irrigation capacity and seasonal distributed water. The main difference between the two systems is that economic life of Hose reel machines is 15 years while dripline are replaced annually. Moreover, Horse reel operational capability is defined by machine characteristics (hose diameter and length), while dripline systems are dimensionless (virtually there are no limitations on irrigable surfaces). The Hose system analyzed in this study is capable of irrigating 35 hectare seasonally, 525 during its economic life. Dripline refers to the quantity of pipes and dripper necessary to cover a hectare of surface. Both the systems distribute 2500 m3 of water per hectare seasonally. The following chart presents the CF footprint of the two systems, regarding the m3 of distributed water.

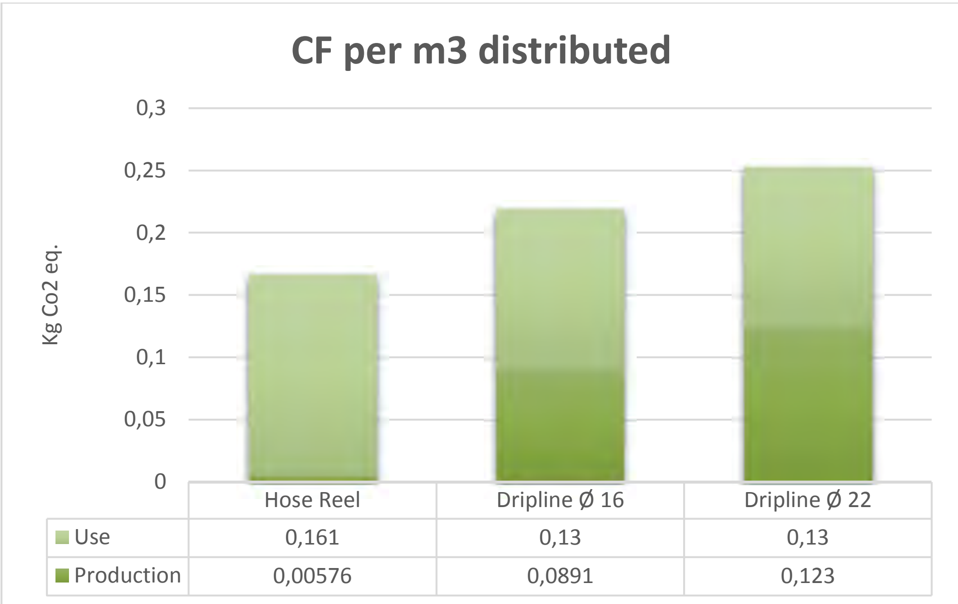

Figure 5. Carbon footprint of the analyze systems, FU=1m3 of distributed water

The 22mm diameter dripline is the system which shows the higher impact, with 0,253 Kg CO2 eq. per m3 of distributed water, followed by 16mm dripline with 0,219 Kg CO2 eq. per m3 and the Hose Reel with 0.167 Kg CO2 eq. per m3. Impact of hose reel production phase has little contribution to the system overall CF (about 3%). On the contrary, production of Dripline systems contributes for 41% of CF for the 16 mm and for 48% for the 22 mm. This is because dripline systems used to irrigate open field cultivations are substituted annually.

Conclusions

The analysis performed in this study shows that the dripline system has the higher carbon footprint referring greenhouse gas emission to 1m3 of irrigation water . This is because dripline are disposable systems and an assessment performed on the entire life cycle of the systems shows that this has an important influence on environment impact . However, this study assesses only one impact indicator (CF) and do not consider possible differences in plant water use related to the irrigation system. In any case, other factors should be assessed when performing analysis on irrigation sustainability such as soil condition and composition, culture, climate zone and weather. The experience and competence of whom operate the systems should also be considered, although it is difficult to measure.

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An olive pruning machine for marginal areas

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Abstract

In many sub-Apennine areas of central Italy, climatic and soil difficulties caused the spread of the olive trees more than other crops, thanks to their ability to adapt to those conditions and thanks to the help of dry stone walls.

In this way in the past was possible to have many olive lands, today in those lands there are marginal olive groves. In fact in such areas, the maintenance of olive groves is expensive and difficult, especially regarding the practice of pruning. In the absence of such pruning, olive trees would return to being new woodland. Pruning also requires workers with specific skills to maintain the right shape of trees. Such labor is increasingly unavailable.

Due to the large gradients, which make difficult and dangerous the machines use, subject to instability and tipping, with consequent risks for the operator, the mechanization is not able to improve the situation totally. In fact in many areas olive groves are neglected, resulting no gains for the farms and also lack of those areas maintenance. It is also necessary to consider the known environmental hazards related.

The aim of the research is to assemble a new machine with pruning bar provided with rotary discs, and totally operated by a remote control. The driver is placed on the ground some meters far from the machine to reduce the risk to his life, in the case of the machine rolling over.

To evaluate the efficiency of the machine some pruning tests will done in marginal areas.

Keywords: Pruning Machine, Steep Ground, Remote Control

Introduction

The olive growing in central Italy is not only a productive sector also one of the main naturalistic resources, which contributes to the hydro-geological protection of the ground, to the conservation of old olive varieties and to the territory defence, through the presence of man and farms often directed to the tourist reception.

The olive tree was the only plant that could adapt in areas with soil and climatic difficulties, thanks to its hardiness and the help of dry stone walls. Thanks to this olive tree attitude, many lands were cultivated in the past. Today on those same marginal lands there is an olive growing difficult to manage, even from an economic point of view.

In fact in such areas, the olive growing is expensive and difficult, especially in regards to the practice of pruning. In the absence of such pruning olive groves will return a new woodland. Labour for pruning, which must have specific skills, is difficult to find.

Moreover, the mechanization is not always able to improve the situation, because of the considerable gradients, which make difficult and dangerous the use of the machines, subject to phenomena of instability and tipping. In fact in these areas it is clear the neglect of the crop, the lack of income for farms, but also the lack of the lands maintenance with the known environmental hazards related. It is necessary to prepare actions that will make cheaper olive cultivation in marginal areas, taking into account the possibilities offered by mechanization and collective machines utilization. It is important to consider that the machines use in the steep grounds, that often are wet because of the presence of grass cover, also produces issues related to operator safety against the risk of tipping of the machines. Moreover the farmers are not young and they have a low level of training and information on the risks present in the workplace.

Aim of the research is to provide a tracked machine, equipped with bar pruning and able to be operated by the driver, placed on the ground, thanks to a remote control. The driver has less risk in the event of tipping of machine.

Materials and methods

Two different elements form the utilized pruning machine. A tracked tractor and a pruning bar were assembled and tested. The tracked tractor is a remote-controlled machine, with hydrostatic transmission. Its peculiar design concept, the low baricenter, the track edges shaped to operate in very bumpy areas still maintaing the greatest traction, special engine oil pan which allows the prolonged use of the machine, in declivity conditions in any direction, up to 50°. It is equipped with a diesel 58 kW engine. The machine sizes are: 2,525 meters in lenght, 1,565 meters in height and extensible width from 1,330 meters to 2,030 meters. The machine weight is about 1000 kg. It is possible to apply many equipments in the front part, to make the machine as multifunction (fig. 1). The remote control has 150 meters range. Two joysticks grant the control of the steering movement and the control of the pruning bar (fig. 2). The market offers two types of pruning bar with rotary discs or with blades. The first is most suitable for cutting wooden elements of large diameter and therefore is able to work on plants not pruned for some years. The first one was chosen. A vertical bar with 8 cutting disks, 2 meters in lenght, carries out the vertical cut. It has the possibility to incline of about 30°. A horizontal bar of 6 cutting disks and 1,5 meters in lenght is assembled on the vertical one. Its inclination is from 0° to 90°. To help the removal of pruning from the bars the rotary disks have a special shape (fig. 3). All bars movements are continuous and performed by remote control. Thanks to the extension of the pillar that supports the two bars, the cutting height arrives up to 4,7 meters (fig. 4).

After the machine assembly, some tests were done in an olive grove of about 10.000 m^2 and of 277 trees, placed on a grid of 6 meters side. The plants were bred as cone-shaped pot. Two years ago the last pruning was done. The ground slope was about 40% (fig. 5).

After the mechanical pruning around the plant, the final work inside the canopy was done manually and the timing for this operation was detected.

Figure 1. The machine assembled and utilized in the tests.

Figure 2. The remote-control.

Figure 3. The particular shape of rotary disks.

Figure 4. The machine at work.

Figure 5. The olive grove.

Results

The machine did not malfunction. Its movement under trees was flowing also on the curves at the end of the field. The forward speed has been about 0.27 m/s and a total time of about 8 hours per hectare. The cut was achieved both on the four sides of the plant (hedging) that in the high part (topping).

It is necessary to report that the driver at the end of day's work was tired. It is advisable to plan some shifts. The objective to have a secure job for driver was achieved. He always worked far from the machine.

The next manual finishing took about 4 minutes per plant for a total of about 18 hours and 30 minutes. The obtained data are smaller than the pruning operation carried out totally manually, which requires about 70 hours per hectare.

The manual labor costs are of 20 euros per hour, while for the machine operation are necessary 90 euros per hour. Therefore the use of the machine and the next manual finishing cost 1.090,00 euros per hectare, while the manual pruning costs are 1.400,00 per hectare.

Conclusions

Mechanical pruning is not new, because several experiences of mechanical pruning in Italy were done, with machines connected to the tractor. The novelty lies in having created a machine with driver on the ground. In fact this position, especially in sloping ground reduces the risks for the operator. In addition, the operator on the ground is not subject to mechanical vibration.

The remote controlled machine is a tool, on which can be mounted other machines for the olive growing, such as an apparatus for treatments, for the shredding of pruning and for the collection. The height of the machine is very low and allows it to move close to the trunk of the plant, for example to perform the shredding of pruning, operation impossible with traditional tractors.

The savings of more than 300,00 euros per hectare is definitely an incentive to the maintenance of olive groves present in marginal areas with steep slopes.

Acknowledgements
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TOPIC 4

"Noise, Vibration, Dust, Endotoxin, Microorganism"

Field and static tests to assess the drift of abrasion dust of dressed maize seeds

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Abstract
Pneumatic precision drills employed in maize (*Zea mays* L.) sowing are responsible for the emission in the atmosphere of abrasion dust containing active ingredient (a.i). In recent years, several insecticides (especially neonicotinoids) employed for maize seed dressing have been claimed to cause mortality and sub-lethal effects to honey bee (*Apis mellifera* L.). Moreover, the emitted particulate matter can be inhaled by the operators during the seed loading and manipulation and during the sowing. This work aims at assessing the amounts of a.i. emitted by precision drills during sowing operations. We carried out static tests, simulating the sowing at fixed point, and real sowings in field. To collect a.i. residues, we used passive samplers (Petri dishes) for the residues at ground level. We employed maize seeds treated with three neonicotinoids insecticides (clothianidin, imidacloprid and thiamethoxam) and with fipronil. The results show the amounts of dust emitted by a pneumatic precision drill during the sowing of maize. Moreover, a method to predict the theoretical dust drift in the field, starting from the results of the static test, is provided.

Keywords: Pesticides, Airborne Particulate, Neonicotinoids, Honey Bee, Seed Coating.

Introduction

Pneumatic precision drills used in maize (*Zea mays* L.) sowing can release amounts of dust coming from the abrasion of dressed seed. In recent years, scientists and beekeepers ascertained a relationship between mortality and decline of honey bees and the spring sowing of maize (*Zea mays* L.) seeds dressed with neonicotinoid insecticides (imidacloprid, thiamethoxam, clothianidin) and fipronil (Greatti *et al*., 2006; Tremolada *et al*., 2010; Pistorius *et al*., 2010; Tapparo *et al*., 2012; Nuyttens *et al*., 2013). Moreover, the emitted particulate matter can be inhaled by the operators during the seed loading and manipulation and during the sowing (Biocca *et al*., 2013; Biocca et al., 2014).

Some test methods have been developed to classify the drills according to their capability to release abrasion dust during the sowing (Rautmann *et al*., 2009; Manzone *et al*., 2014) but it is still lacking a test method recognized as international standard. We have developed a method based on static tests to obtain reproducible test conditions and comparable results. The method is based on the simulation of the sowing of maize dressed seed under artificial wind conditions. The method was used for assessing the efficiency of drift reduction devices applied to the seeder in comparison with the emissions of the conventional machine (i.e., the same drill without the devices) (Apenet, 2011; Biocca *et al*., 2011). Through a data processing method of the results provided by the static tests, it is possible to predict the dispersion of active ingredients (a.i.) that would occur in the field under similar conditions.

This paper provides evidence of the correspondence between the amount of predicted drift at ground level during static tests and the measured residues during field trials.

Methods

Seed

The trials were carried out using commercial maize seed (Pioneer Hy-Bred PR32G44) dressed with four insecticides (Gaucho™, a.i.: imidacloprid; Poncho™, a.i.: clothianidin; Cruiser™, a.i.: thiamethoxam, Regent™, a.i.: fipronil) and a fungicide (Celest™, a.i.: fludioxonil and metalaxyl). According to the manufacturers, the application doses of a.i. were respectively equal to 1.00 mg seed^{-1} for imidacloprid, 1.25 mg seed^{-1} for clothianidin, 0.60 mg seed^{-1} for thiamethoxam and 0.50 mg seed^{-1} for fipronil.

Drills

A six-row precision pneumatic drill, Gaspardo mod. "Magica", was employed, with and without air deflectors applied at the fan opening. Deflectors made up of four pipes that redirect the air stream from the fan exit towards the soil, inside the furrows opened for seed deposition, reducing the dust drift. The device can be removed, restoring the "conventional drill" conditions and allowing the comparison between the conventional and modified machine.

Test system at fixed point

The static tests were carried out in the workshop's porch of CRA-ING, a site protected by external influences (Fig. 1), as described in Biocca *et al.* (2011). In the test site, artificial wind conditions were produced by means of the axial fan (0.735 m diameter) of an orchard sprayer (Nobili Geo 75-600 T) powered by a 60 kW tractor. The air flow produced under these conditions was 22,900 m^3 h^{-1} (fan speed of 2160 rpm). Preliminary tests showed the repeatability and the constancy of wind conditions (speed and direction). The average wind speeds in the sampling site were 1.4 m·s^{-1} at 0.5 m from the soil (min 0.0, max 2.6 m·s^{-1}) and 1.8 m·s^{-1} at 2.0 m from the soil (min 1.6, max 2.5 m s^{-1}).

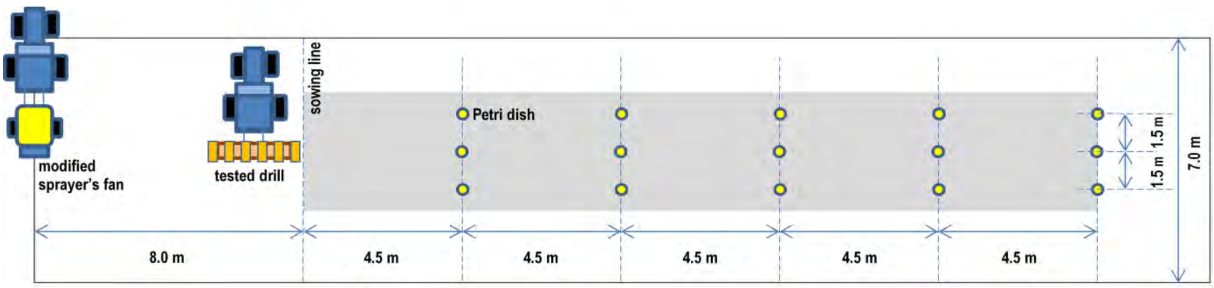


Figure 1. Layout of the static tests area

The drill, suitably placed in the test area, operated the seed distribution by means of an electric engine connected to the driving wheel through a gear-reducer. An inverter (OMRON Varispeed V7) allowed adjustment of the speed of the electric engine and, consequently, of the peripheral speed of the driving wheel, on the desired value of 1.67 m·s^{-1}.

In the test site, which resembled a wind tunnel, we have delimited a 22.5 m long sampling area, downwind with respect to the drill position. Along the sampling area, five series of Petri dishes, spaced 4.5 m, were placed; each series consisted of three Petri dishes spaced 1.5 m; therefore, a grid of 15 sampling points was arranged (Fig. 1). Before each test, the Petri dishes were filled with a 50% acetonitrile-water solution.

The test consisted in the sowing of one sack of seed (25,000 seeds), corresponding to a virtual sowed surface of 3,333 m^2. Each trial was replicated three times for each investigated a.i.

Field tests

The trials were carried out in the experimental farm of CRA-ING (circa 42°5'51.26" N; 12°37'3.52" E; 24 m a.s.l.). To operate at the same seed density of 75,000 seed ha^{-1}, the drill settings were the same as in the static tests. During the trials, the main micrometeorological parameters were monitored.

The tests were carried out sowing 3 ha rectangular plots (~ 140 x 215 m). The evaluation of the dust deposition at ground level was made using the same types of samplers as for the tests at fixed point (Petri dishes with 50% acetonitrile/water solution). The sampling area corresponded to a 20 m wide belt around the field perimeter. The dust ground deposition was observed on all plot sides (North, South, East and West) with the aim of capturing the settling dust at ground level independent of the possible changes in wind direction during the trials. A series of three Petri dishes spaced 1.5 m apart were placed on each side at 5, 10 and 20 m from the field edge; hence, a total of 36 sampling points was obtained (Fig. 2). One field trial was conducted for each investigated a.i.

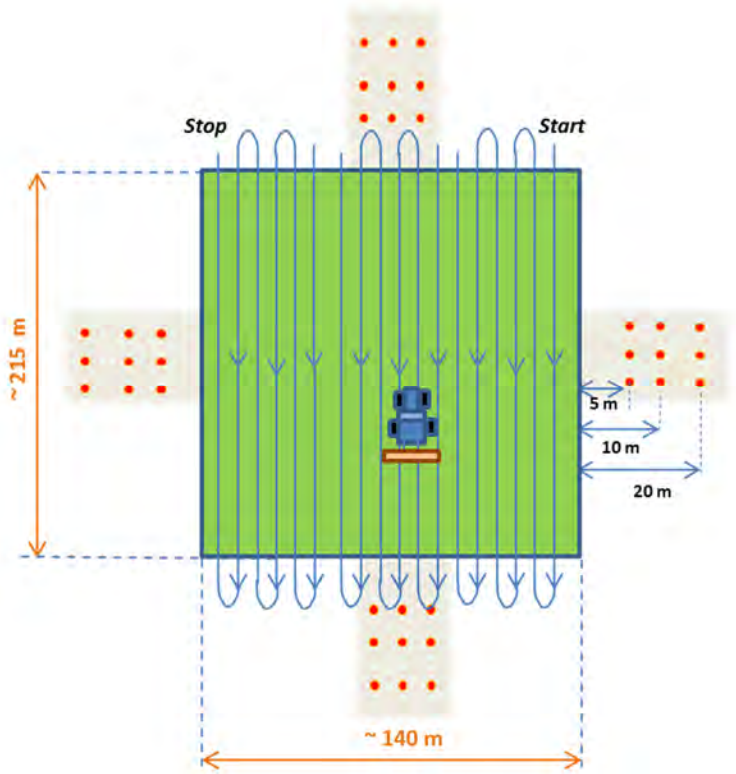


Figure 2. Layout of field trials, showing position of samplers (Petri dishes) (not in scale).

Determination of active ingredients

The determination of active ingredients in the samplers was carried out at CRA-PAV, by means of HPLC coupled to a MSD (Mass Spectrometry Detector) operating with an ES+ (Electrospray Ionisation Interface, positive mode), as described in Biocca *et al*. (2011).

Data processing for the assessment of the theoretical a.i. concentrations in the field

The values of a.i. concentrations obtained at ground level during the trials at the fixed point were elaborated to provide the theoretical a.i. concentration pattern that would occur in the field. The data processing to pass from fixed point data to virtual field data entails the following steps:

- Transforming the values of $\mu g \cdot plate^{-1}$ in $\mu g \cdot m^{-2}$;
- Calculating the area of the virtual plot sowed with the seed quantity employed in the static test;
- Finding the number of passages necessary to sow the virtual plot;
- Recalculating the concentration corresponding to a single passage;
- Obtaining the drift curve.

From the a.i. content in the Petri dishes ($\mu g \cdot plate^{-1}$) and the virtual number of Petri dishes (105.2 m^{-2}) we obtained the a.i. concentration per surface unit in $\mu g\ m^{-2}$. Considering the virtual forward speed, the amount of seed used and the drill's working width, the virtual sowed area has a surface of 3,333 m^2, as indicated above. Such a plot sowed without turns would be 740.8 m long and 4.5 m wide. As previously mentioned, five series of three Petri dishes were placed on the sampling area. To obtain a sampling distance from the initial sowing line equal to the working width (or multiples of it), the five series of three Petri dishes were spaced 4.5 m. Moreover, the distance between two contiguous Petri dishes of the same series was 1.5 m, which determined a reference width of the sampling area of 4.5 m, parallel to the sowing direction. The ratio between the above mentioned distance of 740.8 m and the 4.5 m width of the sampling area provides the theoretical number of drill passages, i.e., 164.6, along the sampling area.

As a consequence, the a.i. concentration after a single passage can be calculated by dividing the concentration observed after the test (average of three values) by the number of passages (164.6). This method provides an estimation of the concentration of the a.i. ($\mu g \cdot m^{-2}$) after one passage at the five sampling distances (4.5, 9.0, 13.5, 18.0, 22.5 m). Under field conditions, the drill distance from the initial sowing line (assumed as zero) and from the Petri dishes of a hypothetic sampling area would increase by 4.5 m (working width) after each passage. For example, after three passages of the drill, the Petri dishes at 4.5 m from the initial sowing line would receive an a.i. amount resulting from the sum of the concentration calculated at 4.5 m (first passage), 9 m (second passage) and 13.5 m (third passage). For *n* passages of the drill, the theoretical concentrations that would occur in the field can be calculated by means of a matrix obtained by repeating the calculated series of values *n* times, taking care to displace the series of one place (4.5 m distance) after each passage. Because there are five sampling distances in the static tests, the maximum number of passages used to generate the matrix would be five ($n = 5$). To achieve the result for $n > 5$, the exponential regressions of the series of five concentration values as a function of the distance were calculated for both the conventional and modified drill. The equations provided by the process were used to calculate the concentration for distances greater than 22.5 m from the initial sowing line.

We considered a distance of 72 m ($n = 16$) as the maximum distance reachable by the drift from the first row of samplers. This distance corresponded to approximately half the width of the field. The resulting matrix provided the global theoretical concentrations at ground level (µg·m^{-2}) at distances ranging from 4.5 m to 72 m from the initial sowing line. The obtained values were then compared with the data measured in the field. The statistical analyses were computed with the software R (R Core Team, 2013).

Results

Figure 3 summarizes the results of the depositions at ground as the average of all active ingredients (µg·m^{-2}), both indoors (static) and in the field tests. For each distance, the samples were composed by 36 values for the ground deposition at fixed point and 48 values for the ground deposition in the field.

In the field and static tests, the use of deflectors caused similar values of dust emission reduction (Table1).

Figure 4 shows the virtual pattern of dust drift (at ground level) resulting from the data at the fixed point processed as described above. The curves show the predicted dust deposition at ground level from 4.5 m to 72 m from the drill, in the hypothesis of 16 drill passages.

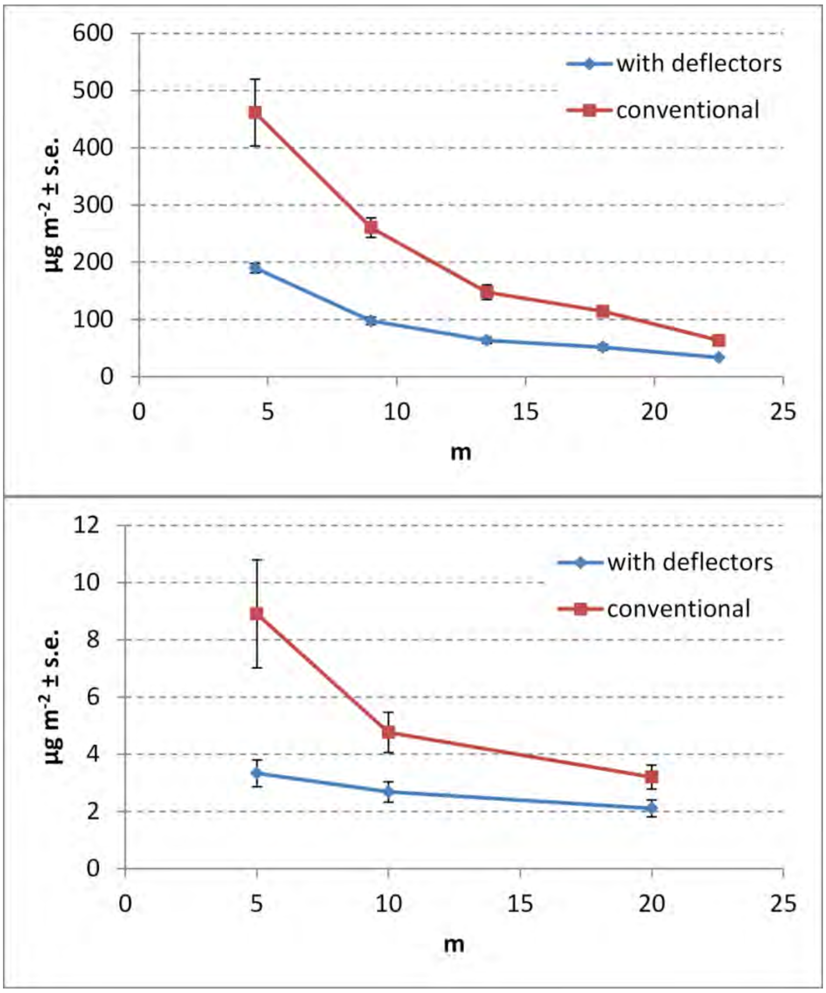


Figure 3. Drift average residues of the four a.i. at ground level (µg m^{-2} ± s.e.) in fixed point tests (up) and in the field (down). The amounts of a.i. in the static tests are very high because the dust dispersed during the sowing is concentrated in a small sampling area.

Table 1. Average percentages of reduction of dust emission caused by the deflectors during field and static tests.

	m.u.	clothianidin	fipronil	imidaclorpid	thiamethoxam	average
Field	%	33.9	43.1	69.4	33.3	48.1
Fixed point	%	47.0	54.0	74.6	51.6	56.0

The curves of figure 4 were utilized to obtain the values at 5, 10 and 20 m (i.e., the sampling distances adopted in the field tests) to compare them with the corresponding values actually observed in the field. Then, linear regressions between the field (measured) and indoor (predicted) values were computed. The regressions were performed for all a.i. (n=48, 24 pairs of values). The results of the regression are reported in figure 5 that also shows the adjusted R^2 values, the formula of linear regressions and the result of probability tests (p value).

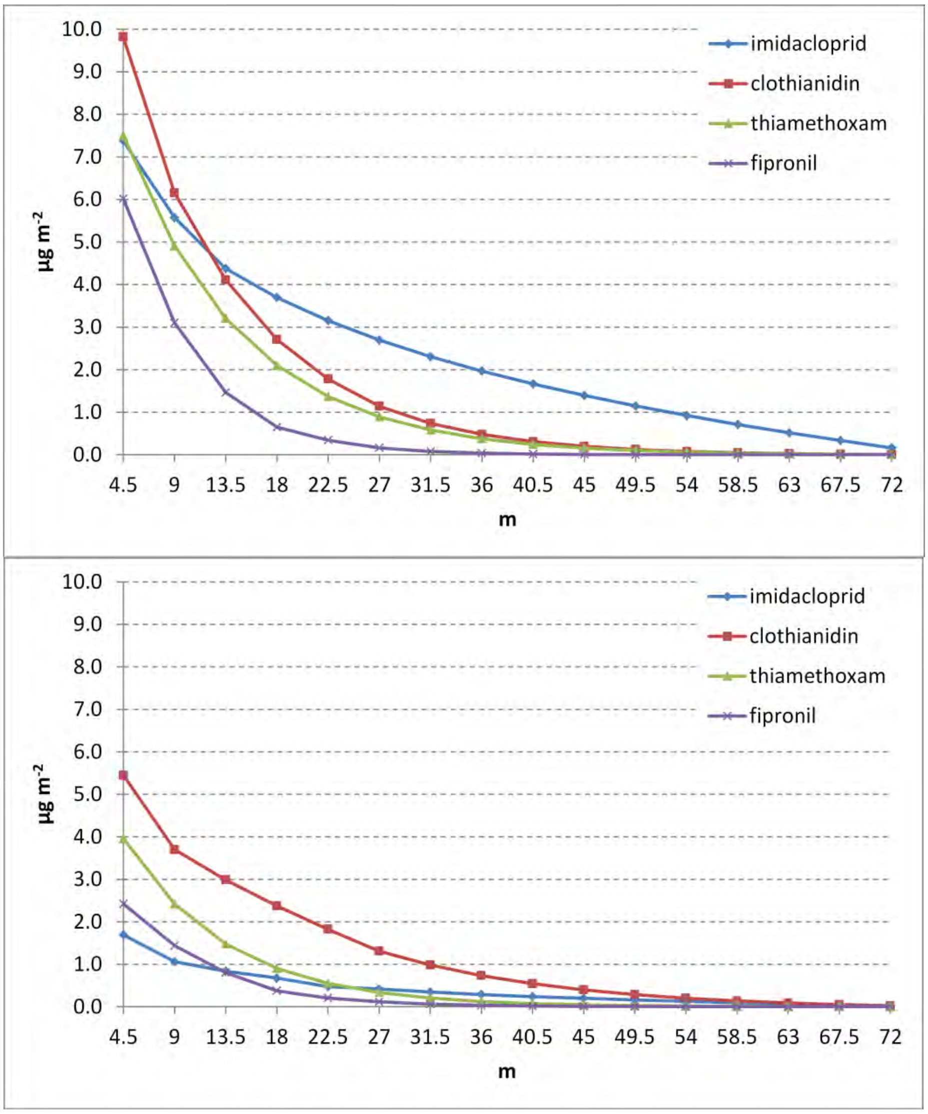
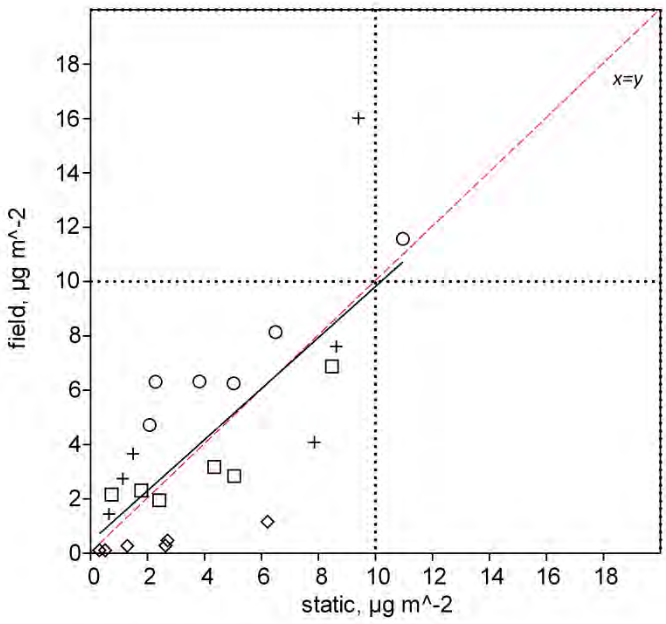


Figure 4. Prevision of the pattern of dust deposition from the results of static tests: conventional drill (up); drill with deflectors (down).



◦ clothianidin ◊ fipronil + imidacloprid □ thiamethoxam

Figure 5. Linear regression (black line) between the values of the ground residues in the static and field tests. The red line means identity (x=y). The regression for all active ingredients (up) was: y = 0.9397 x + 0.4231; adjusted R^2: 0.56; p value = 1.408 · 10^{-5}

The prevision based on the static test data underestimates the measured field data for clothianidin and imidacloprid (differences between field and prevision average values: 2.11 $\mu g \cdot m^{-2}$ for clothianidin; 1.06 $\mu g \cdot m^{-2}$ for imidacloprid). It can be noted that the result for imidacloprid is strongly affected by one single high value observed at 5 m in field tests. As for fipronil and thiamethoxam, an overestimation of data (difference between field and prevision average values is -1.88 $\mu g \cdot m^{-2}$ for fipronil and -0.58 $\mu g \cdot m^{-2}$ for thiamethoxam) was observed. As for the results of the linear regression, the field and static (indoor) data are significantly correlated (p value = 1.408 x 10^{-5}) with a R^2 of 0.58.

Discussion

This paper aimed at verifying the correspondence between the predicted field amounts of dust drift calculated on the basis of the results of static tests and the residues actually measured during field trials. In spite of the variability of environmental conditions, primarily wind speed and direction, that can strongly affect the dust deposition during field tests, the values ($\mu g \cdot m^{-2}$) of the two series (predictions and measurements) are of the same order of magnitude, as are the reductions of the depositions of a.i. caused by the use of deflectors, both in the static and field tests. The correspondence between the two series of data is confirmed by the linear regression, applied to all the active ingredients, that yielded significant results.

In conclusion, the method based on tests at a fixed point with side wind artificially provided, seems reliable, reproducible and accurate. It appears suitable for testing the predisposition of sowing machinery to spread abrasion dust, as well as the contained chemicals and to verify the effectiveness of the devices aimed at reducing dust emissions. The method, through a proper data processing, also seems capable to provide a good estimation of the distribution of a.i. at ground level that would occur in the field, under the same conditions of wind, travel speed and sowing density.

However, to employ the method as a standard method to evaluate drill performance, some practical aspects need to be improved. For example, the analytical phase should be simplified and the risk of exposure reduced. Such objectives could be achieved by using seed dressed with a non-toxic and an easily-detectable tracer. An essential point is that the seed should be dressed similarly to commercial seed to have results referable to normal operative conditions.

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Whole-Body Vibration exposure. An ergonomic evaluation of the effects of an active suspended cab fitted on an agricultural telehandler

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Abstract
Exposure to whole body vibration (WBV) is one of the most important risk factors for musculoskeletal disorders (MSDs). Agricultural machinery operators are particularly at risk and it is therefore important to minimize the transmission of harmful vibrations to the driver as much as possible. Telescopic handlers are self-propelled vehicles very versatile used on different terrains and for different operations. Despite their diffusion few studies investigated their vibrational safety and comfort. The objective of the study was to investigate whether an active cab suspension system fitted on a telehandler was effective in reducing WBV and in improving comfort. Sixteen male healthy professional operators drove a telehandler on a 100 m ISO 5008 smooth track at two different speeds (5 and 12 kph) with activated and deactivated cab suspension system. Adopting an ergonomic approach, different aspects of the human-machine interaction were analyzed: 1) WBV measurements, 2) subjective ratings of general comfort and local body discomfort, and 3) anthropometric characteristics of the users. The suspension system was effective in reducing WBV and in improving comfort, especially for individuals with higher stature, body mass and Body Mass Index (BMI). Some neck/shoulder and lumbar complaints seems to remain, even when the system was activated. Results suggest that the operators, given their wide range of physical variability, may need more adjustable or customizable WBV reduction systems.

Keywords: Ergonomics, Comfort, WBV, Telehandler, ISO 5008

Introduction
Exposure to whole body vibration (WBV) has been identified as one of the most important risk factors for musculoskeletal disorders (MSDs) (Kittusamy 2002; Lyons 2002; Osborne et al. 2012; Zimmermann, Cook, & Rosecrance 1997), having severe effects on low-back pain, neck-shoulder disorders, early degeneration of the spine and herniated discs (Bovenzi & Zadini 1992; Griffin 1990; Kittusamy 2002, 2003; Kittusamy & Buchholz 2004). Some anthropometric characteristics of the users, such as stature, body mass and Body Mass Index (BMI), seem also to play an important role in enhancing (Bovenzi et al. 2006; Milosavljevic, Mani, Ribeiro, Vasiljev, & Rehn 2012) or reducing (Sadeghi, Habibi, & Sajjadi 2012; Wang, Rakheja, & Boileau 2006) the WBV and the subsequent risk of MSDs.

MSDs are a main issue of concern in agricultural industry: in Europe, 2,070,000 out of over 40 millions occupational diseases among agricultural operators are MSDs (EU OSHA 2010). Agricultural and earth-moving machinery operators are particularly at risk because they are usually exposed to vehicle vibrations for a long time (Mayton, Kittusamy, Ambrose, Jobes, & Legault 2008).

The awareness of the hazards related to WBV led to the development of standards and requirements regarding the exposure of workers. The development of WBV standards started in 1966 in Europe, resulting in the publication of ISO 2631 (Paschold & Sergeev 2009).

In order to comply with rules and standards and to promote operators' health, safety and comfort, many technological and design innovations have been introduced on vehicles by manufacturers during last decades (for a review, see Donati 2002 and Tiemessen, Hulshof, & Frings-Dresen 2007). Innovations range from suspended seats (Hostens, Deprez, & Ramon 2004) to correct ergonomic layout of vehicle interior (Pope, Wilder, & Magnusson 1998) and to cab suspension systems (Evers, Besselink, Teerhuis, Van der Knaap, & Nijmeijer 2009; Velmurugan, Kumaraswamidhas, & Sankaranarayanasamy 2012). Concerning cab suspension, different solutions have been developed, from passive systems to more recent semi-active and active ones (Fischer & Isermann 2004): active systems in particular represent an important innovation, not only for WBV control but also for the improvement of ride quality, handling and performance under different operating conditions (Ikenaga, Lewis, Campos, & Davis 2000; Wong 2001).

Active suspension system has been little investigated, in particular with regard to telescopic handler (telehandlers). These vehicles are not typically involved in user trials assessing WBV exposure, despite the fact that the telehandler is a versatile and widespread vehicle used on different off-road applications (construction, agriculture, mining, etc.) on uneven terrains and for a large number of different operations (Bertani 2014).

The objective of the present study was to investigate whether an active cab suspension system fitted on a telehandler was effective in reducing WBV and in improving comfort for the operators. The study took into consideration the anthropometric variability of users and adopted an ergonomic approach "*concerned with the understanding of the interactions among humans and other elements of a system […]*", which considers users' involvement essential "*in order to optimize human well-being and overall system performance*" (International Ergonomic Association 2015; see also Karwowski 2006; Goodman-Deane et al. 2008).

To characterize the effects of the cab suspension system fitted on the telehandler the following aspects of the human-machine interaction were analyzed: 1) objective measures of vibration magnitude, 2) subjective ratings of general comfort and local body discomfort, 3) anthropometric characteristics of the users.

Materials and methods

Participants

Sixteen male healthy professional telehandler drivers took part in the study. Individuals with a minimum of 5 years of driving experience on telehandlers were chosen to participate in the study. The mean age of the participants and their experience operating telehandlers were 39.4 (SD=12.2) years and 20.0 (SD=14.49) years respectively. Participants completed a brief questionnaire based on the one developed by Bovenzi et al. (2006) about their work experience and musculoskeletal disorders history. All the participants did not reported any musculoskeletal disorders and were suitable for the investigation trials.

The telehandler

The telehandler used in the study was a Merlo make, P55.9CS model. It is a 2 axles, 4 wheel drive vehicle equipped with 103 kW Diesel engine and hydrostatic transmission. The maximum forward speed is 40 kph (25 mph). The vehicle is representative of the typical telehandler architecture adopted by most of the manufacturers: the cab, with the driving station, is on the left while the engine on the right of the vehicle median plane. The telescopic boom, in 3 sections for a maximum length of 9 m, is on the median plane of vehicle. The maximum loading mass of the telescopic boom is 5500 kg. The vehicle was fitted during the test with 19,5 LR24 tires on both axles with an inflation pressure of 400 kpa (58 psi). The vehicle was fitted with an air suspended seat (SEAT make, ACTIVO SERIES S698 model) with 100 mm suspension stroke. The telehandler was equipped with hydro-pneumatic cab suspension system. The system has been designed to reduce vibration magnitude along the vertical direction, from the buttock to the head (z-axis) of the driver. The system is covered by a Merlo patent.

Whole Body Vibration
WBV at the driver's seat interface was measured using a rubber seat pad containing an accelerometer (PCB PIEZOTRONICS ICP Model 356B41 with a sensitivity of 100 mV/g). The seat pad accelerometer was fixed on the seat cushion surface between the driver and the seat. It measured accelerations in three directions (x, y and z direction) ranging from 0.5 Hz to 1000 Hz. The signal from the accelerometers was stored on the laptop using a National Instruments data acquisition card (NI9234). Later on the data were processed using a LabView software (National Instruments, 2012).

Subjective ratings
Subjective measures were collected by a questionnaire based on the one developed by Bovenzi et al. (2006). Participants were asked to rate the comfort perceived regarding vibrations during each trial on an 11-point rating scale, ranging from 0 (no comfort at all) to 10 (extreme comfort). Then, they were asked to identify body areas experiencing discomfort and to rate (from 0=no discomfort to 4=extreme discomfort) the amount of discomfort they experienced during the trial for each body area on a body map (Corlett & Bishop 1976).

Anthropometric parameters
The stature, body mass, Body Mass Index (BMI), hip breadth and sitting height were measured for each of the participants in the study, in accordance with ISO 7250-1 (2012) guidelines regarding variable descriptions, instruments and measurement conditions.

Trials
Objective measurements were carried out while the telehandler was driven over a 100 m ISO smooth track (ISO 5008:2002). Previous studies confirmed that the use of ISO-5008 track provides a reasonable basis for comparison of the WBV to which the operator of a field wheeled-vehicle is exposed, due to the high repeatability of vibration data (Cavallo, Deboli, Paletto, & Preti, 2005; Deboli, Calvo, & Preti 2012; Scarlett, Price, Semple, & Stayner 2005). Each of the participants drove the telehandler on an ISO-smooth track in 4 different conditions:

1. Trial 1 (low, OFF): speed of 5 kph, deactivated suspension
2. Trial 2 (low, ON): speed of 5 kph, activated suspension
3. Trial 3 (high, OFF): speed of 12 kph, deactivated suspension
4. Trial 4 (high, ON): speed of 12 kph, activated suspension

Before the trials, each participant performed a training trial during which he had the possibility to adjust the seat, so, in any of the test conditions, the seat suspension travel was set with vertical adjustments for custom comfort. The fore/aft adjustment of the seat was set to fit the most comfort posture for each participant.

Data analysis

Vibration data were analyzed using LabView software and converted from the record time domain to frequency domain acceleration. The resulting data were then converted to root-mean-square (rms) acceleration. This was used to calculate the frequency weighted rms acceleration values for each of the axis (a_w). The averages of the frequency spectra in one-third octave band were computed for the four trials. The frequency spectra of the accelerations recorded at the operator's seat were then analyzed in one-third octave bands.

Regarding subjective measures, descriptive statistics were computed for each of the 4 trials for comfort ratings, body discomfort areas and perceived jolts.

A series of t-tests were computed to determine whether there were any differences between the vibration magnitude measurements and between comfort ratings with activated and deactivated suspension system at the two different speeds. Correlation between vibration measurements, subjective ratings and anthropometric parameters were then calculated.

Statistical analyses were performed using Statistical Package for Social Science 21 (SPSS software).

Results

Whole body vibration measurements

Table 1 compares the means of the accelerations measured on the three axes with activated and deactivated suspension system at the two speeds. When the suspension system was activated, there was a significant reduction of the acceleration, in particular at high speed and on the z-axis.

Table 1. Means, standard deviations and t-test results for x, y and z-axis frequency weighted rms accelerations (a_w) (m/s^2) for low and high speed, with activated and deactivated cab suspension system.

Speed	Axis	Suspension system		t	p-value
		OFF Mean (SD) (m/s^2)	ON Mean (SD) (m/s^2)		
Low	X	0.42 (0.09)	0.43 (0.08)	-1.19	.250
	Y	0.51 (0.05)	0.52 (0.05)	-3.29	.005
	Z	0.69 (0.16)	0.56 (0.11)	5.08	.000
High	X	0.74 (0.51-0.99)	0.67 (0.51-0.78)	2.48	.038
	Y	0.56 (0.49-0.69)	0.64 (0.57-0.78)	-9.81	.001
	Z	1.72 (1.43-2.28)	1.13 (0.82-1.94)	11.06	.000

Focusing in particular on z-axis, Figure 1 summarize the vibration frequency spectra in one-third octave bands on the z-axis recorded with activated and deactivated system. The series of data are the means calculated on the accelerations recorded on the 16 drivers.

As it can be seen, at low speed, the peak accelerations are in the frequency range 2-4 Hz, with a maximum at 2.5 Hz. In this frequency the cab suspension system reduced nearly 27% the accelerations transmitted from the vehicle to the operators. At high speed, the peak accelerations are in two ranges: between 2 and 4 Hz and between 4 and 20 Hz. The reduction of the acceleration when the cab suspension system was activated was limited to 22% at 2.5 Hz, in the lower range frequency, while it was substantially higher, up to approximately 50% at 4.5 Hz, in the higher range.

(a) (b)

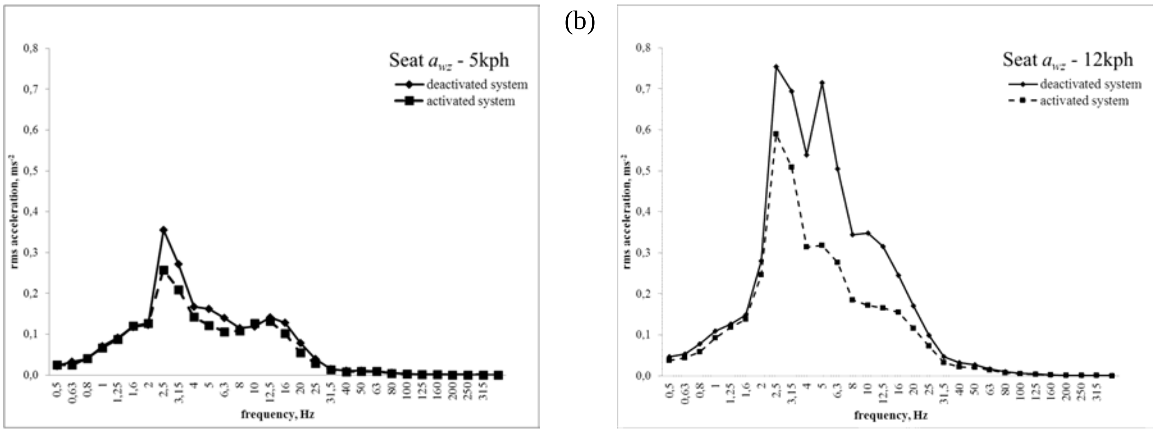

Figure 1. Frequency spectra in one-third octave bands measured on the operator's seat on z-axis at 5 kph (a) and 12 kph (b).

<u>*Subjective ratings*</u>
With regard to comfort ratings in the four trials, the t-test showed that the activation of the system resulted in a significantly higher ratings of comfort at both low and high speed (see Table 2).

Table 2. Comparisons between comfort ratings given at low and high forward speed with activated and deactivated suspension system.

Parameter	Speed	Cab suspension system OFF Mean (SD)	Cab suspension system ON Mean (SD)	t	df	p-value
Comfort ratings	Low	7.13 (1.93)	7.81 (2.04)	-3.47	15	.003
	High	5.19 (2.37)	7.44 (1.99)	-3.92	15	.001

Considering the data coming from the body map, 5 participants reported body discomfort after the trials with deactivated system (Trials 1 and 3) and 4 after the trials with activated system (Trials 2 and 4). Discomfort was reported mainly arising along the lumbar and neck/shoulders regions (see Figure 2) and it was particularly reported for Trial 3. This was the condition with high forward speed and deactivated suspension. A qualitative analysis of Figure 2 shows that, at low speed, there was a slight difference in reported discomfort with activated and deactivated system (Trials 1 and 2), whereas some more consistent differences can be observed at high speed (Trials 3 and 4). In particular at high-speed with activated system (Trial 4) there was not any discomfort reported for knees and ankles. Similarly, in the same trial, discomfort at neck/shoulders and lumbar area decreases.

Overall, when the cab suspension system was activated, there was a reduced number of participants complaining about body discomfort (from 5 to 4 participants) and a reduced intensity of reported discomfort (from moderate to little), with some exceptions in the lumbar area.

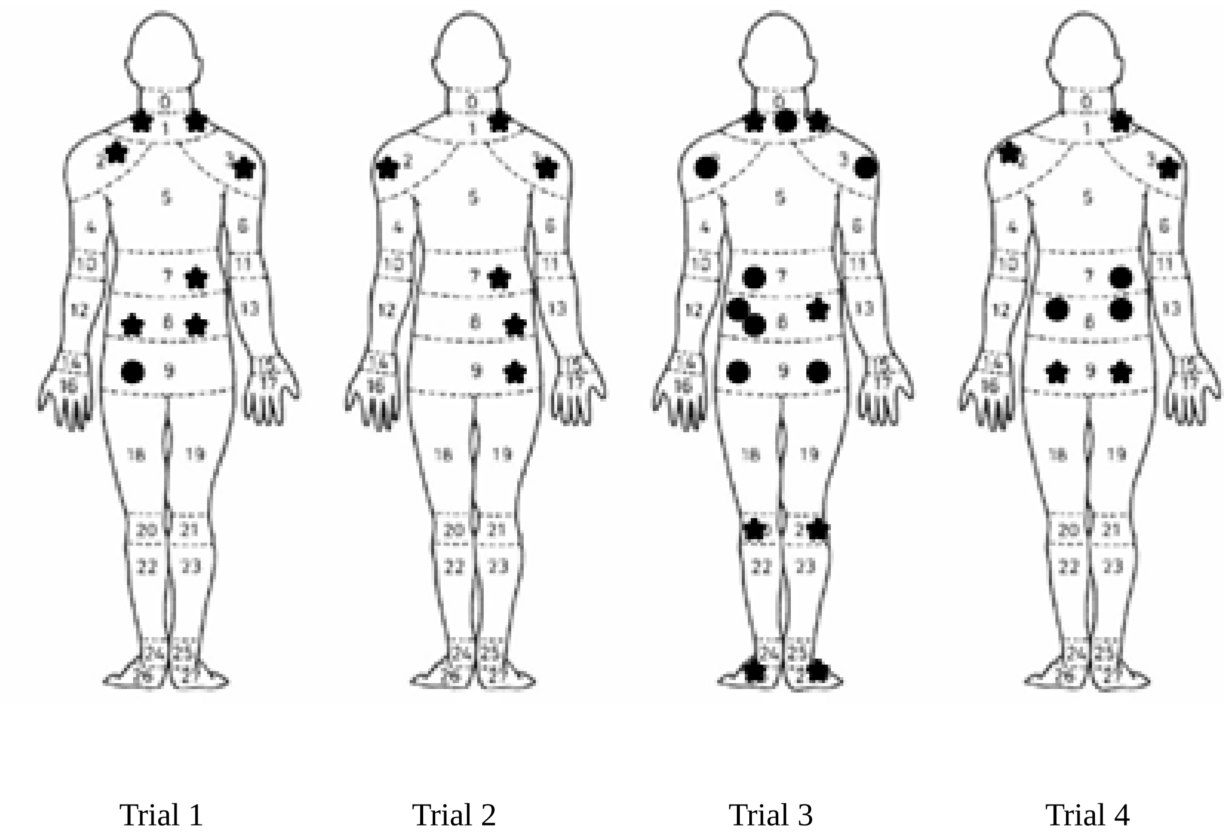

Figure 2. Body maps with levels of discomfort reported by the participants for different body parts during the four trials (star=little discomfort; small circle=moderate discomfort).

Relation between drivers anthropometric parameters, WBV and comfort ratings
The anthropometric characteristics of the participants in the study are reported in Table 3.

Table 3. Anthropometric characteristics of the 16 participants.

	Mean	St.Dev.	Range
Body mass (kg)	88.6	18.5	64-129
Stature (mm)	1751	72	1600-1860
Body Mass Index (kg/m^2)	28.9	5.8	22-42
Hip breadth, sitting	40.6	3.1	35.1-46.5
Sitting height	89.7	4.3	80.4-96.3

The sample was a good representation of the anthropometric variability of the Italian population (ISO 7250-2, 2010; Masali, 2013), with participants from both the 5-10th and the

90-95th percentiles (some participants were even above the 99th percentile with regard to body mass).

Pearson's r correlation coefficients were calculated between anthropometric parameters, WBV measurements along the three axes and comfort ratings for each of the 4 trials. The results are summarized in table 5. The analysis showed that:

1) many significant correlations between objective measurements of vibration and the anthropometric parameters, especially on x- and y-axes;
2) some significant correlations between subjective assessment of comfort and the anthropometric measurements, especially body mass and BMI;
3) no significant correlation between objective measurements of vibration and subjective ratings of comfort.

Table 5. Pearson's r correlation coefficients between anthropometric parameters, WBV measurements along the three axes and comfort ratings for each of the 4 trials.

	Stature	Body mass	Hip breadth	Sitting height	BMI	Trial1 Comfort	Trial2 Comfort	Trial3 Comfort	Trial4 Comfort	Trial1 x	Trial1 y	Trial1 z	Trial2 x	Trial2 y	Trial2 z	Trial3 x	Trial3 y	Trial3 z	Trial4 x	Trial4 y	Trial4 z
Stature	1	.324	.219	.802**	-.054	.065	-.047	-.320	-.091	.260	-.363	-.283	.198	-.397	-.444	.251	-.594*	-.043	-.350	-.627**	.143
Body mass		1	.860**	.132	.926**	.558*	.563*	.140	.662**	-.452	-.201	-.263	-.442	-.305	-.194	-.663**	-.690**	-.392	-.739**	-.653**	-.201
Hip breadth			1	-.056	.804**	.660**	.649**	.287	.775**	-.560*	.051	-.183	-.609*	-.048	-.136	-.730**	-.533*	-.470	-.645**	-.456	-.399
Sitting height				1	-.169	-.039	-.136	-.391	-.234	.402	-.586*	-.241	.429	-.602*	-.291	.401	-.383	-.115	-.099	-.420	.130
BMI					1	.551*	.603*	.260	.719**	-.575*	-.092	-.182	-.538*	-.184	-.046	-.791**	-.498*	-.385	-.650**	-.452	-.260
Trial1 Comfort						1	.922**	.490	.729**	-.428	.107	-.032	-.329	.207	-.020	-.436	-.332	-.275	-.440	-.469	-.558*
Trial2 Comfort							1	.435	.724**	-.446	.138	-.122	-.339	.208	-.076	-.434	-.363	-.424	-.331	-.456	-.619*
Trial3 Comfort								1	.459	-.308	.367	-.083	-.258	.349	-.125	-.173	.119	-.001	-.034	.027	-.063
Trial4 Comfort									1	-.454	.346	.257	-.527*	.304	.178	-.634**	-.282	-.144	-.503*	-.407	-.231
Trial1 x										1	-.273	.353	.916**	-.157	.010	.756**	.039	.462	.536*	-.085	.619*
Trial1 y											1	.412	-.376	.927**	.303	-.100	.435	.285	.095	.313	-.101
Trial1 z												1	.253	.490	.812**	-.002	.329	.453	.294	.176	.309
Trial2 x													1	-.258	.075	.697**	.016	.273	.623**	-.040	.452
Trial2 y														1	.305	.035	.444	.405	.161	.257	-.098
Trial2 z															1	-.315	.445	.003	.297	.437	-.056
Trial3 x																1	.153	.478	.564*	.030	.479
Trial3 y																	1	.235	.389	.866**	-.100
Trial3 z																		1	.054	-.045	.661**
Trial4 x																			1	.503*	.230
Trial4 y																				1	-.148
Trial4 z																					1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Conclusion

WBV is a well-known risk factor for developing MSDs and it is also an important source of discomfort, which can affect performance and lead to injuries (Kittusamy 2002). For these reasons, WBV has to be constantly taken into account and monitored, by means of different preventive measures and solutions (Tiemessen et al. 2007). This is particularly true for field vehicles, given the work they had to perform and the terrain they have to work on, and the time the users have to spend on the machine (Mayton et al. 2008).The present study showed that an active cab suspension system mounted on a telehandler was effective in reducing vibration magnitude and improving comfort in a group of professional users.

An ergonomic approach was adopted in the study to highlight consistencies and discrepancies between different sources of data about WBV exposure and comfort, coming from both the vehicle and the users. Anthropometric characteristics of the users have been considered to investigate which range of physical variability was better protected by the suspension system. At low speed the suspension system reduced WBV especially for taller participants, whereas, at high speed, the cab suspension system led to increased comfort for participants with higher body mass and BMI. The cab suspension system did not eliminate discomfort: some neck/shoulder and lumbar complaints seems to remain.

The results of the study are not conclusive and further investigations are needed to improve vibrational comfort in telehandler users. However, the present study may suggest that the operators, given their wide range of physical variability, may need more adjustable or customizable WBV reduction systems: this may be particularly relevant for those users who have characteristics near to the extreme end of the variability (e.g. aging people, women or migrant workers), whose presence is increasing among the workforce population of the developed countries (de Haan & Rogaly 2002; De Schutter 2013; Ilmarinen 2006).

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Development of an app for using a smartphone as vibro-meter for effects on health evaluation

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Abstract
Italian statistics on work safety are pointing out an increasing number of reports about professional diseases. In this frame are considered the whole-body vibrations (WBV) that could affect operators driving agricultural tractors. The common approach to prevent the related pathologies is to measure some situation that could be representative of the task or to refer to existing database with similar tractor and use. This research follows the approach of monitoring in real time and providing for the development during the working day the driver's level of exposure with a vibro-meter developed as an app to be used with a common smartphone.
This application respects the filters and the weights reported on the ISO 2631:1997; the smartphone has an orientation to respect and gives on the three axis the real time data of exposure (the last minute), the daily exposure (referred to 8 eight hours of work) and the time of exposure. The application has been tested on an agricultural tractor in different operative conditions.
The application provides a simple method for an initial assessment of whole body vibration level of exposure. The system can't substitute a certified chain of measurement but could represent a low-cost device for operator's training for practically explaining the question of the dose of vibration and the importance of monitoring the daily, cumulative dose of vibration.

Keywords: Tractor, Safety, Whole Body Vibration, Early Warning.

Introduction

Italian statistics on work safety are pointing out a decreasing trend about injuries and fatalities but an increasing number of reports about professional diseases.

A mean value of 36% more in the last 5 years has been observed but data in agricultural environment have increased of 383% in the same period.

These data show that the interest about the occupational diseases is increasing.

In this frame are considered the whole-body vibrations (WBV) that could affect operators driving agricultural tractors.

European Parliament Directive 2002/44/EEC sets the minimum requirements for protection of workers from risks to their health and safety arising from exposure to mechanical vibrations and, in 2008, Italy adopted a specific national regulation on safety (Decree no. 81/2008).

The vibration risk for tractor's operator depends from the level and the time of the exposure. Monitoring the exposition is particularly difficult for agricultural tractors because of the heterogeneity of environment and working situations that makes not possible to foresee and standardize the operator exposure to vibration. In operations that involve several different tractors or implements the time of exposure is directly function of the operational time of each operation and is characterized, above all, from the dimensions of the fields and the distance from the farm (Scarlett, 2007; Cutini, 2011; Nguyen, 2011; Sherwin, 2004; Seidel, 1986).

The legislation requires to declare the value of homologation of the seat, but the employer has to evaluate the risk of employees as well. The approach is to measure some situation that could be representative of the job or to refer to existing database with similar tractor and use. This approach is technically correct and recognized from the Authority but doesn't solve the problem of monitoring in real time the driver's level of exposure in specific conditions of work or with a specific tractor (technological level degree of maintenance, etc.).

Another approach that has been introduced concerns the use of vibrometer that could be compared to the use of an exposure-meter, in order to realize a direct measurement of the exposure. The CRA-ING Research Laboratory of Treviglio, Italy, has developed an application for smartphones to measure the exposure to vibration of an operator on the three axis able to predict the development during the working day and provide early warnings.

A first prototype, called INTRAC-vibra, was developed for measuring comfort (Cutini, 2014), according to ISO 2631:1997 part 2, but this doesn't furnish a response about the safety levels of 0.5 and 1 ms^{-2} of the part 1 of the standard, so it was decided to develop a new app.

The new developed application, called INTRAC-safety, respects the filters and the weights of the ISO 2631:1997; the smartphone has an orientation to respect and gives on the three axis the real time data of exposure (the last minute), the daily exposure (referred to 8 eight hours of work) and the time of exposure. The application has been developed in the frame of the INTRAC project, that is addressed to study some fundamental aspect to reduce the risk during the use of agricultural machineries.

Materials and methods

The application was conceived to be used with the most common types of smartphone Android™, for giving a friendly instrument that, anyway, can't substitute the official vibrometers wit seat pad.

Vibration assessment reports the measurement of the weighted root-mean-square (RMS) acceleration considered, it respects the filters and the weights of the ISO 2631:1997 and gives the real-time data of exposure and the daily exposure on the three axis.

The weights ki are multiplying factors defined in the standard and which depends on the point being measured (seat, back or feet) and on the solicited axle (x, y or z). In this case it's referred to the seat and, for experimental studies, carried out on the single axis, it has been assumed:

- kx=ky=1.4
- kz=1

The filters for weighing the measured acceleration are defined in the cited standard and depend on the point of location and on the solicited axle.

The standard requires a measure of vibrations till 80 Hz, this could be a technical limit for smartphone but studies have pointed out that the solicitation on agricultural tractors and the exposure on drivers have the main content of energy below 12 Hz (Cutini, 2010; Deboli, 2012; Park, 2004; Taylor, 2000).

The system requirements of the smartphone are:

- CPU dual core at 1 Ghz (recommended quad core);
- 512 MB RAM;
- at least 20 MB free in the internal memory of the smartphone;
- operating System Android™ 2.3.x (recommended 4.0. or later).

The software has been tested on an actuator generating vibrations and on an agricultural tractor in different operative conditions.

One plate of a four poster test bench has been used (Bisaglia, 2006), fig. 1.

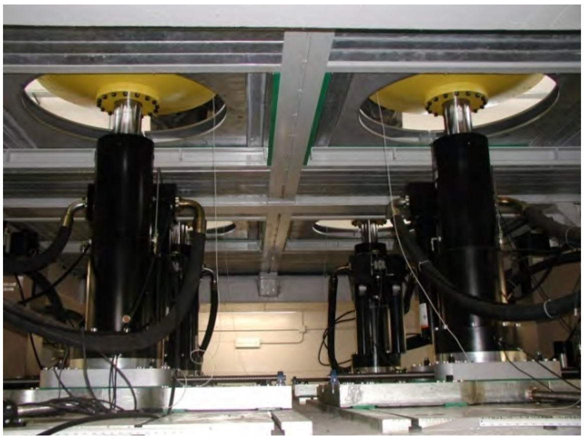

Figure 1. One actuator of the four poster was used for validating the application INTRAC-safety.

The signals adopted were cyclic and random with the following characteristics:

- C_2Hz_8: cyclic, 2 Hz, 8 mm RMS amplitude;
- C_5Hz_1: cyclic, 2 Hz, 8 mm RMS amplitude;
- C_7Hz_0.5: cyclic, 7 Hz, 0.5 mm RMS amplitude;
- C_10Hz_0.5: cyclic, 10 Hz, 0.5 mm RMS amplitude;
- R_1-5Hz_5: random, from 1 to 5 Hz, 5 mm RMS amplitude;
- R_3-8Hz_2: random, from 3 to 8 Hz, 2 mm RMS amplitude;
- R_1-12Hz_3: random, from 1 to 12 Hz, 3 mm RMS amplitude;

The experimental application was carried out using a standard 4WD agricultural tractor nominal 85 kW power. The tractor was fitted with suspended cab and pneumatic seat.

Data obtained with the smartphone were compared with the certified instruments vibrometer HD2030 and a seat pad triaxial accelerometers PCB Piezotronics 356 B 40.

Previous experimental test carried out with the first app developed for evaluating comfort have pointed out at the actuator an overestimation at low frequencies (<2Hz) and an underestimation at frequencies >7Hz. For this reason it was decided to adopt the possibility of modifying, by a gain, the smartphone response respecting the group of frequencies required from the standard. This could allow also to set the software if differences are present between the different positions of the smartphone (i.e. operator's trousers pocket, seat, cab).

The measurements were carried out on three different surfaces and at different forward speeds (fig.2):

- asphalt test track (AT) at 30 km/h: AT_30;
- field with high skeleton content at 6 km/h: SF_6;
- field with high skeleton content at 6 km/h: SF_9.
- ISO 5008 standard test track at 6 km/h: ISO_6
- ISO 5008 standard test track at 10 km/h: ISO_10
- ISO 5008 standard test track at 12 km/h: ISO_12
- ISO 5008 standard test track at 14 km/h: ISO_14

Figure 2. The grassed field and the high skeleton terrain used for test in working condition

Two different positions of the smartphone were adopted:

- in the pocket of the operator's trousers: _P;
- on the side beside the operator: _S.

Results and Discussion

The INTRAC – safety application shows the vibration absorbed during all the working time or during the last minute.

It's possible to install the application as a normal app by downloading and executing the Android™ package with the application "Installer package".

INTRAC – safety starts touching the icon in the "Applications" section.

The smartphone has to be oriented with the screen upwards.

Touching the symbol ► in the upper right corner, INTRAC – safety will start to register the vibrations of the smartphone (fig.3).

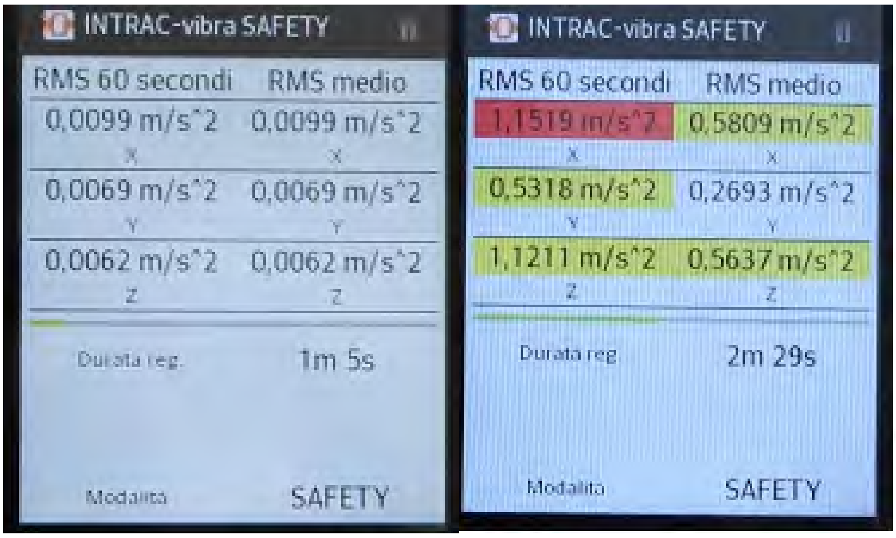

Figure 3. Example of the developed application during working as appeared on the smartphone screen (yellow=uncomfortable; red=dangerous)

After one minute it will start to display the indications. Different levels of alert provide indications to the driver. The yellow fill colour of the value indicates discomfort, the red a value that could be dangerous if considered for 8 hours of exposition.

These limits are, respectively, of 0.5 ms^{-2} and 1 ms^{-2}.

The fields indicate:

- the equivalent level of exposure, each minute (Aeq)
- total RMS of the accelerations measured from the starting of the measurement
- effective exposition time.

The results of the validation of the application at the actuator is reported in table 1.

As expected, it indicates that there's an overestimation of about 20% at low frequencies, less than 5 Hz. This could happen for the different kind of sensibility of the sensors adopted. The value is correct, with an error of about 2%, if the signal is considered between 0 and 10Hz. An underestimation was found with increasing frequencies, in particular over 10Hz (about 30% less).

Table 1. Acceleration value obtained during validation with a setting following the standard

Setting	Vibrometer ms^{-2}	INTRAC-safety ms^{-2}	Mean error %
C_2Hz_8	0.43	0.71	39.4
C_5Hz_1	0.7	0.7	0
C_7Hz_0.5	0.68	0.6	-13.3
C_10Hz_0.5	1.33	1.03	-29.1
R_1-5Hz_5	0.44	0.54	18.5
R_3-8Hz_2	1.5	1.53	2.0
R_1-12Hz_3	0.87	0.78	-11.5

These result confirmed the choice of adopting the possibility of a calibration modifying the gain of the different group of frequencies till 20 Hz. Thanks to this possibility has been optimized the response at the actuator. The smartphone presents difference between 6 and 13% during the random test. The results are reported in table 2.

Table 2. Acceleration value obtained during validation after gain setting

Setting	Vibrometer ms^{-2}	INTRAC-safety ms^{-2}	Mean error %
C_2Hz_8	0.43	0.42	-2.4
C_5Hz_1	0.7	0.67	-4.5
C_7Hz_0.5	0.68	0.66	-3.05
C_10Hz_0.5	1.33	1.27	-4.75
R_1-5Hz_5	0.44	0.51	13.75
R_3-8Hz_2	1.5	1.6	6.3
R_1-12Hz_3	0.87	0.8	-8.8

As already described in the introduction, the standard ISO 2631 requires the measurement of frequencies till 80 Hz. Anyway several studies have demonstrated that the most interesting frequencies, as content of energy, for whole body vibration of operators of agricultural tractors are below 12 Hz. During the test on tractor, the smartphone can't be posed in the same position of the seat pad, so it's necessary to verify if the results could present values of error similar to those at the actuator. The first tests were carried out with the vibrometer as close as possible to the seat pad. For this reason was chosen as location the seat, beside the operator. Also in this case the gain values were adjusted for calibrating the smartphone with the vibrometer. As the possibility of adjusting the gain is common for the three channels, it was chosen to calibrate the z axis. Results present a mean error of 10%. The worst value of error (40%) was obtained during transport on asphalt but with an absolute difference of 0.24 ms^{-2}. The x and the y axis present higher values than the vibrometer and higher values of error than the z axis. The results are reported in table 3.

Table 3. Acceleration value obtained on a working tractor with the smartphone at the seat

Setting	Vibrometer ms^{-2}			INTRAC-safety ms^{-2}			Mean error %		
	x	y	z	x	y	z	x	y	z
ISO_6_S	0.66	0.88	1.72	1.31	0.86	1.42	97.5	2.2	17.6
ISO_10_S	0.79	0.9	2.01	1.40	1.2	1.78	77.2	33.7	11.3
ISO_12_S	0.77	0.88	1.55	1.31	0.90	1.37	71.3	1.8	11.4
ISO_14_S	0.99	0.87	2.53	1.59	1.12	2.22	60.2	28.5	12.2
SF_6_S	0.42	0.86	0.78	0.77	0.61	0.71	84.2	28.7	8.6
SF_9_S	0.80	0.78	1.89	1.54	1.07	1.75	92.2	37.0	7.2
AT_30_S	0.27	0.33	0.61	0.7	1.37	0.85	155.4	318.1	39.9

As one of the aim of the project is the usability of the system, the approach is to define a comfortable location for the smartphone guaranteeing data repeatability. For this reason has been chosen to put the smartphone in the pocket of the operator's trousers.

The calibration setting defined for the position on the seat has been maintained.

The position resulted, as expected, influencing the mean error, as the seat pad is always positioned on the seat. The z axis presents a mean error of 30% but is interesting that remain constant in all the test apart the SF_9_S. There's a worsening of the y axis response while the x axis presents an error lower than on the seat.

The results with the smartphone in the pocket are reported in table 4.

Table 4: Acceleration value obtained on a working tractor with the smartphone in the pocket

Setting	Vibrometer ms^{-2}			INTRAC-safety ms^{-2}			Mean error %		
	x	y	z	x	y	z	x	y	z
ISO_6_S	0.56	0.86	1.42	0.78	1.43	1.77	38.9	65.8	24.7
ISO_10_S	0.81	0.96	1.8	1.23	1.93	2.3	51.3	100.8	28.0
ISO_12_S	0.78	0.86	1.69	1.13	1.88	2.29	44.7	118.9	36.2
ISO_14_S	0.97	0.86	2.25	1.6	2.25	3.12	64.4	162.7	38.5
SF_6_S	0.31	0.68	0.58	0.42	1.05	0.79	34.9	53.9	35.9
SF_9_S	0.83	0.92	1.49	0.97	1.97	2.63	17.5	114.9	77.0
AT_30_S	0.28	0.3	0.61	0.38	0.64	0.78	37.9	113.9	27.5

The values of the correlation ® show a linear relationship between the vibrometer and the smartphone in all the conditions tested for the x and the z axis. This allows to retain that introducing a coefficient could be sufficient for correlating the smartphone position with a correct result. Instead, an in depth analysis has to be carried out for analyzing the response of the y axis that present lower values of linear relationship. In this case the result is retained to be attributed to the low frequencies (<1.5 Hz) characterizing the lateral solicitation that could require a focused setting for y channel. These results are reported in table 5.

Table 5. Correlation analysis (r) between the vibrometer and the smartphone

Position	Correlation	Vibrometer		
		x	y	z
Seat	r (Pearson)	0.97	-0.61	0.98
Pocket		0.96	0.87	0.96

Conclusions

The CRA-ING Research Laboratory of Treviglio, Italy, has developed an application for smartphones to measure and analyze the whole body vibrations regarding the operator's safety. The application has been developed following the requirements of the ISO 2631:1997.

The position of the smartphone resulted influencing results but a correlation was found regarding x and z axis. The setting of the y axis requires an in depth analysis.

The system needs an improvement and verifications with different but could provide a very simple method for an initial assessment of whole body vibration level of exposure.

It could represent a low-cost device for operator's training or for practically explaining the importance of the monitoring of the daily, cumulative dose of vibration.

Acknowledgements

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Noise, vibration and dust emissions of a forestry chipper

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Abstract

Wood biomass is an important energy source, which is attracting much interest from research and agro-industry. Before energy conversion, wood biomass is generally processed into particles of variable size and shape. This treatment is called chipping and it is performed by chippers. Chipping operations generate much noise, vibration and inhalable dust, which can cause potential health risks for the operators. We tested a chipper (Farmi CH260) with loader feeding for chipping of wood material until 260 mm of diameter, powered by a four wheel driven tractor. The tests of chipping were conducted on seven years old poplar trees. The noise and vibration levels were measured in accordance with the ISO 1999:2013 and the ISO 2631-1:2014 standards. The amount of inhalable dust, during field operations, was evaluated according to UNI EN 481:1994. In line with the requests of the Italian law no. 81/2008 and the measured values of noise and dust emitted and vibration transmitted, we calculated the personal daily exposition to noise, vibration and inhalable dust levels, in terms of $L_{EX,8h}$, A(8) and mg m^{-3}, respectively, with the aim to evaluate the most risky parameters of the wood chipping operations.

Keywords: Wood Comminution, Operator Seat, Poplar, Whole-Body Vibrations, Exposure Time, Health Protection.

Introduction

The use of forest and agricultural biomass for energy is an increasingly important topic, particularly in light of the recent debate on climate change. The chipping is a central operation that allows the production of wood chips suitable for energy use. The chippers have been mainly investigated in terms of productivity, cost of the operation, and in recent years, the studies have shifted towards the investigation of more specific variables (Röser *et al.*, 2012; Verani and Sperandio, 2014), but the aspects related to operator safety are still poorly investigated.

Italian Legislative Decree no. 81 of 2008 is the comprehensive act concerning the protection of health and safety in the workplaces. As regards physical agents, the title VIII of the Decree deals particularly with noise and vibration. In the "General part" is stated that health surveillance is carried out on the basis of the risk assessment during daily working time (8 hours).

The Decree states that workers exposed to noise that exceeds 85 dB(A) must undergo to health surveillance. Generally, the health surveillance is carried out once a year, and it can also be extended to workers exposed to 80 dB(A), after their request, and if the occupational doctor confirms the necessity of surveillance. The decree still provides a maximum exposure threshold value equal to 87 dB(A).

As to vibration risks, workers subjected to levels above the action values (0.5 m s^{-2} for the whole body) must undergo health surveillance usually once a year or with different periodicity decided by the competent occupational doctor. Moreover, the decree provides a maximum exposition limit equal to 1 m s^{-2} for the whole body.

As to the risk of exposure to dust, the International Agency for Research on Cancer has classified hardwood dusts as carcinogenic to humans (IARC, 1995), and estimated that at least 2 million people around the world are exposed to the harmful effects of wood dust, especially for respiratory and skin diseases.

The Directive 38/1999 EC, transposed in Italy with the Legislative Decree 81/2008, stated a value for occupational exposure limit (OEL) to wood dust equal to 5.0 mg m^{-3} measured or calculated with relation to a reference period of 8 hours. In 2003, the Scientific Committee of the European Commission for occupational exposure limits (SCOEL) has recommended to apply a lower value of exposure limit, between 1.0 and 1.5 mg m^{-3}, without distinction between wood from deciduous and conifers. In the United States the American Conference of Governmental Industrial Hygienists (ACGIH) and the National Institute for Occupational Safety and Health (NIOSH) set the limit value of exposure to 1 mg m^{-3} (both for softwood and hardwood).

This paper reports the results of a simultaneous test aimed at assessing the risk of noise, vibration and dust caused by a forestry chipper during chipping of wood poplar.

Methods

<u>The forestry chipper and the wood material</u>

The chipper used in the test is a Farmi mod. CH260 with loader feeding for chipping of wood material until 260 mm of diameter. The chipper is composed by a disk rotor of 1050 mm of diameter and weight of 240 kg, with two knives mounted radially. The rotor can work at the speeds of 540 and 1000 min^{-1}. The speed of 1000 min^{-1} was adopted in these tests carried out on seven years old poplar trees. The machine was equipped with an hydraulic loader maneuvered by an operator positioned on a specific seat (Fig. 1).

Figure 1. The tested forestry chipper.

The chipping tests were carried out on 16 poplar plants having the average dimensions reported in Table 1.

Table 1. Average dimensions of the poplar plants (± standard error).

Base diameter cm	DBH diameter (1.3 m) m	Height m	Mass kg
14.4 ± 1.0	11.2 ± 0.7	10.5 ± 1.2	36.8 ± 6.2

During the tests, the operator was sitting on the seat of the hydraulic loader that fed the chipper. The plants were introduced in the loading mouth one by one and the whole operation was timed by detecting the operating times for each separate plant. In Figure 2 is shown the correlation between weight of the plants and the time of chipping.

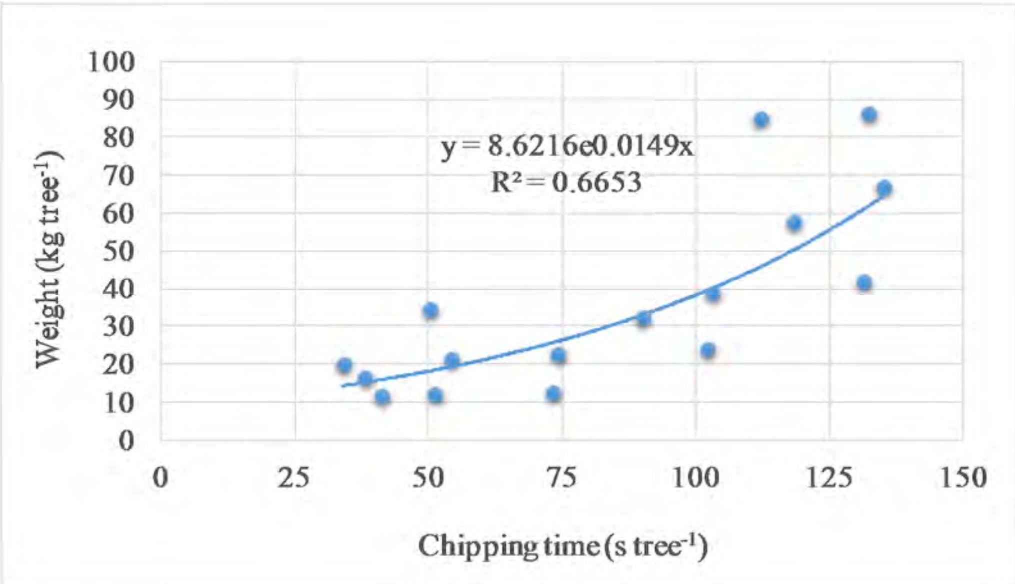

Figure 2. Correlation between chipping time and plant weight.

Measuring instruments

The following instruments were used for the measurements of noise, vibration and dust (Fig. 3):

- signal acquisition and data processing portable system “Soundbook” (SINUS Messtechnik GmbH) with special software “Samurai”;
- microphone Brüel & Kjær, mod. 4189, with wind screen;
- microphone calibrator Brüel & Kjær, mod. 4231;
- triaxial seat pad accelerometer PCB, mod. SEN027;
- calibrator for accelerometers PCB, mod. 394C06;
- personal samplers (air low volume pumps) Zambelli, mod. Ego plus TT.

Figure 3. From left to right: "Soundbook" system for noise; microphone mounted on the operator's safety helmet; seat pad accelerometer; air personal samplers.

<u>*Measurement of sound pressure level*</u>

As for the sound pressure, according to the ISO 1999:2013 standard, it was simultaneously measured the continuous equivalent level of "A" weighted sound pressure ($L_{Aeq,Ti}$) and the maximum C weighted instant sound pressure (p_{peak}). The sound pressure levels were measured for frequency bands in 1/3-octaves in the range 20 Hz - 20 kHz. The measurements were carried out positioning the microphone at 0.1 m from the ear of the operator. Before and after the tests, the deviations from the initial calibration value have been verified by means of the calibrator.

After the measurements, the personal daily exposure levels ($L_{EX,8h}$) were calculated, according to the formula reported by the ISO 1999.

$$L_{EX,8h} = L_{p,A,eqT_e} + 10\,\lg\left(\frac{T_e}{T_0}\right)\,\mathrm{dB} \qquad (1)$$

where:

$L_{p,A,eqTe}$ is the equivalent level of A weighted continuous sound pressure;
T_e is the actual daily working time;
T_0 is the reference working time equal to 8 h.

After having assessed the noise emission levels, the maximum period of exposure was calculated in compliance with the thresholds set by decree D.Lgs. 81/08.

<u>*Measurement of vibration level*</u>

The methodology adopted for the measurement of whole body vibration is reported in the international standard ISO 2631-1:2014. The tri-axial seat pad accelerometer was oriented as shown in Fig. 4. The values of the three axial accelerations (a_{wx}, a_{wy} ed a_{wz}) were simultaneously measured in the 0.5 Hz e 80 Hz frequency range.

The level of exposure to vibrations can be assessed by means of the equivalent acceleration weighted in frequency, referred to 8 h of working time [A(8)], calculated with the relation:

$$A(8) = a_v\sqrt{\frac{T_e}{8}} \qquad (2)$$

where $\boldsymbol{T_e}$ is the actual daily working time and $\boldsymbol{a_v}$ is the acceleration vector:

$$a_v = \sqrt{(1{,}4 \cdot a_{wx})^2 + (1{,}4 \cdot a_{wy})^2 + (1 \cdot a_{wz})^2} \qquad (3)$$

According to the standard, in the relation (2), the calculation can be made using, instead of $\boldsymbol{a_v}$, the higher of the three factors at the second member of the relation (3) if it is much greater than the other two.

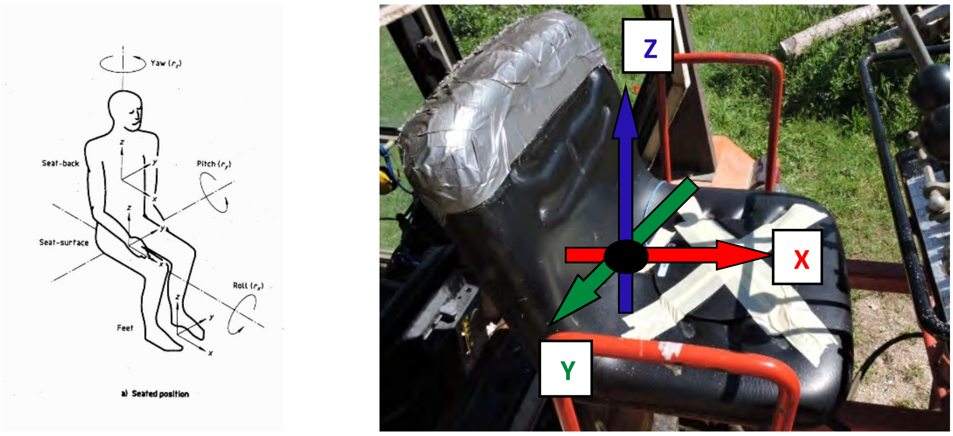

Figure 4. System of coordinates adopted for orienting the seat pad accelerometer, according to the ISO 2631-1:2014.

Sampling of inhalable dust

To measure the concentration of wood dust in the air, two personal air samplers Zambelli (mod. Ego plus TT), were mounted on the frame of the operator's work station. The first sampler was equipped with a cut head "Dorr-Oliver" and it operated at a flowrate of 1.7 L min^{-1}; the second sampler mounted a conical inlet for measuring the total dust and it operated at a flowrate of 4 L min^{-1}. The sampling was carried out by means of 0.45 µm PTFE membrane filter (Millipore, mod. Fluoropore) with a diameter of 37 mm. The mass concentration was determined by gravimetry. All filters were conditioned for 48 h at 50% R.H. before weighing. They were weighted before and after sampling using a 1 µg resolution analytical balance (Gibertini Elettronica).

The sampling method and the classification of dust fractions were in compliance with the D.P.C.M. March 28th, 1983 concerning the "maximum acceptable limit of concentration and exposure to air pollutants in external environment", with the standards UNI EN 481:1994 (Atmosphere in the working place: Definition of granular fractions for the measurement of airborne particles), UNI EN 482:2012 (Atmosphere in the workplace. General requirements of the procedures for the measurement of chemical agents) and UNI EN 14907:2005 (Quality of environmental air. Standard gravimetric measurement method for the determination of the $PM_{2.5}$ mass fraction of the particulate in suspension)

Results

Noise levels

Table 2 shows the values of continuous equivalent level of A-weighted sound pressure ($L_{Aeq,Ti}$) and the maximum value of instant C-weighted sound pressure (p_{peak}).

The values of p_{peak} remain below 87 dB(A), 135 dB(C), as L_{Aeq} are always higher than the exposure limit of 87 dB(A). The values of p_{peak} and L_{Aeq} have been used to calculate the $L_{EX,8h}$ and the maximum utilization time of the forest chipper. In order to not exceed the lower action value [80 dB(A)], the upper action value [85 dB(A)] and the limit value [87 dB(A)], they resulted, respectively, of about 15 min, 30 min and 45 min, very short intervals incompatible with the normal operation, even in presence of workers' rostering. Therefore it is mandatory the use of PPEs for hearing and their evaluation of their effectiveness prior to purchase.

Table 2. Noise levels at the ear of the operator

Thesis	L_{Aeq} dB(A)	L_{Cpeak} dB(C)
Plant 1-4	97.4	121.9
Plant 5-8	98.6	123.0
Plant 9-12	98.3	122.1
Plant 13-16	97.7	123.5
Average	98.0	122.6

Levels of whole body vibration

The values of the axial accelerations a_{wx}, a_{wy} and a_{wz} are reported in the Table 3 together with the values of the sum vector, a_v. As the axial components multiplied by their relative coefficients have similar values, the calculation of A(8) and of the maximum utilization time were made on the basis of a_v.

Table 3. Levels of whole body vibration measured during the chipping of poplar plants

Tesi di prova	a_{wx} m s^{-2}	a_{wy} m s^{-2}	a_{wz} m s^{-2}	a_v m s^{-2}
Pianta 1-4	0.312	0.318	0.432	0.763
Pianta 5-8	0.299	0.278	0.399	0.704
Pianta 9-12	0.206	0.268	0.339	0.620
Pianta 13-16	0.191	0.248	0.298	0.532
Average	0.252	0.278	0.367	0.655

The results show that the levels of whole body vibrations transmitted during the chipping are always lower than the limit value (1.0 m s^{-2}) defined in the D.Lgs 81/08. The A(8) and the maximum utilization time of the chipper always resulted higher than 8 h day^{-1} with reference to the limit value. As to the action value (0.5 m s^{-2}), always exceeded it. Considering the average of a_v (0.655 m s^{-2}), the time would reduce to about 5 h, thus requiring interventions for the reduction of worker exposure.

Amounts of inhalable dust emitted

Table 4 reports the amounts of breathable dust and total dust emitted during the chipping of the poplar wood sample.

Table 4. Results of the dust assessment.

Dust	Cut head	Sampler flow rate	Sampled air volume	Dust on filter	Concentration	Total dust in 8 h(*)
		L min^{-1}	L	mg	mg m^{-3}	mg
Respirable	Dorr-Oliver	1.7	53.6	0.07	1.40	13.4
Total	Conical inlet	4.0	125.7	0.38	3.05	53.8

(*) considering a respiratory rate of 1.2 m^3

The concentrations of both respirable and total dust, respectively equal to 1.40 e 3.05 mg m^{-3}, resulted lower than the exposure limit (5.0 mg m^{-3}) ensuring the respect of the conditions of safety and health according the Legislative Decree 81/08. However, they are higher than the limits proposed by several control organizations (SCOEL, ACGIH, NIOSH).

Figure 5. The workplace and operator during chipping operations.

Conclusions
The test results show that the complexity and variety of forestry work conditions make difficult the assessment of risks for the operator deriving from the exposure to different physical and carcinogen agents. During the chipping of poplar wood, the exposure limits for the dust and, partially, for the vibration were not exceeded, allowing the employment of the same operator, without limitation, for the entire working day.

On the other hand, a drastic limitation of the chipper utilization time is determined by high level of noise emitted by the machine, that represents the limit factor. Basing on these results, the employer is obliged to supply suitable personal protective equipment (PPE) for the hearing, the effectiveness of which must be assured in advance.

The hydraulic loader of the chipper, being devoid of the cabin, does not provide any protection to the operator against the dust and the other microclimatic and environmental parameters. Consequently the operator is exposed to dust generated by chipping. In general, the level of discomfort is increased during summer, by excessive sweating caused by high temperatures.

So considering the work environment and the main types of PPE on the market it is advisable to address the choice on the headset, that is easy to wear and provides an attenuation level close to the standard requirements. Alternatively, expandable earplugs can be conveniently used mainly during summer. Finally, the employer must provide appropriate training and information to workers on the proper use of PPEs and of the operating machines, activating suitable health surveillance for exposed workers.

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Laboratory vibration measurement from hand-held harvesters for olives

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Abstract

Vibration represents the most important risk connected with the use of portable harvesters for olive and other drupe. This research was developed within an inter-laboratory test (Round Robin Test – RRT) with the purpose of measuring the vibration to the hand-arm system produced by one portable harvester. To standardise the measurement under load conditions, a suitable laboratory test bench was used. This paper reports the results obtained by the Section of Mechanic and Mechanisation of the D*i*3A.

The results showed an average acceleration of 2.6 m s^{-2} in idling running and of 13.6 m s^{-2} under load conditions. The highest component was always along x direction (12.8 m s^{-2} under load), the lowest in y direction (1.8 m s^{-2} under load). The test bench proved to be a useful tool to standardise the test conditions, but further studies are necessary to compare acceleration values measured with the test bench and during harvesting.

Keywords: Safety, Olive Harvesting, Vibration Exposure, Hand-Arm System

Introduction

There is a large use of portable harvesters in olive growing aimed at reducing the harvesting costs. The several types available on the market are generally deficient in terms of safety and ergonomics; weight, lack of comfort, high levels of noise and vibration are the most studied aspects (Blandini *et al*., 1997; Deboli *et al*., 2008; Pascuzzi *et al*., 2008). Vibration is probably the most important risk connected with their use, often underestimated by workers, mainly interested in productivity and then exposed to the appearance of the Raynaud syndrome.

Acceleration values reported in literature present great variability (Monarca *et al*., 2007; Pascuzzi *et al*., 2009; Cerruto *et al*., 2010; Çakmak *et al*., 2011; Cerruto *et al*., 2012; Aiello *et al*., 2012; Calvo *et al*., 2014; Deboli *et al*., 2014), so the assessment of the effective risk requires the direct measurement under real working conditions.

This research was developed within an inter-laboratory test (Round Robin Test – RRT), coordinated by Roberto Deboli from the Institute for Agricultural and Earth-moving Machines of Italian National Research Council (CNR), Torino. The RRT had the purpose of measuring the vibration to the hand-arm system produced by one portable harvester. To standardise the measurement under load conditions, the CNR designed and made available to several laboratories a suitable test bench, but each laboratory carried out the measurement using their personnel and equipment. This paper only reports the results obtained by the Section of Mechanic and Mechanisation of the Department of Agricoltura, Alimentazione e Ambiente (D*i*3A).

The laboratory test bench for vibration measurement

The laboratory test bench consists of a square frame 50 cm × 50 cm with a mesh of 5 cm (vertical) × 4 cm (horizontal) of synthetic threads (Figure 1). The horizontal threads have to be subjected to tension manually and then locked by means of clamps, while the vertical ones are pulled by 1 kg masses. This system ensure an almost constant resistance to the rods of the harvesting head, simulating the canopy action.

The frame is applied to a wood structure, made stably by means of suitable weights on its base. The working height is from 140 cm to 190 cm above the ground, so allowing the test of portable harvesters with an angle of about 45°, as usually it happens during the harvesting of olives from trees.

The portable harvester

The portable harvester used for the experimental tests is driven by an electric motor powered by an external 12 V DC battery. Its harvesting head carries the motor and 8 carbon fibres rods, 350 mm long and with diameter of 5 mm. The running frequency, according to the manufacturer specifications, is about 1400 beats per min under load conditions; an electronic card and a software control the rotation speed of the motor, reducing its value at about 400 rpm in idling condition, so to reduce energy requirements and noise and vibration level. The aluminium-made bar is telescopic, with lengths of 1.55–2.60 m and diameters of 25–28 mm.

The experimental activity

Measurements were carried out both at idling and at full load conditions. The machine was only tested with the minimum bar length (1.55 m). Idling tests were carried out with the bar angled of about 45° and each measurement lasted 30 s. Full load measurements were carried out by using the test bench. To this end, the rods of the harvesting head were inserted into the frame at a depth of about 8 cm. After 5–10 s, the rods were extracted and then re-inserted in a different position of the frame, so simulating the harvesting action in an effective olive tree. The measurement time under load conditions lasted 2 min. Measurements were carried out with the machine driven by four operators and replicated five times for each operator.

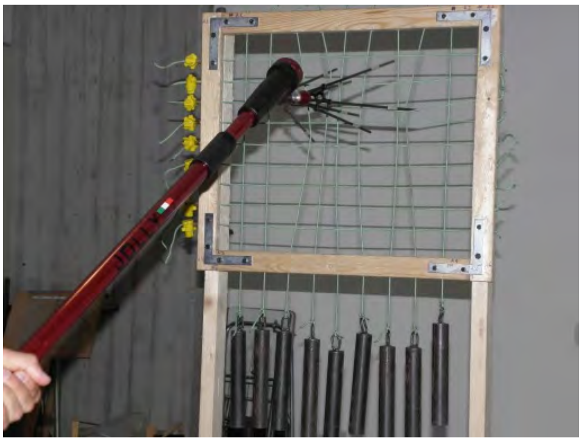

Figure 1. View of the test bench designed at the CNR for vibration measurement.

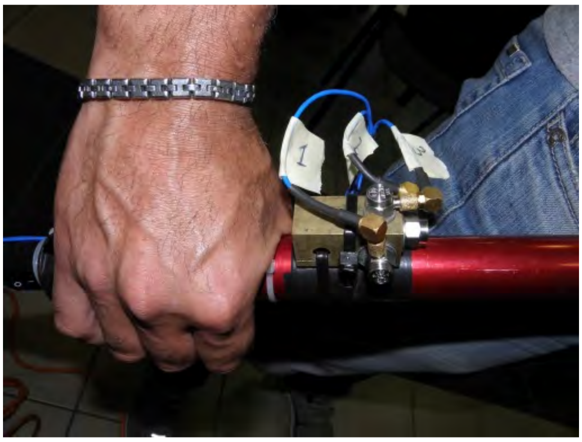

Figure 2. Accelerometer positioning on the bar and reference axes (1: *x*-axis; 2: *y*-axis; 3: *z*-axis).

Acceleration was measured, at different times, next to the hand positions on the bar, at a distance of 85 cm (M1: rear position, near the hand-grip; M2: front position, on the bar) (Figure 2). Weighted rms (root mean square) acceleration values were computed for each reference axis by applying the 1/3 octave analysis in the frequency range 6.3–1250 Hz and then the global weighted acceleration a_{hw} was calculated. Global values were statistically analysed to detect significant differences related to measuring point and working condition.

Results and discussion

The statistical analysis (Kruskal-Wallis test) of a_{hw} values showed that the only significant difference (*p*-level = 0.05) was that between working conditions (Figure 3): on average, the global weighted acceleration was 2.6 m s^{-2} in idling conditions, 13.6 m s^{-2} when using the test bench. Further researches will be developed to compare the results between test bench and harvesting conditions: if the difference will be not significant, the test bench may be an effective tool to standardise the test conditions for portable harvesters. The difference between rear (M1) and front (M2) position was not statistical significant: 8.5 vs. 7.8 m s^{-2}. Finally, the differences between operators were not significant too: acceleration values ranged from 7.4 up to 9.0 m s^{-2}.

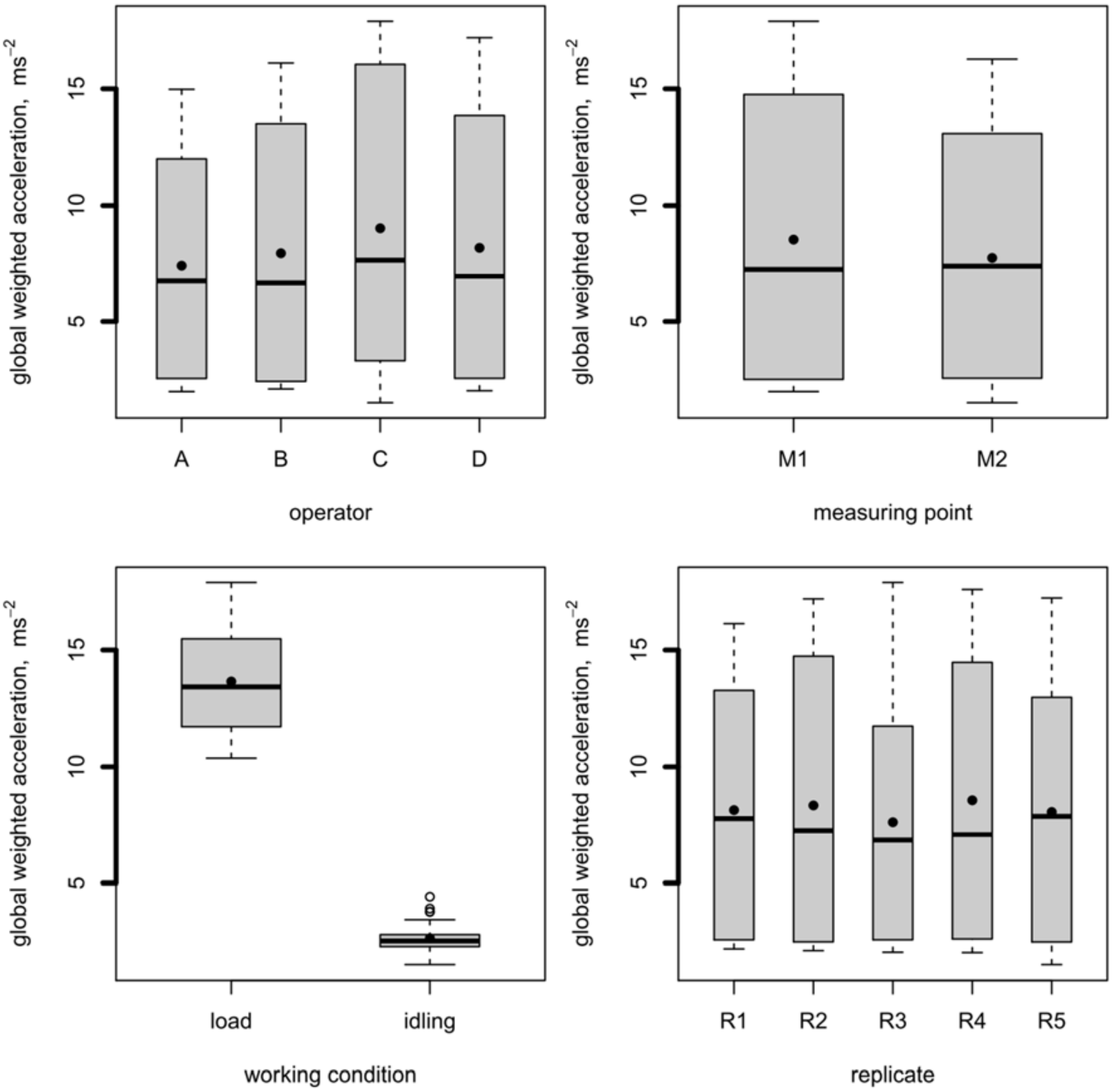

Figure 3. Box-plot of global acceleration values at varying operator, measuring point, working condition and replicate. Points represent mean values.

Weighted acceleration components along the reference axes are reported in Figure 4 at varying the working conditions. In both test conditions, the highest component was that along the *x*-axis, the lowest that along the bar axis (*y*-direction). During idling running, the average *x*-component was 2.1 m s^{-2}, the *y*-component 0.5 m s^{-2}, the *z*-component 1.2 m s^{-2}. The corresponding values under load conditions were 12.8 m s^{-2}, 1.8 m s^{-2} and 4.3 m s^{-2}. So, the interactions between rods and threads of the test bench determined an increase in all the acceleration components from 2.3 (*y* axis) to 5.1 times (*x* axis).

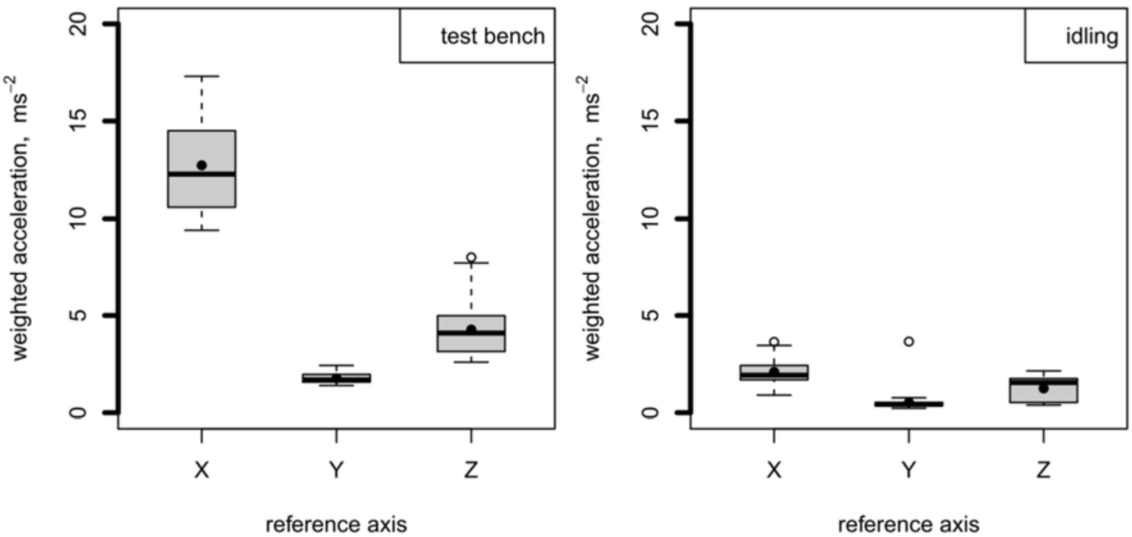

Figure 4. Box-plot of acceleration components values at varying working condition. Points represent mean values.

Conclusions

Portable harvesters for olive harvesting are generally characterised by high levels of vibration and then their use may increase the risk for the safety of the operators. The results of this research confirm this consideration and a lot of studies are still necessary to improve the ergonomic aspects of these machines, mainly regarding the kinematic of the harvesting head.

The average weighted rms acceleration value under load conditions was near 14 m s^{-2}: assuming a daily exposure time equal to 4.5 h (Calvo *et al*., 2014), the corresponding daily vibration exposure value was 10.5 m s^{-2}, much higher than the action (2.5 m s^{-2}) and limit (5.0 m s^{-2}) threshold values established by the Italian regulation 81/08.

The test bench could be a useful tool to standardise the test conditions. However, further studies are necessary to compare acceleration values measured with the test bench and under harvesting conditions.

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Dust emissions with a new hazelnut mechanical harvesting prototype

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Abstract
The mechanical harvesting of hazelnuts (*Corylus avellana* L.) can show a potential health risk because machinery raise soil particles and dust that can be inhaled by the operators. The paper points out the possibility of reducing the quantity of respirable dust emitted into the atmosphere during the harvesting operations by the use of a prototype pick-up harvesting device, mounted on a self-propelled vacuum machine. The tests were carried out in September 2014, to determine the amount of dust emitted into the atmosphere during the hazelnut harvesting. The tests compared the performance of the machine with the novel device mounted and the same model of the vacuum harvesting machine equipped with the conventional harvesting system (consisting of two counter-rotating brushes with rubber blades). A portable particle laser spectrometer and a personal air sampler with a membrane filter were employed to measure the respirable particulate. In average, a lower concentration of dust was recorded near the operator who drives the harvesting machine, with some differences depending on the employed system (spectrometer or air sampler) to assess the dust concentration. The reduction of dust emission is likely due to the configurations of the novel device, which can contain the dust emitted during the harvesting. Further research will be conducted including the determination of the level of free crystalline silica (SLC), another risk factor for the health of operators.

Keywords: Health, Comfort, Particulate Matter, *Corylus avellana* L., Harvesting.

Introduction
The dust emitted from vacuum machines (sometimes containing high levels of pesticides and herbicides) may cause a high environmental pollution during the harvest period of hazel nuts (*Corylus avellana* L.) and constitute a serious risk to the worker's health (Biondi *et al.*, 1992). Engineering solutions have already proposed to reduce the dust drift (Biocca *et al.*, 2012; Cecchini *et al.*, 2012; Fedrizzi *et al*., 2012).

This paper would point out the possibility of using a self-propelled hazelnuts mechanical harvester, which performs its harvesting action through mechanical action with pneumatic suction, limiting the emission of dust in the ambient air. An useful solution may be represented by the employment of the pickup type machines for gathering the fruits form the orchard floor (Ghiotti, 1989). In fact pickup models use a rotating brush to lift the fruits that are then carried forward in the machine passing through succeeding mechanical cleaning and sieving devises. When the orchard floor is covered with grass dust emission is reduced (Fanigliulo and Tomasone, 2009), but this practice remains less common. Being aware of this issue the FACMA, a company based in Vitorchiano (Viterbo - Italy), designed and developed a new prototype pick-up harvesting machine, mounted on a self-propelled vacuum machine. The aim of this work was to evaluate the new technical solutions applied to the machine and to appraise the performance with specific harvesting tests, with particular emphasis to the reduction of dust production.

Methods
The prototype of pickup harvester, model "RM210" (Figure 1), is a self-propelled machine developed for hazelnuts harvesting from the orchard floor. The prototype is powered by Diesel engine, rated 64 kW (86 CV) at 2600 RPM, and complying with the EC/EPA Step 3A emissions standards. The machine has three drive wheels, of which the steering one is placed in the front end of the frame. Power transmission from the engine to the wheels is hydrostatic with differential valve lock on the hydraulic motors coupled to the wheels.

Figure 1. The harvesting vacuum/pick up machine mod. Facma 300 S - RM 210 during the harvesting test.

The hydraulically operated sweeps, placed in the harvester head, gather the product, previously fallen to the ground, into a windrow. The pivoting movement allows the sweeps to follow the soil's profile, reducing the number of fruits left on the ground when not intercepted by the sweeps. The harvesting unit has a total theoretical working width of 2.8 m. A horizontally rotating cylindrical brush, provided with rubber paddles, is placed in the header perpendicularly to the forward direction. The brush, rotating in a direction opposite to the wheels, lifts the nuts from the ground.

The product is so tossed behind and suctioned from the vacuum chamber. The fruits fall onto a cylindrical sieve apparatus for a further sorting of the product, separating all the debris that have a diameter different from that of the hazelnuts. Finally an air stream carries the fruits to sacks held on a tractor-mounted platform or otherwise the nuts are transferred for the final storage, through a flexible tube connection, to a towed trailer with a pantograph lift system for unloading the material. The horizontal cylindrical brush is inserted in an enclosing cylindrical frame, which in the front half holds a metal grid wall. The fine soil passes through the grid form the beginning, while the fruits are lifted from the ground.

Dust falls into a collect chute, holding an auger that pushes the material to the centre of the header. From an opening the dirt is discharged on the ground to one side along the row. The rotation of the auger is powered by a hydraulic motor. The grid helps to remove the soil picked along with the fruits, before it is broken up into smaller particles, so producing lighter dust particles that are more difficult to separate.

The tests were carried out near Sipicciano (Viterbo) Central Italy, (about 42° 31'13" N and 12° 13'17" E) in orchard planted with Italian variety of “*Tonda di Giffoni*” (Figure 2). The test was performed with low or absent wind (mean 0.3; minimum 0.0; maximum 0.5 m sec^{-1}) with average temperature of 25.2° C and relative humidity of 61.2 %.

The orchard floor was covered by a natural grass. The plants had a multi-stemmed training system. Crop management adopted the controlled fine mown turf technique, carried out by making 3-4 passes for each year with a flail mower (starting from spring up to September, just before harvesting time) depending on the seasonal rainfall trend.

The machine settings for an optimal working configurations were made by FACMA’s technical personnel. These regarded mainly: working forward speed and horizontal sweep speed.

Particulate matter (PM) released during the harvesting was sampled on the operator (personal sampling). Personal sampling was carried out by means of an air pump (Zambelli) equipped with PTFE filter membranes, without cutting head, worn by the driver and operating at a flowrate of 4 L min^{-1}, and by means of a portable particle laser spectrometer “Dust track” (TSI Inc.) real-time dust monitor, which can simultaneously measure mass and size fraction (Figure 3), placed in the driving seat.

The tests included two repetitions for each thesis; each plot was composed of three rows of 35 plants (total 410 plants). The test compared the innovative machine with the same machine without the harvesting device mounted (traditional configuration) (Figure 4). During the harvesting tests, the main information regarding the functional aspects of the harvester were also acquired.

Figure 2. The test plot.

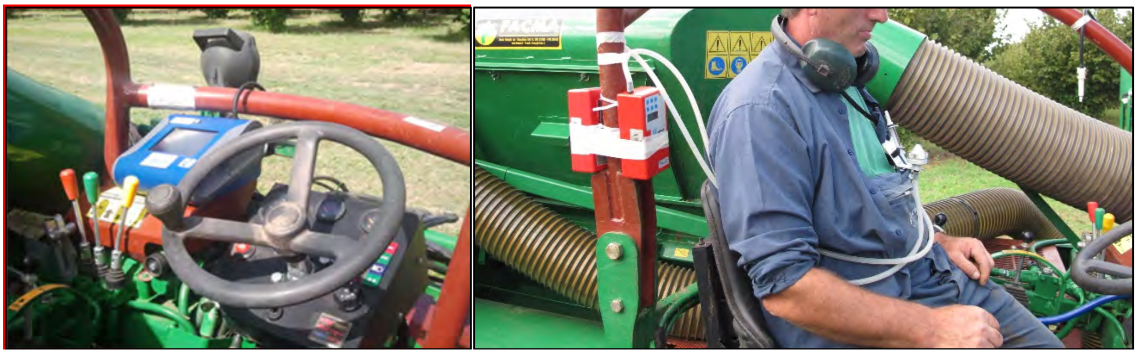

Figure 3. Placement of air samplers on the driving seat (left: "DustTrack"; right: air personal sampler.

Results

The results of the dust sampling, reported in Table 1, showed a slight, but not significant, increased lifting dust from the prototype. Differently, the result of measurements carried out with the laser photometer showed that the prototype pick-up type harvesting machine showed (on average) a reduction in dust concentration of 18.3% with respect to the conventional machine.

Gravimetric analyzes were carried out with samplers without cutting head, while the photometer laser was equipped with a Dorr-Oliver head, for the sampling of the respirable fraction (fractions around the aerodynamic diameter of 4 m). If we consider these different sampling methods, the prototype tested in the field showed lower amounts of fine particles raised (monitored near the driving position).

In fact, the prototype is equipped with a harvesting pick up that "traps" a certain amount of dust, before the aspiration toward the loading hopper. In this way it produces a lower overall quantity of the dust because minor amount of dust can reach the rear cyclones dust abatement.

It is likely that the measurements carried out close to the driving position, take account of this fact. Essentially, the sampling of the total dust is localized, and it referred to the front area of the machine, while in the case of fine particles, which remain raised for a long time, the sampling is index a measure more generalized respect to the position of the sampler.

Table 1. Average concentration of airborne particulate (mg m^{-3}) during harvesting with the traditional machine and the prototype and percentage of dust reduction.

Machine	Sampling method			
	Air sampler	"Dust track"		
		min	max	average
Prototype	8.0	0.001	1.71	0.134
Conventional	7.9	0.004	2.57	0.164
Average reductions	+1.3%			-18.3%

Conclusions

In conclusion, the prototype of the self-propelled hazelnut is an innovative and efficient, suitable for the harvesting from the ground of fruit in shell. In the test conditions, the comparison with the conventional machine with rotating brush showed that the prototype can reduce the overall amount of dust raised from the ground.

Figure 4. The harvesting vacuum machine mod. Facma 300 S, equipped with 2 rotating sweeps

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A filtering-recycling device to reduce dust drift from pneumatic drills

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Abstract
The utilization of dressed seed is a widespread practice to control pests and diseases with reduced doses of pesticides. In recent years, some insecticides employed in seed dressing (namely neonicotinoids and fipronil), have been claimed to contribute to honey bees (*Apis mellifera* L.) spring mortality and decline. Pneumatic precision drills used in maize (*Zea mays* L.) sowing can release amounts of dust coming from the abrasion of dressed seed. To reduce dust spread, we developed an effective prototype device for pneumatic drills, which uses partial recirculation and filtration of the air by means of an anti-pollen filter and an electrostatic filter. Tests at fixed point (simulating sowing of maize seed treated with imidacloprid, thiamethoxam, clothianidin and fipronil) were carried out to assess the efficiency of prototype. Measurements were carried out by sampling, with different methods, the air emitted by the drill in different configurations. With the application of the prototype having the double filtration (anti-pollen plus electrostatic filters), gravimetric and chemical analyses of samples showed values of reduction of emissions always greater than 90%, both in terms of the total mass dust and of the a.i. The application of the electrostatic filter to the system resulted particularly efficient in the reduction of the smaller particles (up 4 µm of diameter). The contribution to the reduction of the sole recirculation system was around 70%. This study contributed to the description of abrasion dust in terms of particle size distribution and provided elements which are useful to further development of the prototype.

Keywords: Neonicotinoids, Honey Bee, Seed Coating, Particulate, Aerosol, Pesticides

Introduction

Pneumatic precision drills (Fanigliulo and Pochi, 2011; Foqué *et al*., 2014) have a seed distribution system based on the vacuum effect created by a centrifugal fan. The sucked air is expelled through the fan opening, dragging with it abrasion dust and seed particles containing dressing (or coating) substances. The drift of dust containing insecticide active ingredients (a.i.) can contribute to the observed mortality or sub-lethal effects on honey bees (*Apis mellifera* L.) and other pollinating insects (Nuyttens *et al*., 2013; Goulson, 2013). Honey bees can come into contact with these compounds in a number of ways (Greatti *et al.*, 2006; Girolami *et al.*, 2009; Samson-Robert, 2014; Bonmatin *et al*., 2015), including aerial powdering with particulate matter containing pesticide residues, during their flight (Marzaro *et al.*, 2011; Pochi *et al.*, 2012). Due to small dimensions of the airborne matter, the drift of abrasion dust containing a.i. can affect large areas, potentially harming the environment and the health of agricultural workers (Biocca *et al*., 2013; Biocca *et al*., 2014) and bystanders. Several factors can affect the extent of the dust drift, such environmental conditions, quality of seed coating, physical properties of dust particles and design and settings of drills.

CRA-ING has developed an innovative device applicable to pneumatic drills to achieve an effective reduction of abrasion dust emissions (Pochi *et al*., 2015). The prototype uses partial recirculation and filtration of the air by means of an anti-pollen filter and an electrostatic filter.

This paper reports the results of tests, carried out at fixed point, aimed at evaluating the prototype efficiency in reducing drift of dust containing four different insecticides.

Methods

Seeds

Commercial maize seed (Pioneer Hy-Bred PR32G44), dressed with Gaucho™, Poncho™, Cruiser™ and Regent™ (respectively a.i: imidacloprid, clothianidin, thiamethoxam and fipronil) and a fungicide (Celest™, a.i.: fludioxonil and metalaxyl) was employed in the tests. The application dose (mg seed^{-1}) was: 1.00 for the imidacloprid, 1.25 for clothianidin, 0.60 for thiamethoxam and 0.50 for fipronil.

Pneumatic seed drills

The sowing machine was a six-row, pneumatic precision drill by Gaspardo (mod. Magica). It was set for a planting a layout of 0.75 x 0.18 m, approximately corresponding to 75,000 seed ha^{-1}. It was originally equipped with a system of four air deflectors, previously tested (Biocca et al., 2011; Pochi et al., 2011). The drill was implemented with two innovative devices (Fig. 1) developed at CRA-ING (called here "APF" and "Electrostatic"). The prototype "APF" works to maintain the abrasion dust, as much as possible, inside the machine by means of a system that recirculate the fan air normal output.

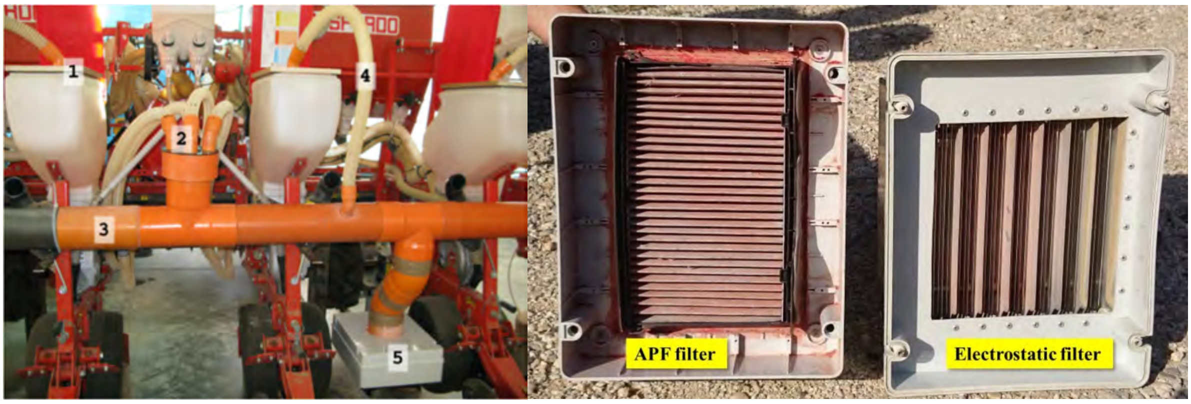

Figure 1. Left: the drill with the device developed at CRA-ING. (1) airtight gasketed lids replacing the normal lids and provided with pipes channelling the air from main collector (3) into the hoppers. (2) collector of pipes coming from the drill's fan; (3) main pipe collector; (4) recycling pipe from hopper to main collector; (5) box with filters, that discharges the filtered air toward the ground. Right: the filters dismounted after use.

The air deflectors was employed to convey the air into a PVC main collector, acting as a compensation chamber of the air pressure. From here, the air flows into the six hoppers, provided with airtight gasketed lids. The air in excess in the system is channelled outwards from the lower side of the main collector, through a box.

The box contains an anti-pollen filter with activated carbon (anti pollen filter)(Bosch), used for air filtration in car cabs (Fig. 1). The prototype “Electrostatic” differs from “APF” only for the presence of an additional electrostatic filter (Expansion Electronics, mod. FE-250) placed before the air exit, to obtain a double filtration (Fig. 1). The electrostatic filter alone has not been tested, so in this work the thesis “Electrostatic” always refers to a double filtration effect. The device is the subject of the international patent application No. PCT/IB2011/053736 (August 25th , 2011).

Test methods
The drills were tested in different configurations using seed dressed with four a.i. (Tab. 1).

Table 1. Sampling scheme (CN= cellulose nitrate filter; PTFE =Teflon filter; OLC = optical laser counter).

Active ingredient	Drill configuration	Sampling
thiamethoxam	Electrostatic	CN, PTFE, OLC
	APF	CN, PTFE, OLC
	Recirculation	CN, PTFE, OLC
clothianidin	Electrostatic	CN, PTFE, OLC
	Recirculation	CN, PTFE, OLC
imidacloprid	Electrostatic	CN, PTFE, OLC
	APF	CN, PTFE, OLC, impactor
	Recirculation	CN, PTFE, OLC, impactor
	Conventional	CN, PTFE, OLC
Fipronil	Electrostatic	CN, PTFE, OLC
	APF	CN, PTFE, OLC
	Recirculation	CN, PTFE, OLC, impactor

The drill configuration named “Conventional” alludes to the drill without any modification; the configuration “Recirculation” is the prototype without the filters (i.e. the drill with the only recirculating circuit mounted); the configurations “APF” and the “Electrostatic” are the complete prototypes (i.e. with filters and recirculating circuit). All the trials were carried out maintaining the drill at fixed point, lifted from the ground, to simulate the sowing of a given amount of seed. The Power Take Off of a 60 kW tractor operated the centrifugal vacuum fan, to generate a -45 mbar pressure. An electric engine, connected to the sowing driving wheel by means of 40/1 gear-reducer, was powered by an inverter (Omron Varispeed V7) to obtain a virtual working velocity of 1.67 m s^{-1}. The distributed seeds were collected in vessels placed under the sowing units and shielded from possible side wind. The time of each single sowing was variable (ranging from 15 to 93 minutes) depending on the seed availability and on the sampling purpose.

Air sampling
In order to test the prototype efficiency, it was carried out a series of samplings of the dust in the drill’s air outlet, with different configurations of the drill. The air samplings were executed in a sampling pipe consisted of a PVC, straight, 2 m long pipe, with diameter of 118 mm, that normalize the air velocity and minimize the particle impacts on the pipe walls. The sampling pipe received the air expelled by the drill by means of deflector pipes connected to the fan air outlet of the drill. An anemometer (TSI, mod. Velocicalc 9535) was inserted into the sampling

pipe to continuously monitor the air speed, allowing airflow calculation. The required isokinetic conditions were identified in preliminary tests.

The air sampling was obtained by means of probes suitably inserted into the sampling pipe. The following determinations were carried out:

1: sampling with membrane filters of cellulose nitrate (CN) for gravimetric determination;

2: sampling with 0.45 μm PTFE (Teflon) membrane filters (diameter 47 mm) to determine the amount of contained a.i;

3: sampling with a multi-stage impactor (Micro-Orifice Uniform Deposit Impactor, MSP-USA, mod. 120), to determine the size distribution of the dust particles within ten size classes (μm): > 18 μm; 10-18; 5.6-10; 3.2-5.6; 1.8-3.2; 1.0-1.8; 0.56-1.0; 0.32-0.56; 0.18-0.32; < 0.18; the filters underwent both to gravimetric and chemical analyses. To collect a significant mass of dust, this sampling was limited only to the thesis with a sufficient quantity of seed (Table 1);

4: determination of the instant numeric concentration of particles within 15 size classes (from 0.3 to 20 μm) by a Grimm 1108 optical laser spectrometer (OLC) (sampling period: 3 s).

The samplings with membrane filters (No. 1 and 2) were carried out by low volume air pumps (Tecora, mod. "Bravo").

The concentration of mass in the filters was determined by gravimetry. All filters were conditioned for 48 h at 50% R.H. before weighing. They were weighed before and after sampling using a 1 μg analytical balance (Gibertini Elettronica).

Chemical analyses

The determination of active ingredients in the samples was carried out at CRA-PAV by means of HPLC coupled to a MSD (Mass Spectrometry Detector) operating with an ES+ (Electrospray Ionisation Interface, positive mode), as described in Biocca *et al.* (2011).

Results

The results of gravimetric and chemical analyses of membrane filters (PTFE and NC, respectively) are reported in Table 2. The data clearly show the efficacy of the filtering system to retain the abrasion dust. In the case of prototype with the sole APF filter, the reduction of emissions (average of three a.i.) is around 94%, both in terms of a.i and mass reduction; with also the electrostatic filter mounted, the reduction increases.

For the a.i. imidacloprid, the comparison involved all the drill configurations and the percentage of reduction is expressed with regard to the conventional drill (i.e. configuration without neither the filter nor the recirculation). This test allows to assess the contribution of the sole recirculation to the total reduction of mass emission and consequently the synergic effect of the filtration and of the recirculation. It seems that about 75% of the dust mass and the 92% of the a.i are retained by the sole recirculation system.

Depending on the a.i., the data show a difference between the emission reduction both in terms of the content of a.i. and in terms of dust mass. In general, there is a greater reduction of a.i. than of dust mass. In other words, it seems that the filters retain a part of dust that contains a greater concentration of a.i.

Table 3 shows the results of the air sampling with the multi-stage impactor. As mentioned, due to seed availability, only three thesis were tested with this sampling.

The figure 2 shows the pattern of particle size distribution obtained with the impactor, in terms of concentration (μg m^{-3}) both of a.i. and mass. For the a.i. imidacloprid, the filtration with APF causes a major reduction of the particles greater than about 4 μm of aerodynamic diameter in comparison with the sole recirculation system. This effect is particularly evident in terms of mass.

Table 2. Concentrations of particulate matter and active ingredients (µg m^{-3}) obtained with the air sampling with the filters and percentage reductions caused by the prototype system (t = thiamethoxam; c = clothianidin; i = imidacloprid; f = fipronil).

Test configuration	Tested a.i.	Active ingredient µg m^{-3}	Mass µg m^{-3}	Reduction in a. i. %	Reduction in mass %
Electrostatic	t, c, i, f	1.4	97.1	99.6	97.4
APF	t, i, f	27.3	179.7	94.7	94.5
Recirculation	t, c, i, f	543.7	2809.5	92.0	74.8
Conventional	i	2704.2	5669.0		

Table 3. Total concentrations of particulate matter and active ingredients (µg m^{-3}) obtained with the air sampling with the impactor (sum of 10 stages) and percentage reductions caused by the prototype system (i = imidacloprid; f = fipronil).

Test configuration	A. i. name	A.i. µg m^{-3}	Mass µg m^{-3}	Reduction in a.i. %	Reduction in mass %
APF	i	4.3	139.6	91.8	50.8
Recirculation		52.2	284.0		
Recirculation	f	99.4	371.2		

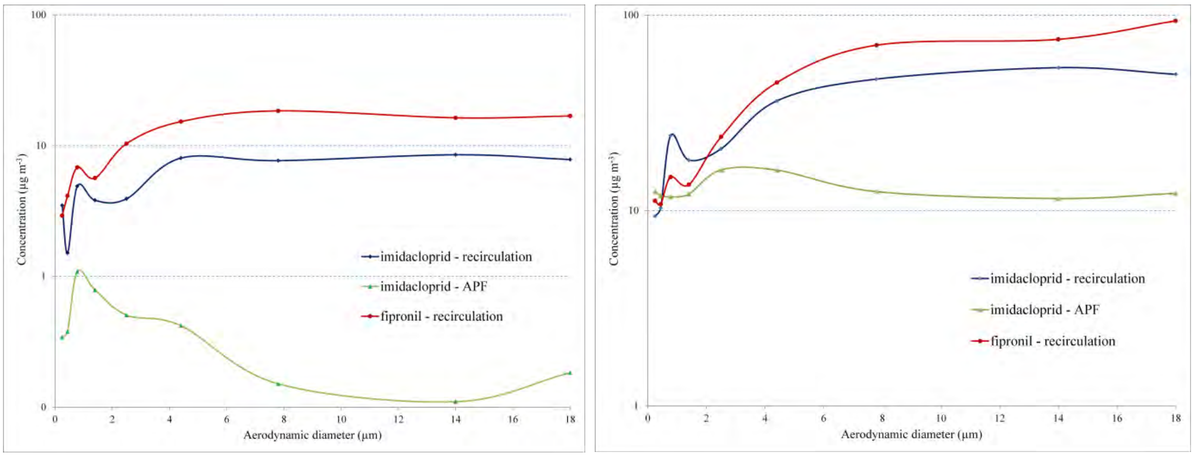

Figure 2. Particle size distribution obtained with the sampling with the multi-stage impactor, in terms of concentrations of a.i. (left) and mass (right).

The sampling with the laser counter allows the determination of the particle size distribution in a different scale of the impactor. Nevertheless, the plot in figure 3 shows once again the strong efficacy of the prototypes in the reduction of emissions. Figure 3 shows the average reduction for all a.i.; it seems that, up to 4 µm of diameter, the electrostatic filter can retain more particles than the APF filter; after this values, the average performance of the two filters is similar, with a slight increase of reduction caused by the sole APF filter for the particles greater than 12 µm.

The figure 4 shows the results obtained with the sampling with the laser counter. The data are expressed in terms of percent number of particles in each size class. Under the diameters of 4 µm, the electrostatic filter retains more particles than the APF filter. This observation is similar from the same data expressed in terms of percentage reduction (fig. 3) where, as mentioned, a threshold of 4 µm has been noted. The figure shows also as the most part of particles have small diameters, generally below 2.5 µm ($PM_{2.5}$).

Conclusions

In this study we showed the efficacy of a novel system mounted on the drill to reduce the amounts of dust emissions during the sowing. A specific trial procedure (consisting in tests carried out with the drill operating a simulated sowing, at fixed point) allowed different kind of samplings of the air stream emitted by the fan of the drill.

The whole innovative device is based on a double treatment of the airflow produced by the drill: the recirculation and the filtration. Firstly, the airflow deposits a part (about 72%) of the dust particles inside the pneumatic circuit of the drill (recirculation effect) and then, particles are retained by an APF filter (about 94%). The electrostatic filter can act a further filtration, reaching around 99% of emission reduction with respect to the conventional (unmodified) drill. The test system was based on measurements of the dust both in terms of gravimetric values and of analysis of chemical content of a.i. Comparing the results obtained in the different configurations, the percentage of the reduction of dust emission is stronger in case we consider its a.i. content, suggesting that the filters can retain fraction of particles with a greater a.i. concentration.

The use of the prototype can be useful in reducing the emissions of dust containing pesticides and to guarantee a healthier workplace for the operator during the sowing. In the same time, the use of the prototype requires a proper handling of the filters, where the dust, that would have been spread in the environment during the sowing, is concentrated. Besides the low dispersion of dust and a.i. in the environment, perhaps, the main advantage from the use of the prototype is that the problem of dust dispersion is displaced from uncontrollable conditions, like the sown field, to controlled conditions, as the farm center, where all the necessary precautions can be taken to avoid the risk for both environment and operators. The lifetime of a filter can be assessed with specific tests. At the end of its lifetime, the filter must be replaced by a new one. The exhaust filters should be considered as toxic wastes derived from the use of pesticides.

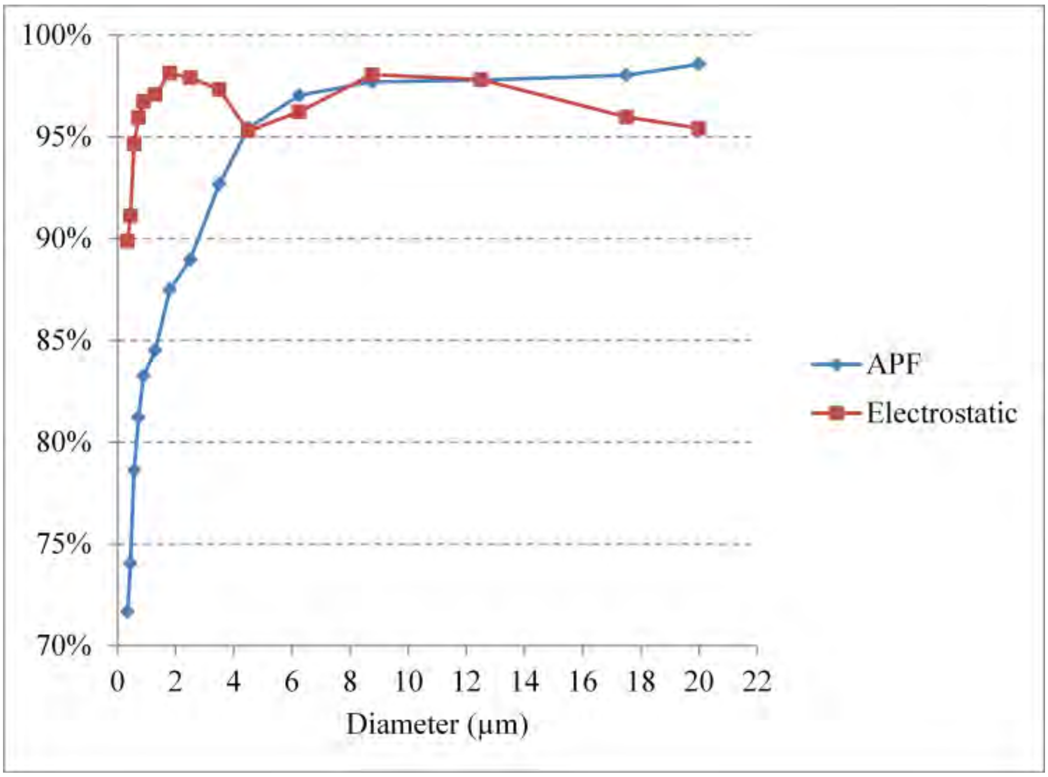

Figure 3. Reduction of particles caused by filters with respect of the recirculation system (average of the four a.i.), in the sampling with the optical laser counter (OLC).

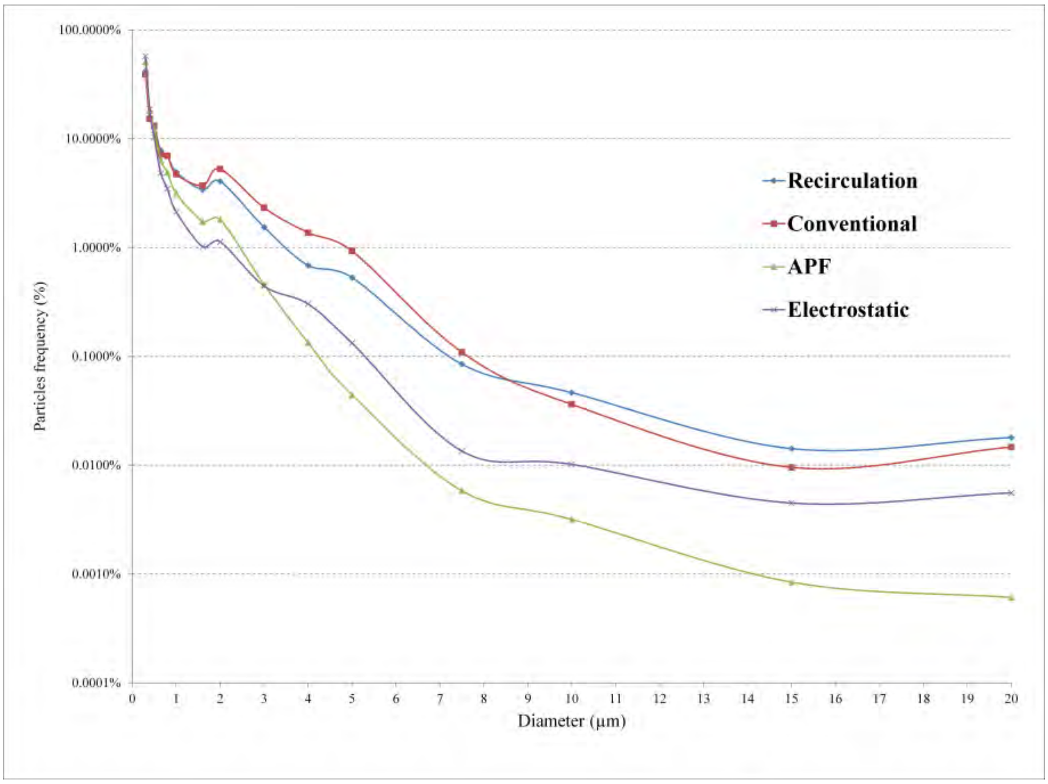

Figure 4. Frequency of particle numbers in the sampling with OLC for the different drill configurations and active ingredients. The vertical axis is in logarithmic scale.

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Risk of exposure to fluoro-edenite fibers of agricultural workers operating in Biancavilla's territory

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Abstract

The municipality of Biancavilla lies on the slope of the Mount Etna, the highest active volcano in Europe, sited in Sicily (Italy), the widest Isle of the Mediterranean sea. A significantly increased standardised rate of mortality from pleural mesothelioma recorded among its inhabitants is comparable to that reported in asbestos-exposed cohorts (Di Paola et al., 1996). This mortality rate has been attributed to exposure to a fibrous amphibole identified by Gianfagna and Oberti (2001) as fluoro-edenite (FE). In the present study, in order to assess the concentration and diffusion of airborne FE fibres in the farmland around the municipal territory, we have used a previously validated sheep model (Rapisarda et al., 2005), as a biological indicator of fibre pollution. In this way it is possible to assess the risk of exposure to FE fibers run by agricultural workers.

Once the risk is ascertained, we are planning to focus on a health surveillance program for this category of workers, so that any pathologies deriving from such unexpected exposure can be prevented.

Introduction

The municipality of Biancavilla lies 515 m above sea level on the SW slope of the Etna volcano in Sicily, Italy. It extends for about 70 km^2 from Mt Etna to the river Simeto and the town occupies a twentieth of its territory. The economy of the city is mainly based on agricultural, sheep and cattle breeding and meat and dairy products.

A significantly increased standardised rate of mortality from pleural mesothelioma recorded among its inhabitants is comparable to that reported in asbestos-exposed cohorts (Di Paola et al., 1996). This mortality rate has been attributed to exposure to a fibrous amphibole identified by Gianfagna and Oberti (2001) as fluoro-edenite (FE), chemically similar to tremolite except that its OH groups are replaced by fluorine. FE fibres have been found in inert materials, such as sand and rubble, extracted from a stone quarry excavated inside the Mt Calvario, lying on the immediate outskirts SE of the town. This material has been widely used for about 50 years for local building (Comba et al., 2003; Paoletti et al., 2000; Rapisarda et al., 2003).

FE has been recently classified by the IARC as carcinogenic to humans (Grosse et al., 2014).

In a previuos study we identified a high risk of pleural plaques in building workers occupationally exposed to FE (Rapisarda et al., 2015).

In the present study, in order to assess the concentration and diffusion of airborne FE fibres in the farmland around the municipal territory, we have used a previously validated sheep model (Rapisarda et al., 2005), as a biological indicator of fibre pollution. In this way it is possible to assess the risk of exposure to FE fibers run by agricultural workers.

Our results seem to demonstrate that a few kilometres from the town there is a certain risk for agricultural workers of inhalation of the dust particles, particularly FE fibres, from the Mt Calvario quarry. Similar results were found by DeNardo and coworkers (2004); they asserted that fiber exposure risk is not confined to the urban area, raising the possibility of hazard to the rural community.

Materials and methods

Six flocks of sheep lying about 3 km from the town were selected and identified using the global positioning system. Their exact position is indicated in figure 1 (areas 1-6).

The shepherds of areas 2, 5 and 6 declared that their sheep always grazed within the same zone, whereas the others (areas 1, 3 and 4) said that in the transhumance period (November-March) their animals are led to a temperate area, about 40 km from the quarry. The mean number of sheep per flock was 190.5 ±45.4.

10 sheep randomly selected from each flock and 10 control sheep from a flock bred in an area of about 30 km from the quarry were sacrificed in a slaughterhouse in September-October. A veterinary surgeon conducted ante- and post-mortem examinations to establish the good health of each animal.

The age range of exposed and control animals was 4.0-6.5 years.

From each sheep we collected the cranial tracheobronchial and one middle mediastinal lymph-node, which drain the right apical lobe and the principal and accessory lung lobes, respectively. Lung tissue from these lobes was also collected.

All samples were fixed in 10% formalin for light microscopy (LM) and in paraformaldehyde 4% in 0.1 M phosphate buffer for scanning electron microscopy (SEM). Special care was taken in removing tissue adhering to lymph-nodes before processing.

Half of cranial tracheobronchial and mediastinal nodes, random selected, were employed for measuring the fibre concentration, whereas the other half was employed for histological observations.

The nodes were digested in sodium hypochlorite solution (15-16% free chlorine; Subalpina, Turin, Italy) according to Morgan and Holmes (12) and the residues were filtrated and collected on 0.2 μm pore size Nucleopore filters. Quantification of ferruginous bodies (FB) and naked fibres was done by LM and SEM, using a Zeiss Axiophot (Oberkochen, Germany) and an electron microscope Philips XL-20, (Philips, Monza, Italy) equipped with an energy dispersion spectrometry x-ray analysis (EDAX) apparatus. Tissue specimens were analysed by SEM with the method described by Tuomi et al. (16). Fibers >1 μm in length and >0.3 μm in diameter were identified, sized and counted at a magnification of x 5000.

Results were expressed as mean ± standard deviation (SD). After variance analysis (ANOVA), data was subjected to Bonferroni's t-test. Significance was established at $p \leq 0.05$.

Results

LM observations did not evidence FB in digested nodes or in histological sections.

SEM analysis of digested lymph-nodes showed some naked fibres, whose X-ray analysis revealed that most of them had the crystallo-chemical features of FE described by Gianfagna and Oberti (8). They ranged from 8 to 41 μm in length and from 0.4 to 1.39 μm in diameter. Their dimensions were similar to those described by Paoletti and co-workers (Paoletti et al., 2000; Rapisarda et al., 2003) in the lung of a housewife from Biancavilla married to a farm worker, who died from pleural mesothelioma. FE fibres were also scattered in histological sections.

No coated FE fibres were observed in digested specimens or in histological sections.

Anthophyllite and man made mineral fibres (MMMF) were discovered in about 3% of samples.

FE fibres were found in all the nodes of exposed animals, but never in those from control sheep. The mean number of fibres, measured as x10^6 fibres/g dry tissue, ranged from 0.06 ±0.01 to 0.11 ±0.05 and was not significantly different among exposed animals. The data regarding fibre concentrations and dimensions in the lymph-nodes of exposed and control animals is reported in table 1.

Discussion

We chose to assess the FE pollution in the farmland measuring the concentration of fibres in tracheobronchial and mediastinal lymph-nodes in sheep habitually grazing at some distance from the quarry with LM and SEM examination.

Sheep lungs are comparable for architecture, volume and respiratory physiological parameters to human lungs (Begin et al., 1981; May, 1970). The sheep model is therefore well suited for dose-response studies to environmental pollutant exposure (Begin et al., 1981; Rapisarda et al., 2005). Sheep have also been employed to study asbestos fibre environmental pollution (Dumortier et al., 2002; McConnochie et al., 1987; Rey et al., 1994).

We studied the tracheobronchial and mediastinal lymph-nodes because they are considered a better indicator of previous asbestos exposure than lung parenchyma: in the latter, the mucociliary and lymphatic systems continuously remove fibres from the lung tissue, thus reducing their concentrations (6), whereas the mineral particles carried from lung alveoli to bronchial nodes accumulate there, turning the nodes into reservoirs of retained material (Gross and Detreville, 1972; Schlesinger, 1985).

Our results seem to demonstrate that a few kilometres from the town there is a certain risk for agricultural workers of inhalation of the dust particles, particularly FE fibres, from the Mt Calvario quarry. Similar results were found by DeNardo and coworkers (2004); they asserted that fiber exposure risk is not confined to the urban area, raising the possibility of hazard to the rural community.

The fibers founds in the nodes were very few compared to those measured in nodes of humans exposed to asbestos (Dodson et al., 1990), but similar to those observed in nodes of non occupationally exposed humans (Dodson et al., 2000).

However, McConnochie et al. (1987) have reported, in the lungs of sheep grazing within 5 miles from an asbestos mine, a tremolite fibers concentration similar to that we noticed in our study.

The presence of a not elevated number of fibers in sheep lymph nodes could be related to: a short time of exposure (maximum 6.5 years); distance from fibers source (minimum 3 Km); low concentration of fibers in house building materials; dispersion of fibers, from Mt. Calvario, with no mechanical alterations so that they still present an aggregation size that does not allow the penetration into respiratory airways.

Conclusions and perspectives

In order to assess the concentration and diffusion of airborne FE fibres in the farmland around the municipal territory, we have used a previously validated sheep model as a biological indicator.

The carried out observations and the laboratory tests show allow us to ascertain a risk of exposure to FE fibres by people living in a FE quarry surrounding.

In particular, obtained results seem to demonstrate that a few kilometres from the town there is a certain risk for agricultural workers of inhalation of the dust particles, particularly FE fibres, from the Mt Calvario quarry.

Once the risk is ascertained, we are planning to focus on a health surveillance program for this category of workers, so that any pathologies deriving from such unexpected exposure can be prevented.

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Table 1. Concentration and size (mean and SD) of FE fibres found in sodium hypochlorite-digested lymph-nodes in exposed and control sheep.

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Control
Concentration x10^6 f/g dry tissue	0.09 ±0.04*	0.11 ±0.05*	0.08 ±0.3*	0.07 ±0.02*	0.07 ±0.03*	0.06 ±0.01*	0 ±0
Fibre length, µm	24.3 ±13.9	23.2 ±12.9	24.1 ±8.6	28.8 ±11.1	26.8 ±10.6	28.6 ±16.8	0 ±0
Fibre diameter, µm	0.87 ± 0.28	0.93 ±0.23	0.86 ±0.35	0.77 ±0.31	0.91 ±0.26	0.85 ±0.41	0 ±0

*$p<0.05$; analysis of variance (ANOVA) exposed *vs.* control.
°$p<0.05$; analysis of variance (ANOVA) exposed *vs.* exposed.

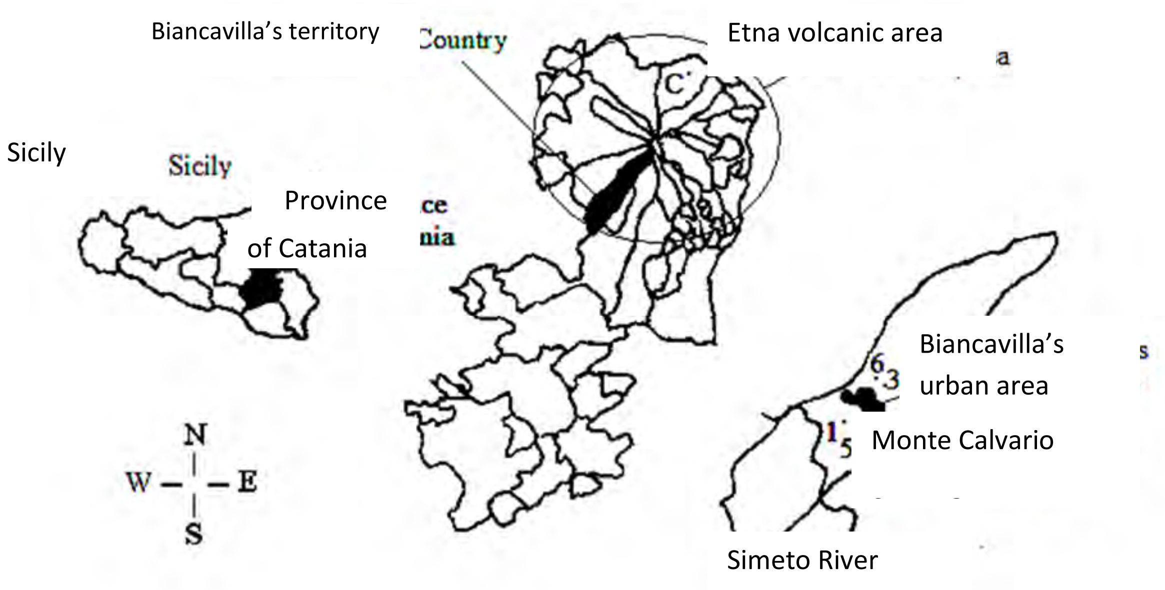

Figure 1. From left to right: map of Sicily; the Province of Catania; the area of Mount Etna (C: the pasture area of the control group); and the territory of the municipality of Biancavilla with the town, the stone quarry and the pastures of the six flocks (1-6).

Noise risk assessment in a modern oil mill plant

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Abstract
High levels of noise usually occur in the oil mill plant because of the machines used to extract extra virgin olive oil. In Italy the Law Decree 81/2008 defined the requirements for assessing and managing noise risk, identifying a number of procedures to be adopted at different noise levels to limit workers exposure. This study aims at evaluating the equivalent and peak noise level inside a modern oil mill plant area. Twenty measurement points were identified inside the oil mill plant area where the machines for olive oil extraction are located (about 200 m^2). The instrument used for the measurements was a precision integrating portable sound level meter, class 1, model HD2110L by Delta OHM, Italy. The measured sound levels exceeded the limits allowed by the regulations in all the measurement points inside the working area; values exceeding the threshold limit of 80 dB(A) were recorded coming up to a maximum value of 93.3 dB(A) close to the hammer crusher. The operators involved are obliged to wear the appropriate Personal Protective Equipment.

Keywords: Noise Risk, Oil Mill Plant, Threshold Limit

Introduction
Noise in agriculture is another relevant risk factor to be taken into account in evaluating health and safety of workers (Vallone & Catania, 2013). Excessive noise is a global occupational health hazard with considerable social and physiological impacts, including noise-induced hearing loss (NIHL) (Deborah et al., 2005).

High levels of noise usually occur in the oil mill plant because of the machines used to extract extra virgin olive oil. Directive 2003/10/EC of the European Parliament was enacted on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise). It stipulates an upper average limit of noise exposure of a worker during an eight hours shift of work at 85 dB(A). This level is supposed to inhibit hearing impairments of workers (Moselhi et al., 1979). Even the ILO (International Labour Organization) indication agree with this.

In Italy, the Law Decree 81/2008 defined the requirements for assessing and managing noise risk, identifying a series of procedures to be adopted at different noise levels to limit workers exposure. Excessive noise, in fact, is a global occupational health hazard with considerable social and physiological impacts, including noise-induced hearing loss (NIHL). This study aims at evaluating the equivalent and peak noise level inside a modern oil mill plant area.

Materials and methods

Oil mill plant
The oil mill plant examined in this study was equipped with the following machines: discharge tank, defoliator, washing machine, hammer crusher, six malaxation machines, horizontal decanter, and vertical centrifuge. Two operators controlled the different phases of the process.

Instruments used during the tests

The instrument used in the tests is a precision integrating portable sound level meter by Delta OHM, Italy, model HD2110L (Fig. 1).

Figure 1. HD2110L integrating portable sound level meter by Delta OHM, Italy.

Experimental tests

The oil mill area has an almost rectangular plant with an area of approximately 200 m^2. Twenty measurement points were located through a square mesh whose sides are orthogonal with respect to the sides of the room (Fig. 2).

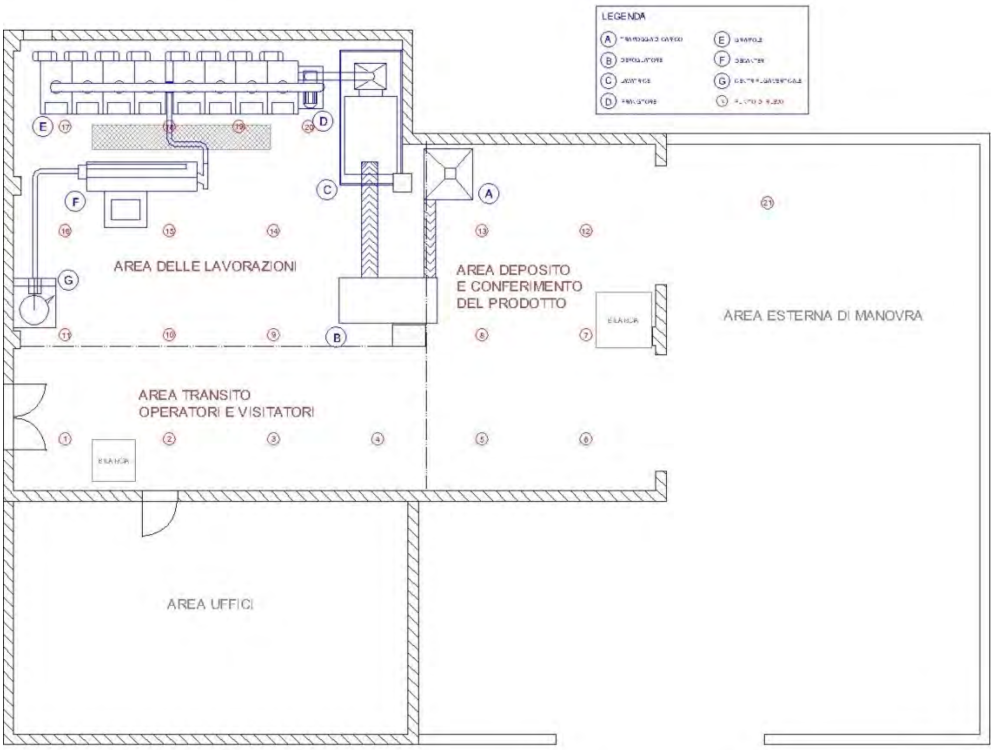

Figure 2. Plan lay out of the oil mill area and measurements points.

The sound level meter was positioned at a height of 1.60 m from the ground with the aid of a tripod; each measurement had a duration of 2 minutes (the case of stationary noise source) and the parameters were analyzed at intervals of 0.5 seconds.

The tests were performed in compliance with EN ISO 9612 and UNI 9432 regulations.

We measured A-weighted time-averaged sound pressure level (L_{Aeq}) and C-weighted peak sound pressure level (L_{Cpk}).

According to article 3 of Directive 2003/10/EC of the European Parliament and article 189 of Italian Law Decree 81/2008, the exposure limit values and exposure action values in respect of the daily noise exposure levels and peak sound pressure are fixed at:

- Lower exposure action values: $L_{EX,8h}$ = 80 dB(A); p_{peak} = 135 dB(C);
- Upper exposure action values: $L_{EX,8h}$ = 85 dB(A); p_{peak} = 137 dB(C);
- Exposure limit values: $L_{EX,8h}$ = 87 dB(A); p_{peak} = 140 dB(C).

where $L_{Eex,8h}$ values (occupational noise) is reported to 8 working hours.

$L_{Eex,8h}$ value is given by the following equation:

$$L_{EX,8h} = L_{Aeq,Te} + 10 \log (T_e / T_0)$$

where Te is the effective duration, in hours, of the working day and T_0 is the reference duration equal to 8 hours. In this case Te was assumed to be 7.5 hours.

Before each series of measurements the instrument calibration was performed applying a sound calibrator. The collected data were downloaded to the PC for further processing.

Results and Discussion

The data obtained by the measurements allowed us to have the equal loudness curves, thereby evaluating the zones with equivalent average sound levels (Fig. 3).

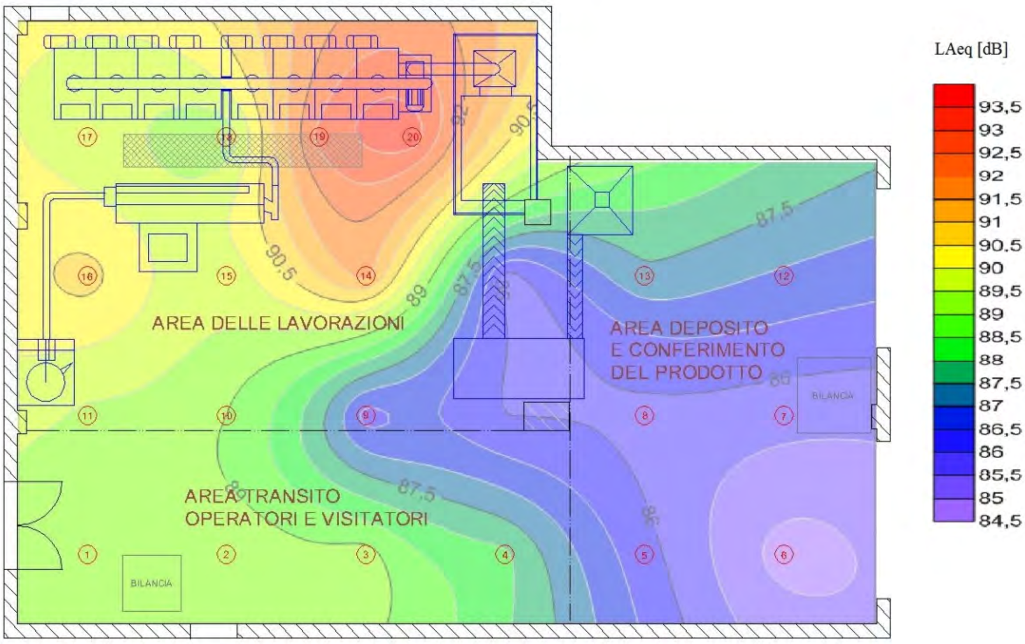

Figure 3. Map of equal loudness curves.

The A-weighted time-averaged sound pressure levels were always higher than the lower exposure action value of 80 dB(A). The minimum noise level was in correspondence of the measurement point number 6 which is located near the storage area, equal to 84.8 dB(A).

The highest value of 93.3 dB(A) was recorded near point number 20, close to the hammer crusher.

Therefore, the highest noise risk for the workers are close to the hammer crusher and the malaxation machines, where the highest noise level was recorded in agreement with the results obtained by Panaro et al. (2005) and Porceddu & Dionigi (2010).

As a consequence, the use of appropriate PPE (Personal Protective Equipment) is required when limits imposed by the regulations are exceeded. In this case, the employer provides workers with personal protective equipment, demanding the use if noise levels exceed 85 dB(A).

With reference to the peak values, neither the exposure limit value equal to 140 dB(C), or the upper and lower action values (equal to 137 dB (C) and 135 dB (C)) are reached or exceeded in any of the measurement points.

In the measurement points number 14, 16, 19 and 20 L_{Aeq} exceeded 90 dB(A); according to the law we are in the presence of dangerous areas where only specialized personnel may access. In all the other measurement points, L_{Aeq} was in the range 85-90 dB(A); therefore it is obliged to use personal protective equipment and carry out an annual audiometric test.

Conclusions

The results show that noise pressure values measured during the test are always higher than the lower action value identified by law, equal to 80 dB(A) In particular, the upper action value equal to 85 dB(A) is reached in all the measurement points located inside the operation area. As a consequence, the use of appropriate PPE is required when limits imposed by the regulations are exceeded.

With reference to the peak values, neither the exposure limit value equal to 140 dB(C), or the upper and lower action values (equal to 137 dB (C) and 135 dB (C)) are reached or exceeded in any of the measurement points.

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Model to analyse semi-active suspension system for a tractor cab

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Abstract

Tractor driving causes comfort and spinal problems due to low-frequency vibrations. For these reasons suspension systems have been adopted in order to limit the vibration transmitted to the driver. However, it has been shown that despite the use of traditional devices like suspensions on the axles, on the cab and on the seat, the level of vibration in some operations is higher than the vibration level limit prescribed by the Directive 2002/44 /CE. The vibration may be reduced through semi-active cab suspension system. The purpose of this research is to develop a specific control system for tractor cab semi-active suspensions in order to reduce the level of vibration compared to traditional suspensions. The analysis of the results shows that the designed control produced a reduction in the level of vibrations transmitted to the driver and an increase in the driving comfort.

Keywords: Ride Vibration, Agricultural Machinery, Controlled System

Nomenclature

$2t_f$	Distance between front right suspension and front left suspension
$2t_r$	Distance between rear right suspension and rear left suspension
a	Distance between reference system center and front suspension
b	Distance between reference system center and rear suspension
[C]	Damping matrix
c_f	Front shock absorbers damping coefficient
c_r	Rear shock absorbers damping coefficient
$[C_{TOT}]$	Global damping matrix
[F]	Linear equation system matrix related to $\underline{v}$
F_{fr}, F_{fl}, F_{rr}, F_{rr}	Forces applied by the semi-active systems in the four cab corners
[K]	Stiffness matrix
k_f	Front springs stiffness
k_r	Rear springs stiffness
$[L_C]$	Linear equation system matrix related to $\underline{\dot{q}}$
[M]	Mass matrix
$\underline{q}$	Degrees of freedom of the system
$\underline{u}$	Forces provided by the semi-active suspension system
$\underline{v}$	Speeds and displacements of the original cab suspension element.
z	Heave displacement
$\dot{z}_{susp,mean}$	Weighted average of the cab corners speed
ϑ	Pitch displacement
$[\Lambda]$	Linear equation system matrix related to $\underline{u}$
ρ	Roll displacement

Introduction

Since the early 60's, most of agricultural machinery manufacturers have begun to install systems able to reduce the whole body vibration (WBV). This is due to the recognition of comfort problems and possible spinal problems caused by low-frequency vibration that arise during the drive of an agricultural tractor. For example the transmission of vibrations to the driver can be reduced with front axle, cab and seat suspensions. However, it has been shown that despite these devices, the level of vibration in some conditions is higher than the exposure limit prescribed by Directive 2002/44 /CE (Scarlett, Price & Stayner, 2007).

Therefore, the introduction of more effective suspensive systems than those currently mounted on tractors is necessary, such as semi-active suspension. These suspensions are able to adjust their damping characteristics depending on the load which they are subjected to (Braghin, Resta & Sabbioni, 2007).The implementation of semi-active suspension in agricultural machinery is a fairly recent event, in fact tractor manufacturers have invested in the development of this technology on high-power tractors only in the last decades.

A control theory widely used on this type of suspension is the Skyhook, a two states control that modifies the damping coefficient of a shock absorber according to the speed at the ends of a suspension (Savaresi, 2010).

However, the Skyhook algorithm has been originally designed for a single degree of freedom system, while the cab is multi degree of freedom system.

The purpose of this research is to develop a specific control system for tractor cab suspensions in order to improve the vibration level compared with passive suspensions.

Materials and methods

The research has been conducted using as a model of study the cab of a tractor with 12.9 L engine size and 441 kW engine power. The weight of the whole tractor is 22126 kg and the cab weight is 1000 kg, estimated from bibliography (Mattetti, 2012).

The tractor is originally equipped with a 4 point cab suspension system with conventional springs and dampers. Therefore, the cab has been modeled as a rigid body in which semi-active suspension systems are installed at the four corners in order to simulate the cab behavior during the ride (Figure 1). Consequently, the cab model has three degrees of freedom: heave (z), roll (ρ) and pitch (ϑ).

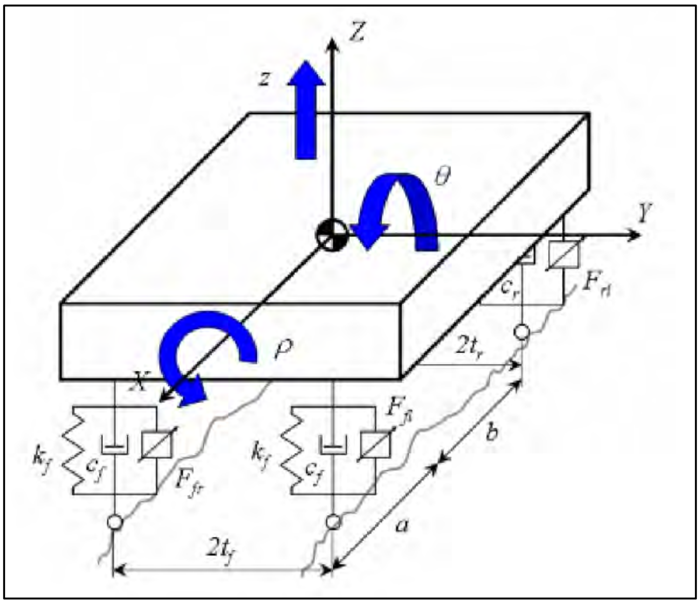

Figure 6. Cab model (Braghin, Resta & Sabbioni, 2007)

The equation of motion of the obtained system is shown in equation 1

$$[M]\underline{\ddot{q}} + [C]\underline{\dot{q}} + [K]\underline{q} = [\Lambda]\underline{u} + [F]\underline{v} \qquad \text{(eq. 1)}$$

Where [M], [C] and [K] are the mass, the damping and the stiffness matrices, respectively. The eight components vector $\underline{v}$ contains the speeds and the displacements of the original cab corners experimentally measured on the ISO 5008 "smooth" test track at 12 km/h (ISO, 2002). Moreover, $\underline{q}$ is a three components vector that contains the degrees of freedom of the system and $\underline{u}$ is a four components vector that contains the forces provided by the semi-active suspension system. The vector $\underline{u}$ is calculated through a modified Skyhook algorithm. First, the values for the damping coefficient have been calculated with the Equations from 2 to 7, being C_{zz}, $C_{\rho\rho}$ and $C_{\theta\theta}$ the diagonal elements of the [C] matrix, respectively.

$$C_z = C_{zz,Max} \ if \ \dot{z}(\dot{z} - \dot{z}_{susp,mean}) \geq 0 \qquad \text{(eq. 2)}$$
$$C_z = C_{zz,Min} \ if \ \dot{z}(\dot{z} - \dot{z}_{susp,mean}) < 0 \qquad \text{(eq. 3)}$$
$$C_\theta = C_{\theta\theta,Max} \ if \ \dot{\theta} \neq 0 \qquad \text{(eq. 4)}$$
$$C_\theta = C_{\theta\theta} \ if \ \dot{\theta} = 0 \qquad \text{(eq. 5)}$$
$$C_\rho = C_{\rho\rho,Max} \ if \ \dot{\rho} \neq 0 \qquad \text{(eq. 6)}$$
$$C_\rho = C_{\rho\rho} \ if \ \dot{\rho} = 0 \qquad \text{(eq. 7)}$$

Then, the obtained values C_z, C_θ and C_ρ have been included as elements of the diagonal matrix [C_{TOT}]. Subsequently, equations 8 and 9 have been used to create a relationship between vector $\underline{u}$ and the matrix [C_{TOT}].

$$[C_{TOT}] = [C] + [\Lambda][L_C] \qquad \text{(eq. 8)}$$
$$\underline{u} = -[L_C]\underline{\dot{q}} \qquad \text{(eq. 9)}$$

[L_C] is a four rows and three columns matrix and its elements have been obtained by solving the equation 8. One can note that equation 8 is an underdetermined system of linear equations. Consequently other conditions on the elements of the [L_C] matrix have been set:

- $L_{11}=L_{21}=L_{31}=L_{41}$: in order to set the same force contribution on all four corners to limit the vertical displacement
- $L_{12}=L_{22}$ and $L_{32}=L_{42}$: in order to set the same force contribution on the same transverse axis to limit the pitch.
- $L_{13}=L_{33}$ and $L_{43}=L_{23}$: in order to set the same force contribution on the same longitudinal axis to limit the roll.

Then the equation 1 could be reformulated like equation 10

$$[M]\underline{\ddot{q}} + \begin{bmatrix} C_z & 0 & 0 \\ 0 & C_\theta & 0 \\ 0 & 0 & C_\rho \end{bmatrix} \underline{\dot{q}} + [K]\underline{q} = [F]\underline{v} \qquad \text{(eq. 10)}$$

Then he cab model has been modeled with the *Power Oriented Graphs (POG)* technique (Zanasi, 2010) and it has been simulated with the software *MATLAB Simulink (Mathworks, Natick, MA)*.

The accelerations obtained from the simulations have been corrected through frequency weighting function according to the ISO standard 2631-1(ISO, 1997), because the human body has different sensitivity to different vibration frequencies. In order to evaluate the benefits of the semi-active suspension system, a comparison has been made between the simulation outputs obtained with the semi-active suspension system activated and the outputs obtained with the same model with the semi-active suspension system deactivated. This has been carried out setting the vector $\underline{u}$ equal to 0.

Results

The graphs in Figure 2 show that there is an acceleration amplitude peak around the 2 Hz frequency. The roll acceleration values are very low, because of the characteristics of the simulated test track and the tractor was running straight.

A big reduction in the accelerations in the range of frequencies between 1 Hz and 5 Hz has been obtained. On the other hand, a slight increase in the acceleration is observable for frequencies higher than 5 Hz. Moreover, the cab equipped with the semi-active suspension system showed a reduction in weighted acceleration of 10% compared with the cab devoid of this system.

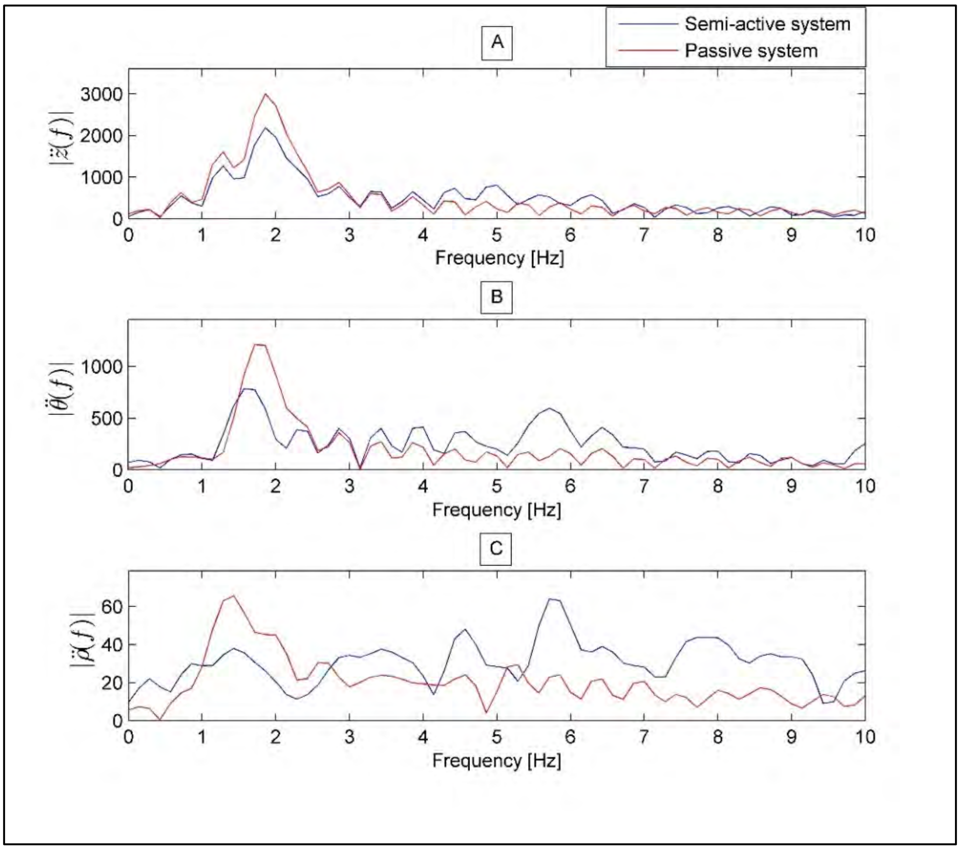

Figure 7. Heave acceleration FFT (a) pitch acceleration FFT (b)

Conclusions

Comfort spinal problems caused by low-frequency vibrations that arise during the drive of an agricultural tractor have been a subject of study over the last decades. A tractor cab equipped with semi-active suspensions is a solid solution for these problems. In the paper a specific control system for tractor cab semi-active suspensions has been designed. The analysis of the results show that the designed control applied to this cab suspension system equipped with semi-active suspension produced a reduction in the vibrations transmitted to the driver and an increase in the driving comfort. A possible future development of this research is the design of a real-time control system based on the control presented in this paper.

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TOPIC 5

"Occupational Health"

Evaluation of safety aspects on a machine for nuts harvesting

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Abstract

The great part of the machine on the market for the collection of the nuts is characterized by a suction member placed over a cart with wheels or tracks, pulled by a tractor. This solution, although effective and efficient in rational cultivation with planting distances designed specifically to allow the passage of agricultural vehicles, misses instead possibility of use in spontaneous mountain hazel, without a regular planting distance. Moreover, the steep slopes that usually occur in wild hazel, make impractical the manoeuvres with the possibility of overturning the tractor vehicle and the carried truck.

Recently were born, also in the traditional way, simple mechanical solutions which consist in placing the suction member for harvesting, above small self-propelled trucks. Recent research has been conducted to evaluate the safety of the operations of harvesting of nuts in sloping land related aspects in noise and roll-over.

In this study was evaluated, in addition to efficiency and to working hours, safety aspects of a machine made by a local craftsman, but that has a commercial success in the Etna area, of considerable importance for the Hazelnuts in Sicily and for the Nebrodi park. The machine is characterized by a vacuum system placed on a self-propelled crawler to collect the nuts in sloping land and with soils corrected with very close terraces and not easy to reach for the traditional mechanization . In particular, attention was focused to aspects of noise level and to stability, evaluated by a tiltable platform.

Moreoverwill be assessed the principle health risks due to biomechanical overload (Work related Skeletal Muscle Disorders), will be analysed through the indices risk assessment of increased use, with particular regard to the operators involved in the harvesting and the manual handling of the product.

Data analysis and evaluation of safety aspects will identify the machine's ability to meet the harvesting operations and any limitations in terms of safety.

Keywords: Safety, Harvesting, Nuts.

Introduction

The production of nuts, in Italy, comes from crops characterized by variable density of planting, often without regular plantation, from steep slopes and rough terrain conditions.

These factors make difficult and dangerous for the operators the use of mechanization in all stages of cultivation, but especially during harvesting. Other factors that affect cultivation are represented by the cost of labor and the lack of economic convenience. Operators, in these areas, rarely uses for harvesting traditional machines available on the market picking machines that aspirate, towed or self-propelled. This kind of machine reduce health hazards and are useful solution (Ghiotti, 1989).

The harvesting aspirating machines, used in awkward areas, are towed.

These machines have small dimensions and a low weight compared to all other machines, allowing use with tractors of small and medium power.

However, the first major obstacle to the use of these harvesters is represented by the presence of the tractor that operate under conditions of high slopes and terraces in addition with risk of roll-over problems. Moreover the reduced interfile are incompatible with the overall mechanization.

So one of the things that most penalizes the labor productivity under these conditions is to find the machines for awkard areas.

So was subjected to study an aspirating compact machine, capable of being transported by simple means such as small tracked pallet.

Methods

Aspects of rollover

Experimental tests were conducted on a suction machine of particularly reduced dimensions assembled to a mini-transporter crawler, schematized in figure 1. The mass and small size of the innovative machine have been selected and designed with the intention to operate in poor areas, characterized by steep slopes and rugged conditions.

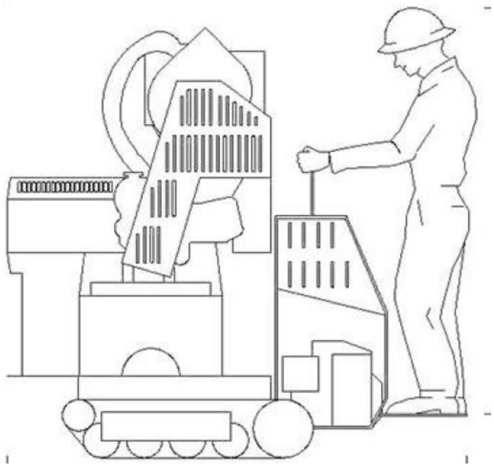

Fig.1: Schematic design of the tested machine.

The overall dimensions of the transpallet were 1.10 m x 2.00 m x 1.75 m of height, the mass was 330 kg, and the load capacity was 500 kg. The technical features of the aspiration device are shown below in Table 1.

Table 1. Technical features of the machine

Total size (m)	length 1,5 - width 1,1 - height 1,4
Mass (kg)	150
Engine	Internal combustion
Mode of leaf removal	a roller with interchangeable cylinder
Suction hose	maximum length 15.00 m
Storage product	movable box 0,54 m x 0,36 m x 0,33 m (h)

The machine was tested using, where possible, established methods and recognized internationally.

To determine the center of gravity was used, the procedure described in Standard ISO 789-6:1982 "Agricultural tractors – Test procedures – Part 6: Centre of gravity".

For stability tests on an inclined plane has adapted the norm UNI ISO 22195-1/2 "Carrelli industriali: verifica della stabilità".

Aspects of noise

For the noise evaluation we used the integrator photometer Brüel & Kjǽr model with responded ISO 9432. The equivalent weighted sound level in curve A of noise exposure of workers during the eight working hours;

1. The peak level.

$$L_{EP,d} = L_{Aeq,Te} + 10\log(\frac{Te}{T0}) \ \text{(dB(A))} \qquad (1)$$

where,

$$L_{Aeq,Te} = 10\log\left\{\frac{1}{Te}\int_0^{Te}\left[\frac{p_a\ (t)}{p_0}\right]^2 dt\right\} \qquad (2)$$

Te represented the daily duration of worker exposition to noise;

T_0 represented the duration of working turn of 8h;

P_a represented the acoustics instantaneous pressure weighted in curve A, expressed in [Pa];

P_0 represented the pressure of 20 μPa audibility threshold.

$$L_{paek}(dB) = 10\log\left(\frac{p_{peak}^2}{p_0^2}\right) \qquad (3)$$

Where, P_{peak} defined come acoustic instantaneous an weighted pressure. This value had the purpose to quantify the characteristics of impulsive sound event because they represent an additional risk factor in the evaluation. The risk bands defined in the abrogated low were:

- L_{EP} > 90 dB(A) o L_{picco} > 140 dB (A)
- L_{EP} > 85 dB(A) e fino a 90 dB(A)
- L_{EP} > 80 dB(A) e fino a 85 dB(A)
- fino a 80 dB(A) di L_{EP}

This bands procured rights, obligations and duties from the prevention figures, mentioned in the norm.

The equivalent measured levels (at least 3 measurements per station), were processed: the data series of equivalent collected levels, was represented through its arithmetic average, and the variability degree (data attitude to arrange around the average value) through the standard deviation:

$$\sigma = \left[\sum_{i=1}^{n}\left(LA_{eq},T - LA_{eq},TM\right)^2/n\right]1/2 \qquad \text{[dB(A)]} \qquad (4)$$

Where:

LA_{eq},TM = level average equivalent value, calculated on n data.

With L. D. 626/94, evaluation methodologies didn't change, compared to the previous legislation until the Legislative Decree 195/06, that integrated the Decree of 1994 with the Title V Bis. The Title V Bis, replaced by the daily noise exposure level (LEX, 8h): [dB (A) refers to 20 Pa]: defined by international standard ISO 1999: 1990, section 3.6. It was referring to all kind of noise at workplace, including impulsive noise;

$$LEX, 8h = L_{Aeq,Te} + 10 \log \left(\frac{T_e}{T_0}\right) \qquad \text{[dB(A)]} \qquad (5)$$

From the point of view of calculation there was no difference between the LEP,d and the LEX, 8h; while a diversity observed with the peak level that wasn't measured as L_{peak} in linear form but as a peak acoustic pressure (p peak), that is the maximum value of the instantaneous acoustic pressure frequency weighted "C";

$$L_{picco}(dB) = 10 \log \frac{p_{peak}^2}{p_0^2} \qquad \text{[dB(C)]} \qquad (6)$$

The introduction of Title V Bis went to change even the previous risk bands, imposing new exposition limits:

LEX,8h = 87 dB(A) ppeak = 200 Pa (140 dB(C) related to 20 μPa).
Higher action values:
LEX,8h = 85 dB(A) ppeak = 140 Pa (137 dB(C) related to 20 μPa).
Lower action values:
LEX,8h = 80 dB(A) ppeak = 112 Pa (135 dB(C) related to 20 μPa).

Per quanto concerne la valutazione del rischio per il sistema mano-braccio si applica la norma UNI EN ISO 5349-1:2004 (versione in lingua italiana della norma ISO 5349 del 1986, aggiornata nel 2001 dalle EN ISO 5349-1/2).

Aspects of vibration to the hand-arm system

With regard to the assessment of risk to the hand-arm system has been applied to the UNI EN ISO 5349-1: 2004 (Italian version of ISO 5349 in 1986, updated in 2001 by EN ISO 5349-1 / 2) .

Aspects of efficiency and to working hours

For testing the experimental methodology used is that given by CIOSTA (Commission Internationale de l'Organisation Scientifique du Travail en Agriculture): in particular the work time are classified in accordance with Recommendation AIGR. For analysis of the working times tables we were used chronometric precision for the relief of the times.

Following the analysis of harvest times, repeated for a few hours on several plots with different characteristics between them, with variable gradients from 24% to 35% it is determined the amount of hazelnuts gathered in one hour of work.

Aspects of health risks due to biomechanical overload

The study, in this early stage, concerns the analysis and risk assessment of biomechanical overload in the hazelnuts cultivation. This is an multi-tasks complex analysis in an annual cycle, in which the seasonal characteristic of the agricultural sector will greatly influence the work and therefore the workers exposure to the risk.

Furthermore in mountain *corilicoltura* many of the cultivation operations, which generally are mechanized, are performed manually constituting a major source of physical overload.

The first phase has focused on the identification of hazelnuts processing, by the plant at harvest and post-harvest, with the subsequent decomposition of the work in the elementary stages.

In the slope less relevant, where it was possible to perform the collection through machine facilitator, the operation of the worker involved in the collection is reduced, in this case, to the only movement of the aspiration tube. Were carried out, therefore, harvesting tests, employing different types of handles for the aspiration tube to verify which provides greater comfort.

For gathering was carried out an initial risk assessment of biomechanical overload due to the repetitive motion, using the OCRA checklist.

Results

Aspects of rollover

Regarding the tests for determining the center of gravity, the coordinates which identify its location have been identified with the method of successive weighings, and with the longitudinal inclination of the machine by an angle of 20 degrees so as to cause a mass transfer on the axle on the ground.

The recorded values are reported in Tab. 3 where (x) identifies the distance of the center of gravity from the plane passing through the center of the conductor axle (rear sprocket), (y) indicates the distance from the vertical median plane (positive to the right) and (z) locates the center of gravity height from the ground.

Table 3. Coordinate position of the center of gravity of the prototype.

Coordinate	Value (m)
x	0,444
y	0,09
z	0,583

Regarding the tests for determining the stability on an inclined plane, in table 4 are shown the values of stability carried out, in the month of January 2015 at the CRA-ING of Treviglio, in static conditions and with any machine discharge collected.

It assessed whether the condition without operator, both the one with the possible operator on the platform through a ballast placed on a stand on the platform one meter high. Therefore, such circumstances must be properly considered when operating under real conditions, with the machine running and operator led.

The test was repeated in three positions, the first with the longitudinal axis of the machine parallel to the tilting axis of the plane (fig.4), the second with the longitudinal axis of the machine perpendicular to the tilting axis of the plane (fig.5) and the third with an angle such that the center of the wheel of the front axle aligned rearly with the center of the axle result parallel with the tilting axis of the plane .

All configurations have been repeated for both sides.

The results are reported in table 4 where appears the different level of stability between right and left side due to the decentering of the center of gravity with respect to the longitudinal axis. It is possible to note that the presence of the operator reduces the stability of the vehicle on a slope.

Table 4. Slope values to which you record the lifting of the track.

Slope to the lifting of the track (°)

	WITHOUT OPERATOR	WITH OPERATOR
Frame lined	30,8 (left) / 26,4 (dx)	26,8 (sx) / 23,9 (dx)
Transverse frame	26.4 (down) / > 35 (uphill)	32,6 (down) / 21,6 (uphill)
Slanting frame	29 (left) / 33 (right)	25,1 (sx) / 28,5 (dx)

<u>Aspects of noise</u>

As regards the reliefs related to the sound pressure, in a measurement time of 30 minutes, was detected 84 (Leg (A)) in the transfers, in a measurement time of 5 minutes, 94.6 for the harvesting phase of the hazelnuts with engines running close to the machine, and 77.0 at the end of the aspiration tube for a time of 120 minutes.

<u>Aspects of vibration to the hand-arm system</u>

The assessment tests of the hand arm system made during the transfer in the field of the machine showed a maximum Aw sum (m / s2) equal to 15,00 for a time of 60 minutes, while in the phase of hazelnuts harvesting sensors have highlighted a Aw sum (m / s2) equal to 2.40 for a time of 60 minutes. Therefore, the A (8) is equal to 5.37.

<u>Aspects of efficiency and to working hours</u>

The site collection organized with the prototype at the Sicilian companies reported a labor productivity of 21 kg / h with one operator, compared with 8.5 kg / h of the traditional (manual harvesting), then with productivity gains of 2,5 times. Ultimately, the same amount of hazelnuts harvested with the aid of the prototype with two workers, requires collection of traditional 5 employees.

In a traditional site collection manual, an operator (usually the labor costs in the collection phase is female) has an hourly capacity in average value of about 8.5 kg /h, which corresponds to about 60 kg /day. So the same amount of hazelnut harvest "mechanically" with 2 people, need to "manual" of 5 people.

<u>Aspects of health risks due to biomechanical overload</u>

Harvesting tests were made using different types of handles for the suction hose to verify which provides greater comfort. The operator, who often works on his knees, according to its experience, choose whether to carry out the gathering with one or both hands.

The harvest is characterized by a high frequency of gestures and by continuous pinch of the fingers. In pending the operator, if he works standing, bend less his back keeping the arms under the shoulder height.

In less sloping land, the operator curve over his back to pick the fruit, working with his arms at shoulder level. The stereotypy is high because are always repeated the same actions.

The force required for harvesting is negligible, but the displacement of the bucket, which gradually fills up, requires gradually more and more effort to be reckoned in the risk calculation.

From risk assessment through OCRA checklists, the manual harvesting is within the viola range, in which there is a real risk of biomechanical overload.

The tests conducted with the aspiration machine showed some employed handles do not ensure a grip smoother. Moreover, the limited length of the aspiration tube, forces the worker, even in this case, to work with hunched back. Checks showed, also, that the handles that can be contested with both hands, with ergonomic handle (soft and non-slip), associated with work gloves that help grip, are preferred over other solutions. The movement of the tube provides static ports of the hand and arm movements that never get to reach extreme postures. Also in this case always repeat the same actions. The force required for the collection is relative to the weight of the tube. From evaluation through checklists OCRA, funding through facilitator is within the range of average risk.

Conclusions

The prototype developed in this work is proposed as a possible solution to the mechanization of harvesting the nuts in soils with planting distances and irregular with slopes. On the occasion of the technical evaluation carried out in November 2014, it looked at whether its size that were contained; the steering angle that thanks to the tracks and to the hydraulic transmission is reduced.

In the same survey it was verified the suction capacity of hazelnuts. The ability to manage slopes found objective evidence during the tests conducted at the Laboratory of Treviglio the CRA-ING at which the car was conducted in the month of January 2015.

The checks carried out on the prototype have therefore confirmed the efficiency of the machine in its ability to do the work of aspiration, not the high acoustic impact and rollover resistance to the slopes in the study.

The harvesting through facilitator, as well as to significantly increase the capacity to collect, significantly improves working conditions. It appears, in fact, a significant reduction in the risk of biomechanical overload compared to manual harvesting mainly due to better posture of the back and arms. The presence of an ergonomic handle also reduces the effort for the handling of the suction tube. The possibility of alternation in the operations of collection is, also, a further advantage to be taken into consideration.

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Safe in the field: a project for training and integration of foreign agricultural workers

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Abstract

The project "Safe in the Field", funded by the Lazio Region and activated by Department of Science and Technology for Agriculture, Forestry, Nature and Energy and "Innovation & Resources" Ltd, was launched September 15, 2014 and ended March 14, 2015.
The first phase of the project was a research regarding the training needs for workers in the farms of Lazio Region. Subsequently training courses were provided, each lasting 10 hours, per groups of workers from different nations (Italy, India, Romania), with the presence of native tutors in the classroom and the availability of educational materials in language.
One of the aims of the research is to understand the relationship between risk perception among farmers and the main risk factors to which they are exposed. Furthermore to investigate the influence of the training in risk perception in agriculture.
The research regarding the training needs for workers was done by means of a study on distribution of different crops in the region, a study on injuries and occupational diseases in agriculture (Lazio) and a questionnaire submitted to a sample of farms.
As it regards the research on risk perception, the data collection was made possible thanks to the use of a questionnaire designed to investigate the perception of risk that was given to a sample of 99 agricultural workers at the beginning and at the end of the courses.
The results of the project consist in training of agricultural workers. A product of the project was the site *http://ergolab.wix.com/sicurincampo* that provides a platform for the support of teaching materials for work health and safety training for farmers (training materials in 5 languages).
A previous research from the same Authors showed that the perception of risk is related to having attended training courses, but those who report having attended safety courses do not always enact safe behavior.
While we cannot draw conclusions about the behavior of workers after attending the course, the analysis of the questionnaires shows a clear improvement in the perception of risk.

Keywords: Training and Information, Foreign Workers, Safety And Health

Introduction

The project "Safe in the Field", funded by the Lazio Region and activated by Department of Science and Technology for Agriculture, Forestry, Nature and Energy (University of Tuscia, Viterbo, Italy) and "Innovation & Resources" Ltd (Rome, Italy), was launched September 15, 2014 and ended March 14, 2015.

The first phase of the project was a research regarding the training needs for workers in the farms of Lazio Region. Subsequently training courses were provided, each lasting 10 hours, per groups of workers from different nations (Italy, India, Romania), with the presence of native tutors in the classroom and the availability of educational materials in language.

One of the aims of the project was to understand the relationship between risk perception among farmers and the main risk factors to which they are exposed.

The European Agency for Safety and Health at Work (EU-OSHA) defines risk "the likelihood that a hazard will actually cause its adverse effects, together with a measure of the effect". This is a probabilistic concept, not indicating the conditions or factors that determine or contribute an occurrence. A linguistic definition of risk is a "possibility of suffering harm related to the circumstances as far as is predictable" (www.treccani.it). This definition introduces the dimension of knowledge and perception: the damage takes place for the occurrence of circumstances that could be expected in the case of knowledge and perception of their negative potential effects. Knowledge of risk affects the perception, but this is due to a subjective dimension that is related to cognitive, organizational, cultural and emotional factors. As evidenced by Slovic it usually results in a harmful discrepancy between the subjective perception of risk and its objective evaluation (Slovic, 2000). An assessment can only be based on knowledge, but be carried in such a way so as not to lead to an underestimation of risk causing an inadvertent exposure or an overestimation of risk that would cause panic and inability to make decisions (Lavanco, 2003). In both cases, there is an increase of probability of a "mistake", that means a wrong answer to a condition of adaptation; cognitive "dysfunctions" happen, with an alteration in the perception of risk; therefore to remedy it is necessary to identify the environmental, psychological and behavioral causes (Marino et al, 2010).

The perception of risk is the result of a very broad range of factors, primarily cognitive, emotional and socio-organizational (Antonucci et al, 2012). Unfortunately there is not always a consistent perception of risk between operators. The overestimation or underestimation of risk are problematic. Both have serious consequences on people's ability to manage risk properly from the point of view of prevention.

An objective of the research is to investigate the influence of the training in risk perception in agriculture.

Methods

The research regarding the training needs for workers was done by means of a study on distribution of different crops in the region, a study on injuries and occupational diseases in agriculture (Lazio) and a questionnaire submitted to a sample of 60 farms.

As it regards the research on risk perception, the search tool that we delineated is a questionnaire consisting of 25 items to be answered on a scale from 1 (poor / no effect) to 5 (good / relevant). The main issues were: the risk due to tractor overturning; the exposure to noise and vibration; the chemical risk; ergonomics (posture, handling of heavy loads and handling of low loads at high frequency); the use of personal protective equipment; information and training.

The questionnaire was submitted to a sample of 99 agricultural workers at the beginning and at the end of the courses. The collected data were analyzed with software Excell®.

Results

As it regards the training needs for workers, the knowledge of the working context is very important. The main characteristics of agriculture in Lazio Region are:

- the extreme "pulverization" of farms;
- the extreme "polarization" of the size distribution of farms (90% less than 5 ha, 0.7% more than 50 ha);
- the farm fragmentation (47% one body farms, 9.8% more than 5 bodies);
- the scarcity of processing industries (often by family);
- small farms often employ family labor (in many cases made by elderly or figures with

poor alternative employment).

The main agricultural sectors are (Carbone et al, 2004): sheep and goat (2nd in Italy for milk, 3rd for meat); vegetable productions (8% gross marketable production in Italian horticulture); actinidia (Latina province) (1st in Italy); hazelnuts (Viterbo province) (2nd in Italy); olive oil; sheep cheese; wine production.

Important factors consist in the increasing number of foreign workers (table 1) and in educational disadvantage of workers and farm owners (figure 1) (ISTAT, 2010).

Table 1. Total workforce, number of people for citizenship (Lazio)

Province	Italian	Foreign from EU country	Foreign from extra EU country	Total
Viterbo	60420	1101	566	**62087**
Rieti	27488	433	210	**28131**
Roma	67452	1626	995	**70073**
Latina	64132	3203	4287	**71622**
Frosinone	73419	193	774	**73690**
TOTAL	**292911**	**6556**	**6832**	**305603**

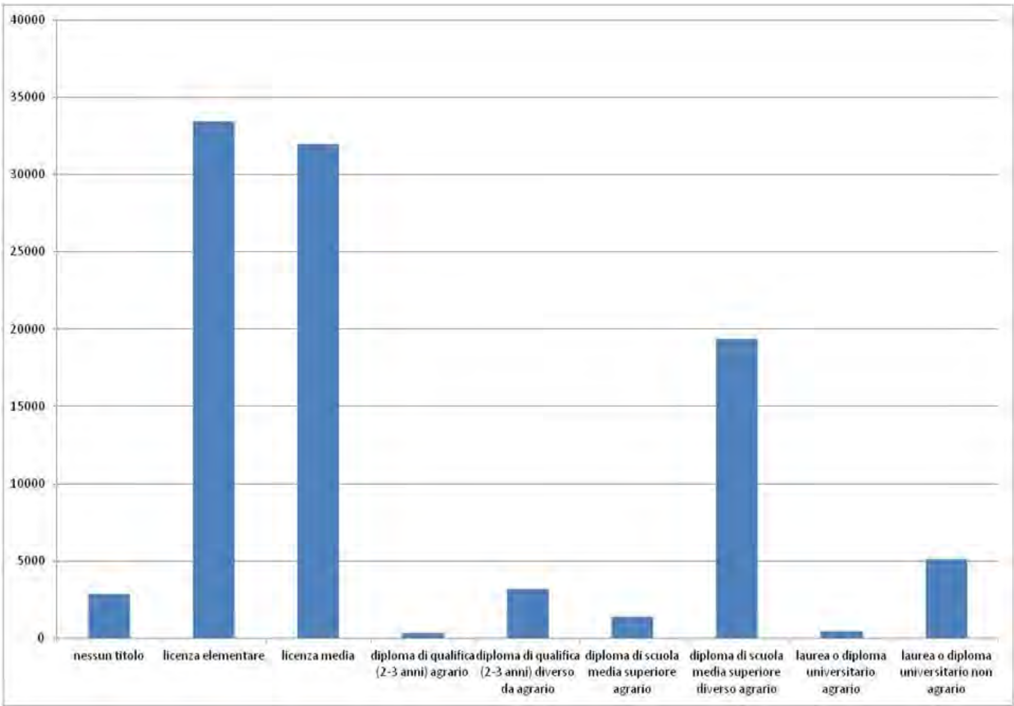

Figure 1. Qualification of farm manager (Lazio)

During the last years the trend of work injuries in regional agriculture is decreasing (figure 2), but fatal accidents are quite constant (figure 3) (INAIL, 2014).

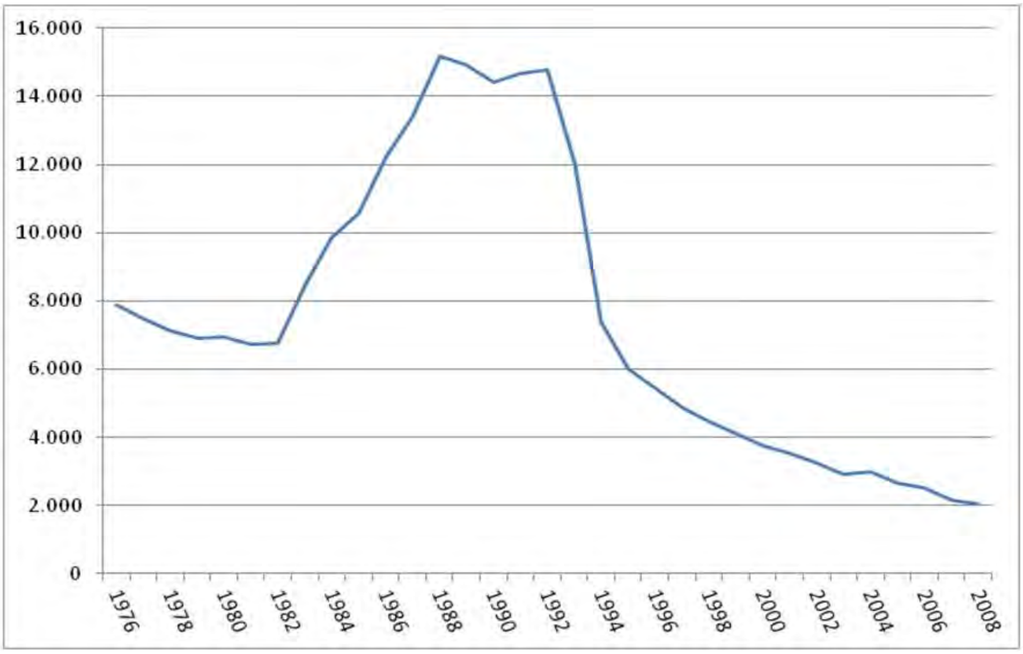

Figure 2. Accidents occurring in each year and reported to INAIL in agriculture (Lazio)

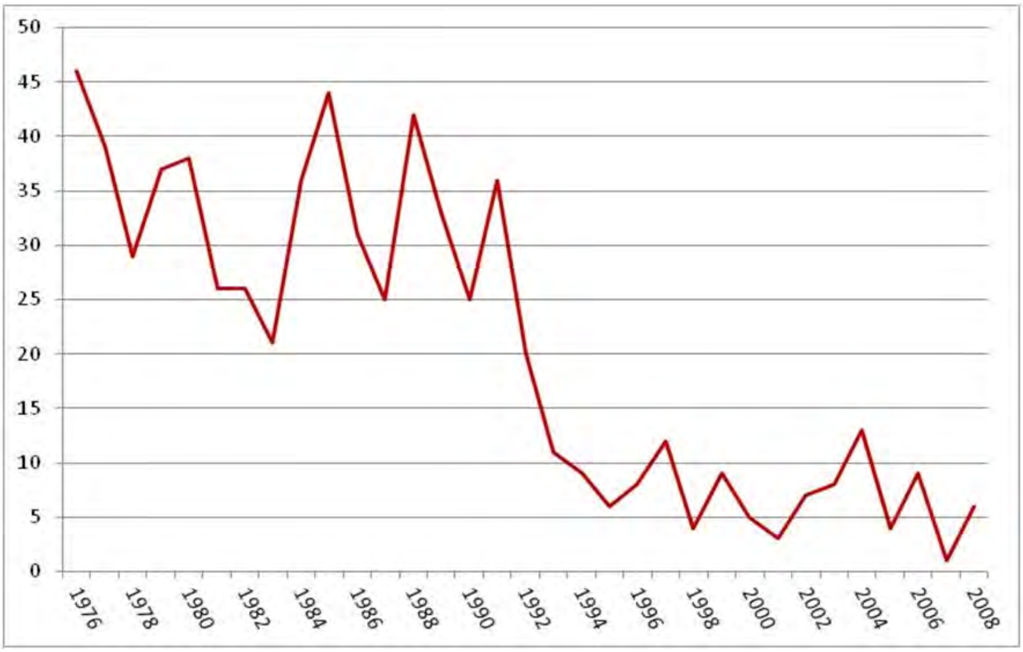

Figure 3. Fatal accidents occurred in each year and reported to INAIL in agriculture (Lazio)

Very different is the trend for occupational diseases (table 2) (INAIL, 2014) for which a surge of complaints of suspected occupational diseases can be observed (especially for female workers). The decline of traditional occupational diseases, such as hypoacusis, joins the growth of diseases related to biomechanical overload of the musculo -skeletal system in its broadest sense.

Table 2. Complaints of occupational diseases for birthplace, sex, year (Lazio)

		Anno di protocollo									
Luogo di nascita	Genere	2009		2010		2011		2012		2013	
	Maschi	1.108	79,71%	1.196	74,15%	1.325	74,11%	1.276	70,54%	1.591	72,58%
				7,94%		*10,79%*		*-3,70%*		*24,69%*	
Italia	Femmine	282	20,29%	417	25,85%	463	25,89%	533	29,46%	601	27,42%
				47,87%		*11,03%*		*15,12%*		*12,76%*	
	Totale	**1.390**	**100,00%**	**1.613**	**100,00%**	**1.788**	**100,00%**	**1.809**	**100,00%**	**2.192**	**100,00%**
				16,04%		***10,85%***		***1,17%***		***21,17%***	
	Maschi	10	58,82%	22	56,41%	21	61,76%	31	77,50%	40	64,52%
				120,00%		*-4,55%*		*47,62%*		*29,03%*	
Unione Europea	Femmine	7	41,18%	17	43,59%	13	38,24%	9	22,50%	22	35,48%
(esclusa Italia)				*142,86%*		*-23,53%*		*-30,77%*		*144,44%*	
	Totale	**17**	**100,00%**	**39**	**100,00%**	**34**	**100,00%**	**40**	**100,00%**	**62**	**100,00%**
				129,41%		***-12,82%***		***17,65%***		***55,00%***	
	Maschi	20	60,61%	39	76,47%	37	75,51%	32	76,19%	40	66,67%
				95,00%		*-5,13%*		*-13,51%*		*25,00%*	
Extra Unione Europea	Femmine	13	39,39%	12	23,53%	12	24,49%	10	23,81%	20	33,33%
				-7,69%		*0,00%*		*-16,67%*		*100,00%*	
	Totale	**33**	**100,00%**	**51**	**100,00%**	**49**	**100,00%**	**42**	**100,00%**	**60**	**100,00%**
				54,55%		***-3,92%***		***-14,29%***		***42,86%***	
	Maschi	0	-	0	-	0	-	0	-	0	-
				-		-		-		-	
Non determinato	Femmine	0	-	0	-	0	-	0	-	0	-
				-		-		-		-	
	Totale	**0**	**-**	**0**	**-**	**0**	**-**	**0**	**-**	**0**	**-**
				-		**-**		**-**		**-**	
Totale		**1.440**		**1.703**		**1.871**		**1.891**		**2.314**	
				18,26%		***9,86%***		***1,07%***		***22,37%***	

The above figures are even more alarming when considering the reduction of the workforce that has taken place in recent years (-30% from 2000 to 2010).

One of the objective of the project is the training of agricultural workers. Four courses were organized in the period January - February 2015. A product of the project was the site *http://ergolab.wix.com/sicurincampo* that provides a platform for the support of teaching materials for work health and safety training for farmers (training materials in 5 languages).

A previous research from the same Authors (article in press) showed that the perception of risk is related to having attended training courses, but those who report having attended safety courses do not always enact safe behavior.

While we cannot draw conclusions about the behavior of workers after attending the course, the analysis of the questionnaires shows a clear improvement in the perception of risk. Excluding the course restricted to workers of Indian citizenship, for which there was unavailable a statistically significant number of post-course questionnaires, after attending the lessons we observed the following increases of the average values of the scores of the answers:

- Course 1 (only Italians): + 0.32 (from 4.15 to 4.47)
- Course 2 (Italians and Romanians): + 0.33 (from 4.35 to 4.67)
- Course 3 (Italians and Romanians): + 0.27 (from 4.30 to 4.57)

Conclusions

The project "Safe in the Field" was an opportunity to analyze the work environment in the agricultural sector in Lazio Region and the trend of accidents and occupational diseases in the same field.

For the logical sequence adopted and the results obtained we can say that the project can be considered a "reference" replicable in other regions and in other working sectors.

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Influence of training, procedural and organizational measures in the reduction of the risk due to manual handling of loads

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Abstract

The link between the musculo skeletal disorders (especially those affecting the bones, nerves, joints, muscles, tendons and blood vessels) and manual handling of loads, is nowadays worldwide recognized. This risk is present in many production sectors, but in some activities more than others, including agriculture (INAIL), risk indexes are often above the warning thresholds.

The research evaluated 20 agricultural and agro-livestock Lazio's farms, using a methodology proposed by EPM Research Unit (Milano, Italy) in compliance with criteria laid down by Annex XXXIII of the Italian Legislative Decree n. 81/2008 (transposition of several European Directives including 90/269/EEC about manual handling of loads).

This research also studied appropriate ways to make a quantification of the efficiency and effectiveness made by the procedural and organizational redesign proposal, presenting concretely and economically feasible measures, useful in the short term.

Keywords: Niosh, Risk Analysis, Prevention, Safety And Health

Introduction

The link between musculoskeletal diseases and manual handling of loads is nowadays worldwide recognized (Colombini et al, 2003; Nicoletti et al, 2013).

Manual handling of loads consists in transporting or supporting of a load and its shares of lifting, putting down, pushing, pulling, carrying or moving.

The risk of disease due to biomechanical overload, especially of the back, is the result of unfavorable ergonomic conditions (European Directive 90/269/EEC).

The working rhythms imposed on the weather, the conditions of cultivation, the frequent use of unskilled seasonal workers make agriculture one of the most affected sectors by these diseases. These critical factors are complementary for the biomechanical overload.

Methods

The Council Directive 90/269/EEC is transposed in Italy by legislative decree 81/2008.
Annex XXXIII of Leg.dec. 81/08, entitled "Manual handling of loads", gives reference elements to the employer for carrying out a proper risk assessment.

The same Annex requires the employer to consider the personal risk factors of each potentially exposed subject, in order to make a proper risk assessment induced by manual handling of loads, in particular:

- physical unfitness to carry out the task, given the differences of gender and age (maternity, childbirth, youth, old age, etc.);
- clothing, footwear or other personal effects worn by the worker;
- insufficient knowledge, inadequate education and training.

In the observed firms, a manual handling of loads risk assessment model in Excel®

format, provided by EPM - Research Unit (Milano, Italy), has been used for tasks and composite variables.

This model makes possible to carry out a risk assessment providing risk indexes (RI), in accordance with the NIOSH (National Institute for Occupational Safety and Health) method and the technical standards EN 1005-2 and ISO 11228-1.

The model provides the lifting index (in conformity with EN 1005-2 and ISO 11228-1 standards), the value of the risk index obtained by the NIOSH equation (U.S. Department of Health and Human Services, 1994) and an overview of the data entered with the critical issues marked in red.

In addition to the value of lifting indexes, the extract of the spreadsheet associates each class of RI to a color:

• green - risk below the threshold;
• yellow - value close to the limits of attention;
• red - presence of certain risk;
• purple - presence of high risk.

The observations, lead by farm inspectors, were performed during the second half of 2014 on 20 farms and agro zootechnical firms in central Italy.

During the survey, essential data have been detected, as required by the technical standards, as well as additional information in order to operate considerations on efficiency and effectiveness of the preventive measures proposed.

Data have been collected about the presence or absence of training in line with the provisions of article 36 and 37 of the Leg.dec. 81/2008 with the aim of observing how this parameter, considered crucial for the correct postures in the operations of manual handling of loads, influences the efficiency and efficacy of the proposed interventions.

Results

This assessment discovers any critical issue in obtained risk indexes, proposes a suitable design of procedural and organizational measures, aimed at reducing risk, especially trying to assess its efficiency and effectiveness.

The aim of the research is to make a deep survey based in on site interviews and observations, on the working methodologies used by the employees, especially during operations involving the manual handling of loads with magnitude exceeding 3 kg.

The data elaboration highlighted the differences between the risk values obtained by applying the European standard EN 1005-2, the ISO standard 11228-1, and the NIOSH equation. Data were acquired previously and after the application of preventive, organizational and structural measures.

The second part of the research focused on a closer analysis about the influence of the presence or absence of training on the detected risk indexes.

Figure 1 shows the results of a first general analysis. This analysis compares the variation in risk between evaluated and estimated conditions, after the application of the proposed preventive measures. These preventive measures could potentially lead to a reduction of risk ratings: in particular, the values after the application of the suggested measures are 59% (average) less than the values of the initial risk.

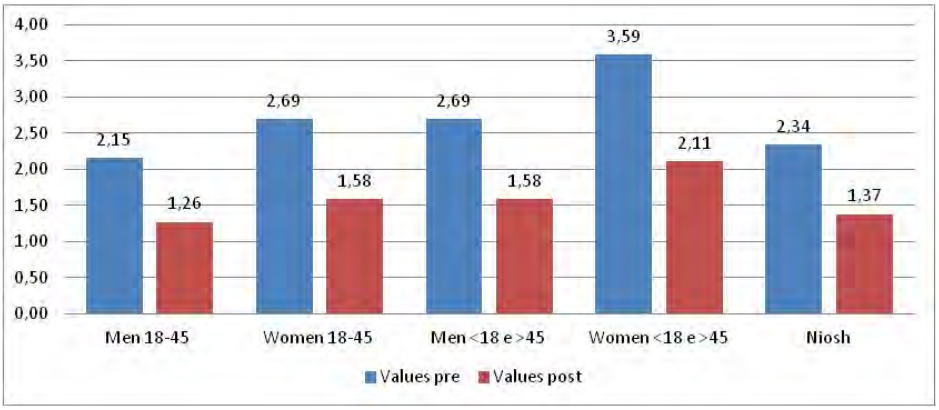

Figure 1. Risk reduction after the application of preventive measures

As it regards the influence of training in the reduction of the risk, as shown in figure 2, we can see that in the farms where workers wasn't subject to training the risk index is increased of 12% (average).

Figure 2. Comparison between risk indexes in farms where training is done and farms where training isn't done

It is important to underline the fact that farms where training was carried out were less than 30% of the total sample (figure 3).

Below there are the results from the second part of the study. The aim is a comparison between the risk indexes in the initial conditions and after the application of technical and procedural measures of prevention in farm.

The proposed measures determine overall reduction of risk ratings. The correct handling procedures can be easily feasible with proper training (posture, lifting of objects with both limbs, lifting of objects in two or more persons, etc.).

In order to evaluate how preventive optimization measures acted on the initial risk, we calculated the ratio between the average risk index after optimization and the average risk index pre optimization.

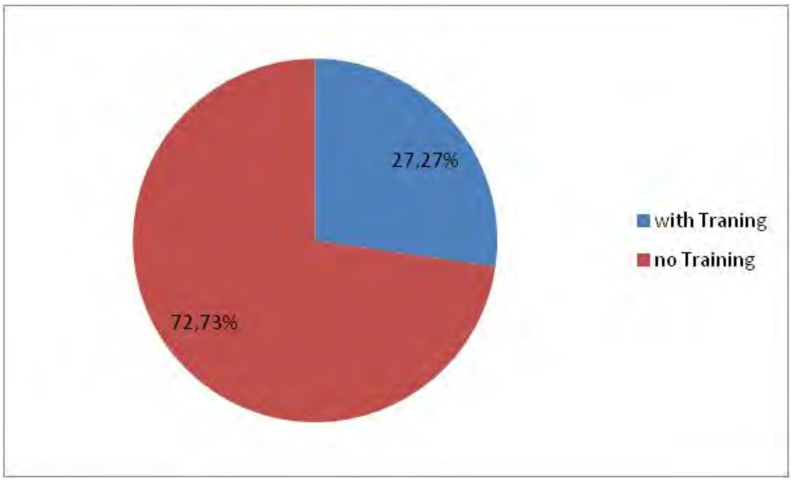

Figure 3. Percentage of farms with and without training

Adopting this method we can obtain the percentage of risk reduction. Example: the initial risk index is quantified 1.98 (average); adopting the preventive measures it is 1.35 (average); in order to estimate the risk reduction, compared to baseline, we apply the following formula: (1.35/1.98)*100=68.18%.

The thus obtained value indicates that, thanks to the adoption of the suggested interventions for the optimization, the risk is reduced to 68.18%, comparing it to the initially assessed one (efficiency of the measures is calculated as: 100-68.18=31.82%).

The obtained values show how the optimization is able for the risk index reduction.

The difference between the percentage values obtained can be used to estimate how much training could be effective in reducing the risk from manual handling of loads. These values, along with those of efficiency estimated, are shown in table 1 corresponding to the entries: efficiency and effectiveness of optimizations (estimated in percentage).

The table shows the pre and post proceeding values, taking into account the comparison between average values in farms with trained workers and not.

Table 1. Comparison to evaluate performance of training in reducing risk levels by gender and age

	Men18-45	Women 18-45	Men <18 e >45	Women <18 e >45	Niosh
Training first	1,98	2,47	2,47	3,3	2,15
Training post	1,35	1,70	1,70	2,26	1,47
Optimization	68,18%	68,83%	68,83%	68,48%	68,37%
no Training first	2,22	2,77	2,77	3,69	2,41
no Training post	1,23	1,54	1,54	2,05	1,34
Optimization	55,41%	55,60%	55,60%	55,56%	55,60%
estimated efficacy in%	12,78%	13,23%	13,23%	12,93%	12,77%

Conclusions

The preventive measures proposed are aimed to reduce the risk index, so as to protect workers from occupational accidents and diseases. The aim of the research was to estimate, where possible, the optimization efficiency and effectiveness, both at organizational and procedural level.

We evaluated the effectiveness of the proposed improvements with a mean decrease of risk observed by about 59%. The factor examined, whose absence contributes significantly to increase risk ratings, is the training, that, although present in only 27.3% of the companies observed, show a risk reduction of approximately 12÷13%.

Information and training have a direct effect on reducing the risk as regards the postural attitude (bending of the legs, twisting of the body, etc.) and also for the use of both limbs or lifting of bulky items or too heavy in most people.

The comparison of risk indexes before and after optimizations, among the farms where a suitable training is done and those without training, show that the efficiency of operations in the first farms is approximately 31%, while in farms without training is around 44%.

The lower efficiency measured in companies with training provided, reveals how the training is a preventive measure, with an efficacy estimated around 13%. This efficacy may be far greater with the implementation of a correct training as it regards the manual handling of loads.

Absolutely not negligible and worrying is the absence of training in over 70% of farms, since this is considered an intervention of effective prevention, for this and other types of risks.

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A population-based comparison of injuries among farm and non-farm adults in Alberta, 1999-2010: A retrospective cohort

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Abstract
Agriculture is considered as one of the most hazardous occupations with the 4th highest mortality rates by industry in Canada. The purpose of this study was to examine the rates and risks of (1) all-cause and (2) agricultural injury across adult farm and non-farm populations in Alberta.
We conducted a population-based retrospective cohort study utilizing data from multiple administrative health databases. Crude injury rates were calculated and proportional-hazards regression with a counting process was applied to obtain hazard ratios for injury adjusting age and sex.
We identified a total of 220,911 adults who experienced 947,247 injuries. Rural Non-Farmers experienced the highest death rates at 74/100,000 person-years, followed by the Farm Rural study group at 58, the Urban group at 52.1 person-years and the Farm Urban group at 48.1. All cohorts had higher hazards of all-cause injury when compared to the urban cohort after adjusting for age, and sex (Rural Non-Farm Hazard Ratio (HR)=1.09, 95% CI 1.07-1.10; Farm Urban HR=1.09, 95% CI 1.07-1.10; Farm Rural HR=1.08, 95% CI 1.07-1.09). Farmers experienced 87.5% of all agricultural injuries, with the HR= 4.68 (95% CI 4.39 – 4.99) for Farm Rural and HR= 2.87 (95% CI 2.66 -3.11) for Farm Urban when compared to the Rural Non-Farmers and adjusted for age and sex.
This study identified that injury incidence rates, severity and intent varied among urban, farm and rural cohorts. These observations suggest that intervention initiatives, with specific population and mechanism targets, are needed to tackle the challenges of injury prevention in different rural populations.

Keywords: Agriculture, Injury, Health Data, Death

Introduction

Agricultural work in the United States and Canada continues to be one of the most dangerous vocations (Voaklander, Hartling, Pickett, Dimich-Ward, & Brison 1999; Brison, & Pickett 1995; Pickett, Hartling, Brison, & Guernsey, 1999; Frank, McKnight, Kirkhorn, & Gunderson, 2004; McCurdy, & Carroll, 2000; Statistics, Bureau of Labor, 2006). In 2005, agriculture had the highest occupational fatality rate in the United States (US) with 32.5 fatalities per 100,000 workers; this is a 23% increase from 2004 (Statistics, Bureau of Labor 2006), while in Canada the fatality rate is somewhat lower at about 20.3 fatalities per 100,000 workers, ranking it historically as Canada's fourth most dangerous occupation (Pickett, 1999). Furthermore, farmers residing on farms are inherently exposed to farm machinery and the associated hazardous risks regardless of whether or not they are participating in farm work (Marlenga, Pickett, & Berg, 2001; Voaklander, Day, Hagel, Dosman J & Pickett W 2012).

It is also well established that rural living is a risk factor for injury. Rural factors that persons at higher risk include: greater distances traveled and higher driving speeds (Mitchell-Taverner, & Zipparo, 2011), more frequent alcohol use (Muelleman, & Mueller, 1996), lower occupant restraint usage (Belton, 2005) as well as lower socio-economic status (Gilbride, Wild, Wilson, Svenson, & Spady, 2006; Singh, 2002).

However, what is not known is the risk for injury across farmers, rural non-farmers and urban dwellers. Using data linkage of government registries we had a unique opportunity to compare the injury experience of both farm and rural non-farm populations to urban dwellers in the province of Alberta, Canada.

Methods

Study Design

We conducted a population-based retrospective cohort study with a closed population to examine rates, risks and patterns of all-cause and agricultural injury in the adult farm and non-farm populations in Alberta during the period starting January 1, 1999 to December 31, 2010.

Data Sources: Injury data were obtained from four administrative health databases: The Alberta Vital Statistics File containing mortality data; the Hospital Discharge Abstract Database (DAD) provided data on hospital admissions; the Ambulatory Care Classification System (ACCS) containing emergency department (ED) visits; and the Physician Claim File that contained data on physician encounters. The Physician Claim File consisted of services performed in a physician office, in the hospital, in the ED, or other diagnostic/therapeutic settings. Demographic information on subjects including age, sex, first three digits of the postal code, migration, health zone, and socio-economic status was obtained from the Alberta Health Care Insurance Plan Registry file. Records for each individual were linked across these data sources, using a scrambled personal health number. The resulting database contained multiple injury records at different levels of care (e.g. hospitalization, emergency department visits) for each individual.

Study participants

The study participants were categorized into farm, urban and rural groups. Farm-based individuals were identified using the Farm Fuel Tax Rebate system that captured addresses from all commercial farm operations in Alberta. Address data from this system were probabilistically linked to Alberta Health Care Insurance Plan registry to identify farm residents of all ages. Urban non-farmers and rural non-farmers were randomly selected via postal codes to create size equivalent comparison groups.

As there were farmers with non-rural postal codes, the farm group was further subdivided into Farm-Rural and Farm-Urban groups to examine differences in rates and hazards for injury between the two groups.

The study included subjects who were 18 years of age or older and lived in Alberta in the fiscal year 1998/99. During the study period, subjects were considered lost to follow up upon the fulfillment of the following conditions: the first move-out from Alberta; the first move-out from rural to urban areas or vice versa; and the first discontinuance of registration in the Alberta Health Insurance plan (99% coverage).

Injury identification

Injuries were identified using the following International Classification of Disease (ICD) 9 and 10 codes for external causes of injury found in any of the diagnosis fields of each medical record. Any injuries that occurred in an urban setting, except for those occurring in the Farm-Urban group, were excluded from the analysis of agricultural injuries. As vital statistics records contained only one diagnosis field for the cause of death, it was not possible to identify fatal agricultural injuries by place of occurrence, thus restricting the analyses of fatal agricultural injury to machinery, transport and poison related events only.

Injury episode

As stated above the created data set contained multiple injury records per individual post database linkage. As treatment of a single injury incident may require more than one healthcare visit, some of the records represented healthcare visits due the same injury. In order to calculate incidence rates, distinct injury episodes that omit follow up visits for the same injury needed to be identified (Lestina, Miller, & Smith, 1998). To create such an episode, all records were sorted by personal health number, date of service and level of care and any follow up visits for the same injury were identified using carefully selected criteria as outlined in Table 1 (Kim, 2013). The identified follow up visits were subsequently removed leaving a single record at the highest level of care to represent a distinct injury episode. As the severity of an injury correlates with the type of healthcare service needed by the individual, the level of care of each episode was used as a proxy to the severity of the injury. In order to exclude visits that were actual follow ups of injuries which occurred before the study began (January 1, 1999), records from three years prior to the study were used in the episode creation process.

Table 1. Criteria used to differentiate between follow up and new injury records.

Criterion	Description
1	The injury record had ICD codes for sequelae or late effect of injury
2	The injury record appeared on the same day
3	The injury occurred within 7 days in the same category of body region or the nature of injury
4	The injury occurred within 180 days in the same category of both body region and nature of injury
5	The injury occurred within 180 days with the exactly same diagnostic codes in all ten ICD diagnostic fields compared with the previous injury record
6	The injury record had ICD codes for sequelae or late effect of injury
7	The injury record appeared on the same day

Statistical analysis

Descriptive statistics including frequencies, percentages and means were used to summarize participants' demographics. One-way ANOVA and Chi-square test were used to determine significant differences in the demographic variables between study groups.

Crude incidence rates of all-cause and mechanism-specific injuries were calculated using injury episodes as the numerator. Crude relative risks of cause-specific injury and their 95% confidence intervals were calculated for each cohort using the urban cohort as the reference group. For the analysis of agricultural injuries, the rural farm group was used as the reference group for the same.

Several distinct injury episodes were experienced by some participants. In order to account for the recurrent time to injury events, proportional-hazards regression with a counting process was applied to obtain hazard ratios (HR) of injury while adjusting for confounders such as age and sex. Robust standard errors were used to adjust for correlation between the multiple outcomes per individual. Data management and statistical analysis was conducted using SPSS Version 22.0 and SAS Version 9.4.

Results

Sample demographics

There were 143,431 farmers of all ages identified through data linkage with equivalent groups of rural non-farmers and urban dwellers generated through random sampling. After restricting the study population to those 18 years and older and removing First Nations persons (n=11,933) there were 102,758 urban, 88,623 rural non-farm and 100,822 farmers available for analysis. The average age among the study groups varied between 43.5 to 46.9 years (Table 2.). Majority of farmers and Rural Non- farmers were located in the Central (34.8% and 31.3% respectively) and Northern regions of Alberta (28.4% and 29.2%). A portion of farmers however resided in urban areas (27.0%) and was located mainly in the Central and Edmonton regions (32.1% and 22.0% respectively).

During the study the Rural Non-Farmers had the highest loss to follow up among the groups (57.3%), which was mainly due to movement to an urban location.

All-Cause Injury

Between January 1, 1999 and December 31, 2010, we identified a total of 220,911 adults who experienced 947,247 injuries. These were comprised of 617,173 (65.2%) Physician's office visits, 300,729 (31.7%) Emergency Department visits, 27,783 (2.9%) Hospitalizations and 1,562 (0.2%) Deaths.

The highest crude incidence rates of all-cause injury were among the Rural Non-Farmers except for physician office visits, where the Farm Urban study group had the highest rate followed by Urban and Rural Farm groups (Table 3.).

Hazard rate analysis showed that the rates of injury were higher in all study groups in comparison to the Urban group, when adjusting for sex and age (Table 4.). The hazard rates increased with increasing level of care for all groups indicating that farmers and rural inhabitants were more likely to experience a severe injury than the Urban group.

Males had a higher hazard of all-cause injury than females across all levels of care with the highest hazard rate for fatal injuries (HR 2.35 95% CI 2.11 – 2.62).

By intent the highest incidence rates of all-cause injuries were observed with unintentionally inflicted injuries for all groups (Table 5.). The main mechanisms included falls, struck, transport, overexertion, and cut (Table 6.). Among transport injuries the main mechanisms were motor vehicle traffic accidents for the non-farm groups and other land transport (including animal or animal drawn vehicle and special off terrain vehicles) for the farm groups. Both the farm groups and rural non-farmers were at a higher risk of unintentional injuries when compared to the urban cohort and at a lower risk of self-inflicted and purposefully (violently) inflicted injuries.

Agricultural Injury

Agricultural injuries represented 1.21% of all-cause injury. There was a total of 11,439 injury episodes identified in the study period which were composed of 10,066 (88.0%) Emergency Department visits, 1,332 (11.6%) Hospitalizations and 41 (0.4%) Deaths. The highest rates of agricultural injury were experienced by the Farm Rural group followed by the Farm Urban cohort across all levels of care (Table 7.).

Comparing the hazard rates of agricultural injury at different levels of care, both farm groups experienced significantly higher hazards of injury in comparison to the Rural Non-farm group when adjusting for age and sex (Table 8). These were particularly higher for injuries requiring hospitalizations suggesting that farmers were at a higher hazard of more severe injuries. The hazard ratios for fatal injuries appeared in contrast to the above observations and were lower than for hospitalizations, however underestimated values for fatal agricultural injuries were expected due to the limited vital statistics coding available.

Males overall experienced higher hazard rates of agricultural injury than females across all groups with a hazard rate ratio at 4.03 (95%CI 3.82 – 4.25). This ratio increased with increasing severity of injury.

A slight decrease in the hazard rate of overall agricultural injury was observed with increasing age; at 0.5% with every year increase, while adjusting for sex and group allocation.

The mechanisms of agricultural injuries with the highest crude incidence rates were environmental factors[1] (mainly animals) and machinery across all groups (Table 9). The highest incidence rates for fatal agricultural injuries as presented by the available data were for machinery and transport related injuries (26 and 14 out of 41 deaths respectively) and were mainly among farmers (22 and 13 respectively).

Conclusions

This study enabled a detailed assessment of injuries within various populations by amalgamating data from several healthcare databases.

Injury rates and types were compared between an urban population and different rural and farming populations. The urban group was found to be at a lower hazard of overall injury, as well as having less severe injuries, this being more prominent when compared to the farmers. Multiple studies have previously addressed the difference in injury rates between urban and rural settings, concluding urban settings to be safer (Young, Wasiak, Webster, & Shayne, 2008; Myers et al., 2013; Boland, Staines, Fitzpatrick, & Scallan, 2005). Very often however, this was limited to unintentional injuries. When the intent of injury was considered, our study showed the urban group to be at higher risk of self-inflicted and violently inflicted injury than any other group in the study.

Unintentional injuries being the leading cause of injury among the rural and farm groups indicated an exposure to hazards distinctive to the rural and farm environments. Rural communities have been described to be exposed to more challenging environments; for example transport over longer distances and with more hazards on the roads than their urban counterparts (Canadian Institute for Health Information, 2006; Young et al., 2008). Farming itself is considered as one of the most hazardous occupations by industry and is unique in that farmers both work and live in their occupational environments (Sharpe, & Hardt, 2006; Canadian Agricultural Injury Reporting (CAIR), 2012). These factors largely contribute to injury exposure.

The top mechanisms of unintentional all-cause injury were falls and transport. Breaking these down further showed farmers to have experienced more animal related transport injuries than the urban and rural non-farm groups. This was consistent with agricultural environments and further heightened the concept of injury diversity among the study groups.

The analysis of agricultural injuries showed that the rural non-farmers were exposed to agricultural injuries although their rates and severity were significantly lower than for farmers. This suggests that a proportion of the rural population participated in on-farm activities although farmers experienced higher hazards of injury as well as injuries with higher severity.

The study was also able to include in the analysis a group of urban famers, that is, individuals living in urban areas that were also farm owners. Similarly to the rural farmers, this group had higher hazards of all-cause and agricultural injury when compared to the

[1] Environmental Factors: Natural environment including living and non- living things including mammals, arthropods, their bites and stings, heat, cold etc.

reference groups, but were at a slightly lower hazard of injury than their rural counterparts. Their mechanisms of injury were also similar to the rural farmers. This indicated that owning a farm regardless of registered residence, placed individuals at a higher hazard of injury than other urban or rural residents.

The top mechanisms of agricultural injury involved the exposure to animals and machinery. Both are identified as a major occupational risk for famers (Pickett, Brison, Niezgoda, & Chipman, 1995; CAIR, 2012; Casey et al., 2014). Furthermore this also correlates with the major agricultural sectors of Alberta, namely livestock and crop production.

Overall agricultural injuries were experienced more by male than female individuals which correlates with the available data on gender specific farm ownership and on farm activity in Canada. There are more single male farm owners than female farm owners and females tend to spend less amount of time working on farms than males (Statistics Canada, 2001).

The heightened severity of injury experienced by farmers in comparison to the other groups was prominent in both the all-cause and agricultural injuries. This correlates with the aforementioned uniqueness of the farm environment and the dangers of the occupation. Farmers work more closely with animals and operating machinery, they are known to work beyond the anticipated retirement age and factors such as seasonality and sleep deprivation have also been shown to contribute to farmers' injuries (Voaklander, Day, Dosman, Hagel, & Pickett, 2012; Heaton, Azuero, Phillips, Pickens, & Reed, 2012). Limited access to health care due to the remote location and longer emergency response times have also been identified as contributors to severity of injuries for overall rural populations (Rogers et al., 1997; Grossman et al., 2010; Simons at al., 2008; Myers et al., 2013). It is important to recognize these specific challenges especially in the development of injury prevention initiatives as well as organization of emergency response in rural areas.

Limitation of the study were linked to the inherent limitations of using administrative databases for research. Administrative databases provide consistent and more complete data including standardized entry, inclusion of individuals that may have not been captured in other study designs and/or surveys as well as limiting losses to follow-up for reasons other than movement from designated study groups. In spite of the wealth of information provided, administrative databases have not been designed for epidemiological purposes, thus limiting the control of the type of data collected. The vital statistics database presented such a case in this study, where the absence of information on death location reduced the ability to identify all agricultural fatal injuries. In spite of this limitation the obtained rates of the fatal injuries were able to contribute to the understanding of rate distributions as well as injury severity.

Erroneous data entry presented another limiting factor to the study but as it would create non-differential misclassification of injuries within the groups studied, it would not affect the study measures.

The study presented an approach that allowed for a comprehensive analysis of injury in different populations in Alberta. Different rates, hazards, patterns and mechanisms of injury were clearly identified among the different groups. More attention needs to be paid to these population specific vulnerabilities so that injury prevention strategies as well as support services development can be tailored towards unique populations and mechanism targets.

Table 2. Subject Demographics

Description	Urban N= 102,758	Rural non-Farm N=88,623	Farm-Urban N=27,278	Farm-Rural N=73,544
Gender (male)**	49.3%	49.9%	54.5%	54.3%
Age (years, mean±SD)**	43.5±16.8	45±17.8	46.9±16.0	45.8±16.0
Health Services Zones				
Calgary	41.0%	19.0%	12.1%	10.8%
Central	8.1%	31.3%	32.1%	35.8%
Edmonton	38.1%	7.3%	22.0%	4.4%
North	6.3%	29.2%	18.7%	32.0%
South	6.5%	13.2%	15.2%	17.1%
Lost to Follow up**	31.0%	57.3%	21.1%	27.6%
Person-years followed				
Female	515,647	324,984	132,738	341,765
Male	482,540	313,199	156,180	401,729
Total	998,187	638,184	288,918	743,494

*p-value < 0.001 ** Any subsidy received for health care insurance premium

Table 3. Crude incidence rate of all-cause injury by level of care

Level of Care	Urban			Rural non-Farm			Farm_Urban			Farm_Rural		
Crude incidence rate (injuries/100,000 person years) (95% CI)												
Physician claim	**23786.5**	(23783.9,	23789.2)	**22315.8**	(22312.6,	22319.1)	**24022.1**	(24017.1,	24027.1)	**22585.1**	(22582.1,	22588.2)
ED visits	**9053.1**	(9051.3,	9054.9)	**13106.6**	(13103.9,	13109.2)	**11454.1**	(11450.4,	11457.8)	**12592.6**	(12590.2,	12595.0)
Hospitalizations	**869.6**	(869.0,	870.2)	**1313.4**	(1312.5,	1314.3)	**947.7**	(946.6,	948.8)	**1073.7**	(1073.0,	1074.5)
Deaths	**52.1**	(52.0,	52.2)	**74.0**	(73.8,	74.2)	**48.1**	(47.9,	48.4)	**58.0**	(57.8,	58.1)

Table 4. Hazard ratios of all-cause injuries

Level of Care	Rural Non-Farm			Farm_Urban			Farm_Rural		
	Hazard Ratio (95% Confidence Interval), Reference group: Urban								
All Levels of Care	**1.09**	(1.07,	1.10)	**1.09**	(1.07,	1.10)	**1.08**	(1.07,	1.09)
Physician Visits	**1.02**	(1.01,	1.04)	**1.08**	(1.06,	1.10)	**1.08**	(1.06,	1.10)
Emergency Visits	**1.24**	(1.22,	1.26)	**1.15**	(1.13,	1.17)	**1.17**	(1.16,	1.19)
Hospitalizations	**1.30**	(1.26,	1.35)	**1.13**	(1.08,	1.19)	**1.25**	(1.20,	1.29)
Deaths	**1.34**	(1.18,	1.52)	**0.995**	(0.83,	1.20)	**1.18**	(1.04,	1.34)

Table 5. Crude rates and rate ratios of all-cause injuries by the intent of injury

Intent of Injury	**Level of Care**	**Urban**	**Rural non-F**	**Farm-U**	**Farm-R**	**Rural non-Farm**			**Farm-Urban**			**Farm-Rural**		
		Incident Rate (Injuries per 100,000 person-years)				Rate Ratio (95% CI), Reference Group: Urban								
Unintentional	ED visits	7052	11669	9849	11214	**1.65**	(1.64,	1.67)	**1.4**	(1.38,	1.42)	**1.59**	(1.57,	1.61)
	Hospitalizations	756	1163	877	992	**1.54**	(1.49,	1.59)	**1.16**	(1.11,	1.21)	**1.31**	(1.27,	1.36)
	Deaths	27	51	35	42	**1.92**	(1.63,	2.26)	**1.33**	(1.06,	1.67)	**1.58**	(1.34,	1.86)
Self-harm/ Suicide	ED visits	92	36	22	10	**0.39**	(.34,	.45)	**0.24**	(.19,	.31)	**0.1**	(8.24,	.13)
	Hospitalizations	54	48	20	22	**0.89**	(.77,	1.02)	**0.38**	(.29,	.49)	**0.4**	(.34,	.48)
	Deaths	16	17	11	13	**1.05**	(.82,	1.34)	**0.7**	(.48,	1.02)	**0.81**	(.63,	1.04)
Violence/ Purposely inflicted	ED visits	226	194	96	79	**0.86**	(.80,	.92)	**0.42**	(.37,	.48)	**0.35**	(.32,	.38)
	Hospitalizations	23	23	9	9	**0.99**	(.80,	1.22)	**0.39**	(.26,	.58)	**0.39**	(.30,	.51)
	Deaths	1	1	0	1	**1.01**	(.44,	2.32)	**0.25**	(3.25,	1.88)	**0.86**	(.37,	1.99)
Undetermined	ED visits	28	43	26	32	**1.53**	(1.30,	1.81)	**0.92**	(.71,	1.18)	**1.15**	(.97,	1.37)
	Hospitalizations	9	21	7	12	**2.25**	(1.73,	2.94)	**0.74**	(.46,	1.20)	**1.24**	(.93,	1.66)
	Deaths	8	5	1	2	**0.59**	(.39,	.89)	**0.17**	(6.18,	.46)	**0.23**	(.13,	.40)

F - Farm; U –Urban; R-Rural; ED - Emergency Department; 95% CI - 95% Confidence Interval

Table 6. Mechanisms of unintentional all-cause injury

Mechanism	Urban	Rural non-F	Farm-U	Farm-R	Rural non-Farm			Farm-Urban			Farm-Rural		
	Crude rate (injuries per 100,000 person-years)				**Crude Rate Ratio (95% CI), Reference Urban**								
Fall	2283	3270	2293	2366	**1.43**	(1.41,	1.46)	**1.00**	(0.98,	1.03)	**1.04**	(1.02,	1.06)
Struck	992	1392	1129	1240	**1.40**	(1.36,	1.44)	**1.14**	(1.09,	1.18)	**1.25**	(1.22,	1.29)
Unspecified	934	1757	1250	1574	**1.88**	(1.83,	1.93)	**1.34**	(1.29,	1.39)	**1.69**	(1.64,	1.73)
Transport	929	1314	1158	1232	**1.42**	(1.37,	1.46)	**1.25**	(1.20,	1.30)	**1.33**	(1.29,	1.37)
Overexertion	858	1125	840	879	**1.31**	(1.27,	1.35)	**0.98**	(0.94,	1.02)	**1.02**	(0.99,	1.06)
Cut	744	1390	1156	1316	**1.87**	(1.81,	1.93)	**1.55**	(1.49,	1.62)	**1.77**	(1.72,	1.82)

Table 7. Crude incidence rate of agricultural injury

Level of Care	Rural Non-Farm			Farm-U			Farm-R		
Crude incidence rate (injuries/100,000 person years) (95% CI)									
ED visits	**201.5**	(201.2,	201.9)	**575.9**	(575.1,	576.8)	**957.1**	(956.4,	957.8)
Hospitalizations	**21.0**	(20.9,	21.1)	**84.5**	(84.1,	84.8)	**128.3**	(128.1,	128.6)
Deaths	**0.9**	(0.9,	1.0)	**3.1**	(3.1,	3.2)	**3.5**	(3.5,	3.5)

ED - Emergency Department

Table 8. Hazard ratios for agricultural injuries

Level of Care	Farm_Urban			Farm_Rural		
	Hazard Ratio (95% Confidence Interval), Reference group: Non-Farm Rural					
All levels of care	**2.87**	2.66	3.11	**4.68**	4.39	4.99
Emergency Visits	**2.80**	2.57	3.04	**4.62**	4.32	4.94
Hospitalizations	**3.96**	3.97	5.34	**6.39**	5.28	7.74
Deaths	**3.19**	1.14	9.00	**3.93**	1.62	9.56

Table 9. The leading causes of agricultural injuries

Mechanism	Rural non-F	Farm-U	Farm-R	Farm-Urban			Farm-Rural		
	Crude rate (injuries per 100,000 person-years)			**Crude Rate Ratio (95% CI), Reference Urban**					
Environmental Factors	50	163	253	**3.23**	(2.80,	3.72)	**5.02**	(4.46,	5.65)
Machinery	41	159	228	**3.86**	(3.32,	4.49)	**5.56**	(4.88,	6.33)
Other CI	30	76	149	**2.56**	(2.11,	3.11)	**5.00**	(4.28,	5.83)
Struck	22	73	111	**3.28**	(2.65,	4.06)	**4.99**	(4.18,	5.97)
Fall	22	68	102	**3.14**	(2.52,	3.90)	**4.71**	(3.93,	5.65)
Cut	20	46	100	**2.35**	(1.84,	3.00)	**5.10**	(4.22,	6.17)
Overexertion	14	31	54	**2.18**	(1.64,	2.92)	**3.73**	(2.98,	4.68)
Transport	15	31	45	**2.11**	(1.58,	2.82)	**3.08**	(2.45,	3.87)

F - Farm; U –Urban; R-Rural; 95% CI - 95% Confidence Interval

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Assistive Technology Database for Farmers and Agricultural Workers with Physical Disabilities

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Abstract
Purdue University manages the largest known database of assistive technology appropriate for safely enhancing the independence and productivity of farmers and agricultural workers with physical disabilities. The poster will explain the organization structure of the database (www.agrability.org), the contents and how it is used internationally by rehabilitation professionals working with farmers. Data on visits to the site and the most commonly used components will be presented.

Key components of the website relate to both commercially available devices and locally fabricated devices that have been designed to increase the independence of those engaged in production agriculture. The database currently includes over 1,100 items. Additional resources include technical articles on a wide range of barriers faced by persons with disabilities.

Users of the site represent over 20 countries and include primarily rehabilitation professionals and farmers with disabilities. Approximately 5,000 unique visits are made to the site each month.

Injuries for female workers in agriculture – An initial study on causes and preventive measures

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Abstract

The aim of this paper was to contribute to the future prevention of women's occupational injuries in agriculture via identifying the main causes and circumstances related to these injuries.

The study included analyses of existing data of occupational injuries during a five year period (2009-2013) suffered by women working in agriculture in Sweden. The injury data consisted of compensated work injury claims from the AFA Insurance and work injuries reported to the Swedish Work Environment Authority. Descriptions of the specific events of about 600 injury claims and reports were studied thoroughly in order to gain a deeper understanding of the causes and circumstances. The data regarding, for instance, the source of injury, age, time of year, type of production, injury characteristics and other factors, were analysed. Based on the statistical output, the causes and possible preventive measures were discussed with a reference group consisting of people with extensive practical experience in the area of agriculture work environment.

Preliminary findings indicated that the majority of injuries were animal-related (~55 % of the injuries), with cattle as the most commonly involved animal followed by horses. Cases associated with sorting/moving cattle, leading horse and milking tasks represented high proportions of the injuries. Working with livestock were subjects to the injury in 64 % of the cases, and younger women (<25 years) seemed to be overrepresented in the statistics. The injuries occurred more frequently in the months of September and December.

The further analysis of the injuries should be carried out as a case study together with the suffered persons in the field to gain more detailed information of the underlying causes and suggest more specific measures. The focused areas of preventive measures were also discussed.

Keywords: Prevention, Risk, Work-Related Injury, Statistics, Animal.

Introduction

According to European Agency for Safety and Health at Work (EU–OSHA, 2010), the number of jobs in agriculture has declined for both women and men. There are more women than men work involuntarily in the agriculture sector in fixed-term jobs. Agriculture is one of the most accident-prone industries. In recent years, the most serious work-related accidents and fatalities has been reduced in Sweden (SäkertBonförnuft, 2013). However, the latest statistics reveals that women are exposed to a higher risk of work-related injury as compared to the men who work in the agriculture (AFA, 2013; Swedish Work Environment Authority, 2013; EU-OSHA, 2014). The AFA Insurance (AFA, 2013) has shown that the risk rate (number of serious accidents at work per 1,000 persons employed) in agriculture was 7.1 for women and 4.9 for men in 2011 (Table 1).

Table 1. Approved serious accidents at work for men and women in agriculture (agricultural, forestry and gardening) and the proportion of accidents that led to medical disability in 2011, as well as risk rate during years 2009 to 2011 (AFA, 2013).

	No of claims 2011	Share with medical disability,%	Risk rate * 2009	2010	2011
Men	168	71.4	4.5	5.3	4.9
Women	78	66.7	6.4	5.2	7.1

** Number of serious occupational accidents per 1 000.*

Statistics from the Swedish work environment authority (ISA, 2014) showed the similar results when the number of notified occupational accidents per 1 000 workers in agriculture for women (6) was twice higher than that for men (3) during years 2011-2013 (Table 2). In addition, women's relative injury rate has remained constant during years 2008 to 2013, while men's gradually dropped. This means that the risk of the serious occupational accidents in general for women working in agriculture seems to be higher than that for men.

Table 2. Number of accidents per 1 000 working people of men and women in the field of agriculture and hunting during years 2008 to 2013 (ISA, 2014).

	2008	2009	2010	2011	2012	2013	No. of claims 2013
Men	5	4	4	3	4	3	135
Women	6	6	6	6	6	6	89

The most common work-related accidents in agriculture in general are accidents with animals and machines as well as falls. With the knowledge available today, however, we cannot say about the misfortunes suffered by women is due to a higher exposure to risk or if there are other factors that have an impact. Therefore, the present study is implemented to see how the incidences of work-related injuries widespread.

The overall objective of this study is to contribute to the future prevention of women's occupational injuries in agriculture *via* identifying the main causes and circumstances related to these injuries. The results can be used as a basis for the suggestion on possible prevention strategies.

Materials and methods

The study included analyses of existing data of occupational injuries during a five year period (2009-2013) suffered by women working in Swedish agriculture. The injury data consisted of compensated work injury claims from AFA Insurance and work injuries reported to the Swedish Work Environment Authority. Descriptions of the specific events of about 600 injury claims and reports in total were studied thoroughly in order to gain a deeper understanding of the causes and circumstances.

The data regarding the source of injury, age, time of year, type of production, injury characteristics and contributing factors were analysed. Based on the statistical output, the causes and possible preventive measures were discussed with a reference group consisting of people with extensive practical experience in the area of agriculture work environment.

Results

The studied statistical data showed that there were3 deaths, i.e., one took place at loading of calves, one happened in the feeding of horses and one occurred when working with suspended forage wagon during the five-year period (2009-2013). A total of 30 % of the 592 accidents led to a sick leave for more than 14 days. By AFAs, 355 cases were the 45% that was serious injury that led to sick leave for more than 30 days and/or medical disability, and 27% which led to medical disability.

Of investigated accidents that resulted in medical disability it was 57% who were directly or indirectly related to work with animals, that is, occurred during milking, cleaning/strewing, feeding, removal and loading of animals and riding/driving. Moreover, it was widely circulated on the operations.

Number of notified occupational accidents per year

Figure 1 shows the number of notified occupational accidents per year suffered by women in agriculture for the period 2009-2013. The number of notified cases has grown steadily over this period.

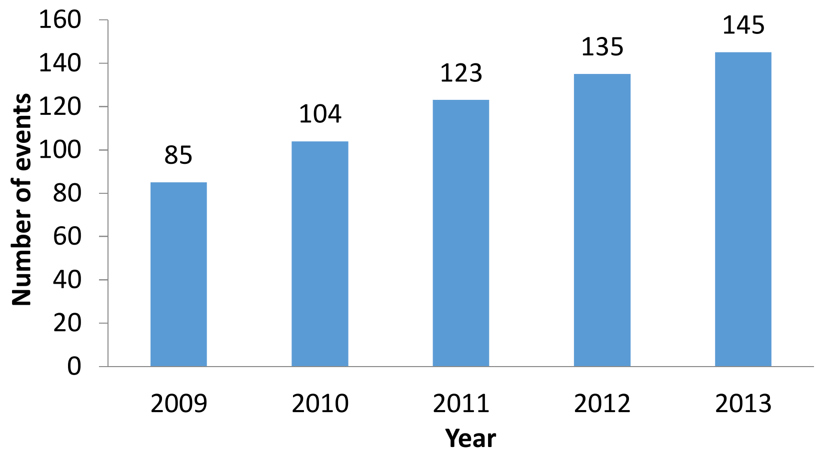


Figure 1.Number of notified occupational accidents in agriculture during the years 2009-2013 (merger of AFAs and AVs data, a total of 592 cases).

Time over the year

Figure 2 shows how the numbers of notified accidents suffered by women are distributed over the year. Most accidents occurred in September, followed by the December and March. The least number of accidents occurred in May and August.

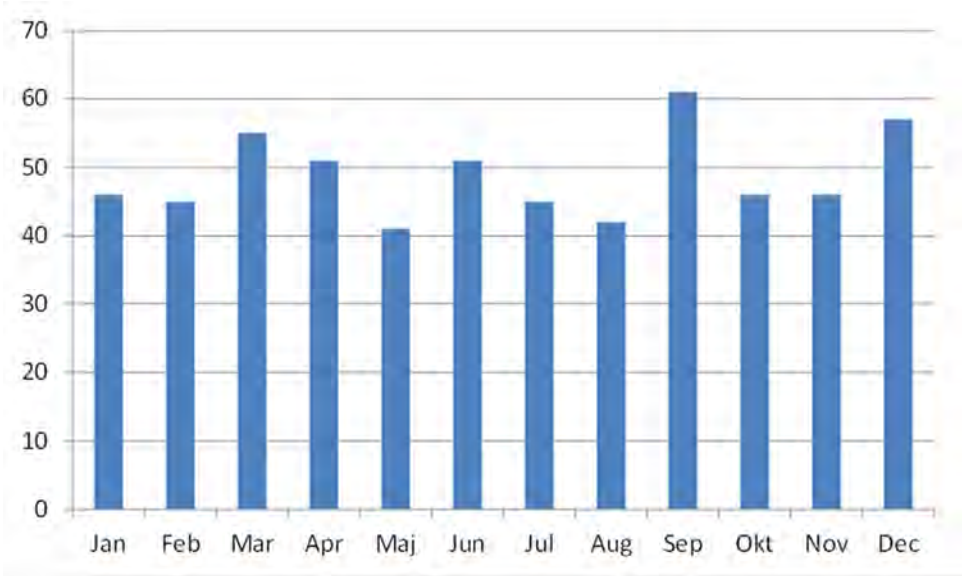
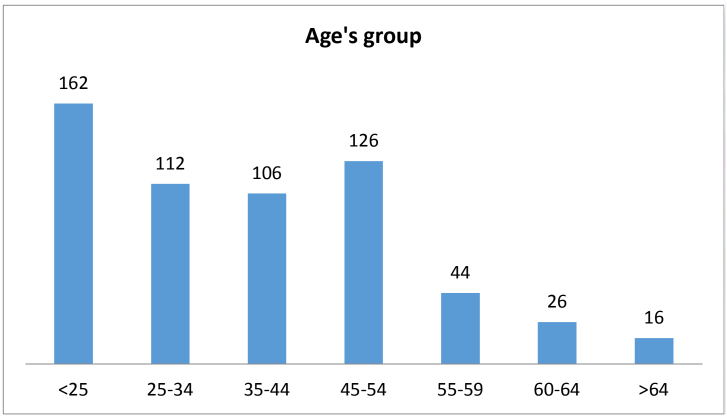


Figure 2. Distribution of number of notified occupational accidents per month during the years 2009-2013 (587 of 592 cases, 6 were missing date of injury).

Age distribution

Figure 3 shows the accidents distributed in different age groups. In 27% of accidents (162 of 592) were the injured women younger than 25 years. Only 15% of those injured was 55 years of age or older. The other injured were distributed relatively evenly between the age groups 25-34 years, 35-44 years and 45-54 years. The average age for all damaged at the time of the accident was 38 years. To be able to parse the result, this aging is related to the age distribution of the overall number of women working in agriculture.



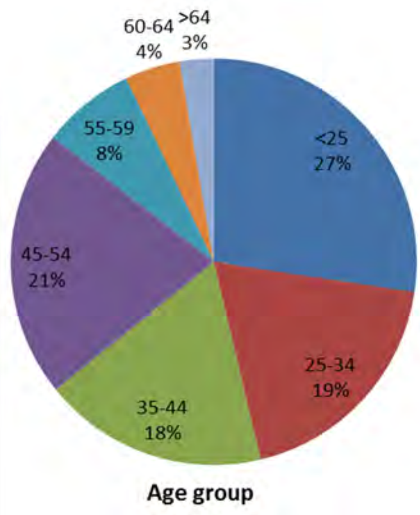


Figure 3. Number and proportion (%) of notified occupational accidents in different age groups (total for the years 2009-2013).

Furthermore, it has specifically been studied on how the distribution of accidents looks within occupational groups for the age group < 25 years, because this particular age group had the highest proportion of accidents by all professional groups.

Damage caused by animals constituted the majority of accidents in women < 25 years. An analysis of the external factor that caused damage of work showed that cattle were the external factor of 38% of the accidents and horses were that of 22% of the accidents. The operations where most accidents took place were in milking, followed by other cattle handling, remove/sorting of cattle and lead/moving horse.

About 14% of the 162 accidents led to a sick leave beyond 14 days and a total of 18 injuries reported as having led to any degree of medical disability (that is, permanent physical disabilities).

Operations

The most common operations performed in connection with that accident happened was milking, moving/sorting of cattle and other handling of cattle (Figure 4). These three operations accounted together for 28% of the total number of accidents. A significant proportion of accidents (15%) were also associated with horse handling of various kinds, i.e., leading/moving horse, riding/driving horse and other horse care. A more detailed description of these operations and the underlying causes are presented in "*Common accidents at specific operations*" section. Animals of other animals include animal beaten pig, sheep, poultry and a case with llama. The accidents took place mainly in connection with insemination, vaccinations and other treatments as well as killing.

In the figure 4, the category of "Animal care" includes elements in different ways that means the management of the animals, while feeding and cleaning/strewing presented in separate categories. Accidents related to feeding and cleaning/strewing accounted for 12% of cases. Common accidents in the feeding were falls (slipping/tripping/ wrong ramp) and kind of animals (be run/kicked/on hit). Even during cleaning, the accidental falls and blows from animals occurred frequently. Also, there exists a chemical damage of disinfectants and pinching during cleaning of the conveyor belt.

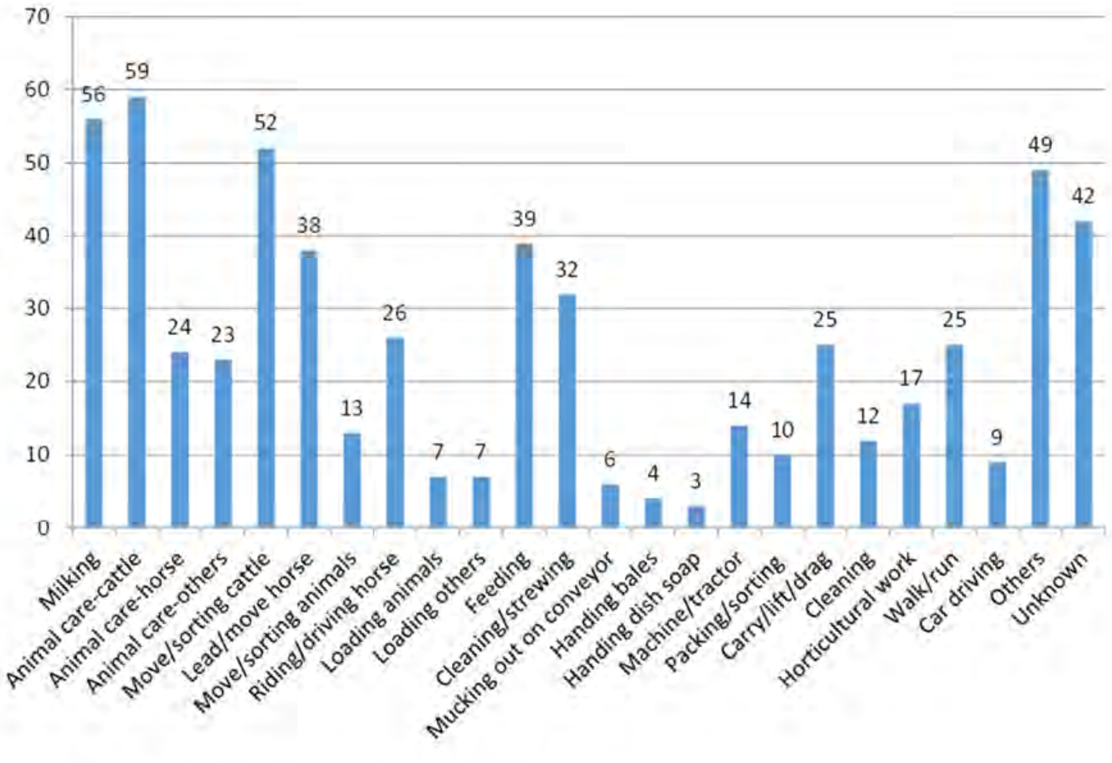


Figure 4. Number of notified occupational accidents that occurred in the context of the various items or stages of work (total 592 accidents).

Moreover, the most injury prone operations, and how and why accidents happen has been analysed in the following *common accidents at specific operations*.

Caring for cattle

There were 59 accidents, which occurred at other maintenance of cattle (other than milking and relocation of animals). The largest share (17%) occurred in the treatment, such as blood sampling, vaccination and treating calving paralysis. Table 3 shows all the operations in other cattle management.

The cows were the external injury factor in 63% of the injuries in the maintenance of the bovine species (including 7% was cow with calf), followed by calf for 10% of the damage, heifer in 8% of the damage and the bull in 5%. Other injuries had an exterior damage factor, i.e., floor/surface (7%), grind/tube (3%) and cutting machine/knife (3%). Common injures were kicked, hit, pinched, walked and jostled.

Table 3. Operations are included in the category of "Animal care-cattle" (Figure 4). Number and percentage (%) of accidents during years 2009-2013.

Operations	No of claims (share in%)	Case in point
Treatment	10 (17)	-Be wielding to head just when the person would stick in the syringe, stick in hand -Help vet, cow became afraid, walked
Pregnancy-study	7 (12)	-In pregnancy investigating a cow, another cow pushed himself between me and the cow with the result that my arm pinned firmly
On/off with the Halter necklace	6 (10)	-Tie up and put the Halter on cow. Kind of cow face
Handling cow	6 (10)	-Tried to stop cow, hand caught between pallet and cow -Would help a cow stuck in the fastening, cone got up and became stamped on the person's foot
Calf management	5 (8)	-Help the calf to drink (breast-feed), jostled by calf
Insemination	5 (8)	-Pinched when the animal moved out
Supervision	5 (8)	-Controlled new born calf and newly calved cow. The cow butted me
Calving	3 (5)	-Back problem was triggered during an ongoing helps process with chain at calving
Clipping	3 (5)	-I coin with cut machine, got cut up in mouth
-Mouth machine manufacturing	3 (5)	-Cow kicks the arm at the fixation of bone
Miscellaneous	6 (10)	-Heifer had stuck under a gate, fired at frightening -Close a gate, a bull kicked at the gate
Total	59 (100)	

Of these 59 occupational accidents, the body part that was damaged in the accidents that occurred during care of cattle. The most common case was bone including knee (12%), back/spine/vertebrae (10%), arm, including elbow (10%) and hand (10%). In these injuries, were 21 (i.e., 36%) that have been leading to a sick leave longer than 14 days, and 8% of these cases led to some degree of medical disability.

Moving/sorting cattle

52 accidents occurred at work to move or sort the cattle. The animal category cow was the external injury factor in 29% of the damage (of which 4% was cow with calf), followed by Heifer in 27% of the damage, bull in 8%, veal in 4% and unknown cattle in 4% of cases. Other injuries had exterior damage factor on floor/surface (19%). Those cases of accident resulted in the damage were slipped, stumbled or stepped wrong, and grind/tube (10%). Typical cases of accidents when moving/sorting of cattle were:

- An animal went to fit, jammed against the gate
- Running to catch up with shoes, slipping on the grass, falls
- Downloaded cows in loose operation. Among the cows was an untethered bull. While working the bull attacked from behind, butted over and pressed the person along the floor towards the Interior
- Heifer's turned, ran at boom who met someone in the chest that fell

Common injures were kicked, punched between the animals and the wall/decor as well as attacked. The injured body parts that were most abundant at the accidents that occurred during removal/grading of cattle were back/spine/vertebrae (11%) and bone including knee (11%; Figure 5).

Of the 52 accidents that occurred when moving/sorting of cattle were the 20 cases (at 38%), which led to a sick leave longer than 14 days, and 8% of which led to some degree of medical disability.

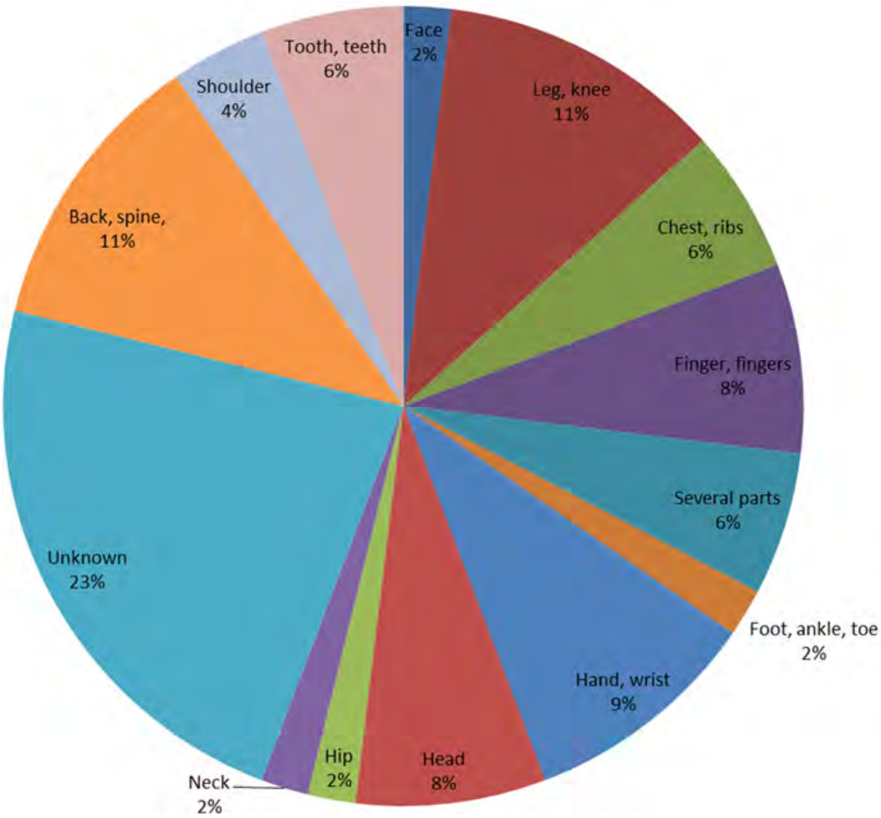


Figure 5. Injured body parts in the accidents incurred during remove/sorting of cattle.

Milking

56 occupational accidents occurred during milking. Cow or heifer was external injury factor in 93% of accidents. In 64% of cases was the damage by kicked, and another common event was that the person was pinched. Typical cases of accidents in milking were:

- During milking, the person was kicked out by the cow and fell down in the gutter, and then broke her hand
- Put on milking organ and would prepare the cow for milking. Was kicked out of the cow. Kicking against the rear head which results in severe headaches
- Con settles in milking, pinched hand
- Met a cow in a narrow time, was pinched between the cow and the wall

In milking, hand/wrist was the most abundant injured body part with 25% of the damage (Figure 6). Generally, the upper extremity was particularly affected during milking. Of the 56 occupational accidents which occurred at milking were 22 cases, or 39%, which led to a sick leave beyond 14 days and 7% which led to some degree of medical disability.

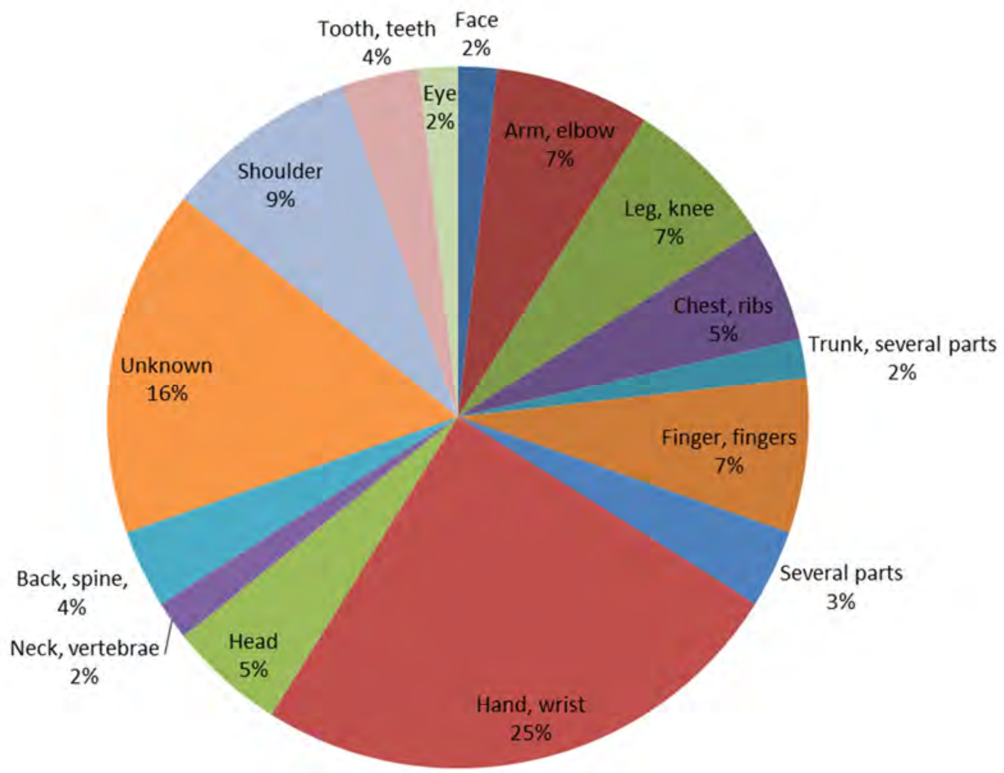


Figure 6 Injured body part in the accidents occurred during milking (56 cases).

Work with horses

88 occupational accidents occurred at work with horses. Normal operation when the accidents occurred was leading/moving horse (43%), horse riding/running horse (30%), production/shoeing (7%) and treatment (e.g. put on sores, worms; 7%). Common events was kicked (26%), from the horse at horse riding (24%), trampled, over on ran and pinched. Examples of accidents at work by horse were:

- Rowdy foal kid who tried to tear himself away. Kept both foals kid and strain as early as attempted to close a gate. Foal kid jerked to the rope which the person gave in and then broke the finger
- Leading a horse. care of the horse, hard kicked in the back
- Put on a wound on the leg of the horse, the horse put down the hoof on the finger
- Held in the young horse that would be affected, the horse got scared, throw themselves, squeezing hand against wall

- While were leading horse. Horse were afraid of lawn mowers, pinched between the input and the horse
- She rained/rode a horse. The horse stumbled and the horse and the person both went down, she landed in the horse

When worked with horses, hand/wrist, fingers and legs including knee were the most common damaged body parts with 13%, 11% and 11% of the damage (Figure 7). Of the 88 occupational accidents which occurred at work with horse were the 37 cases, or 42%, which led to a sick leave beyond 14 days and 19% that led to some degree of medical disability. There were largely young women to be injured, close to two-thirds of those injured were under the age of 35 years and 38% were under the age of 25 years.

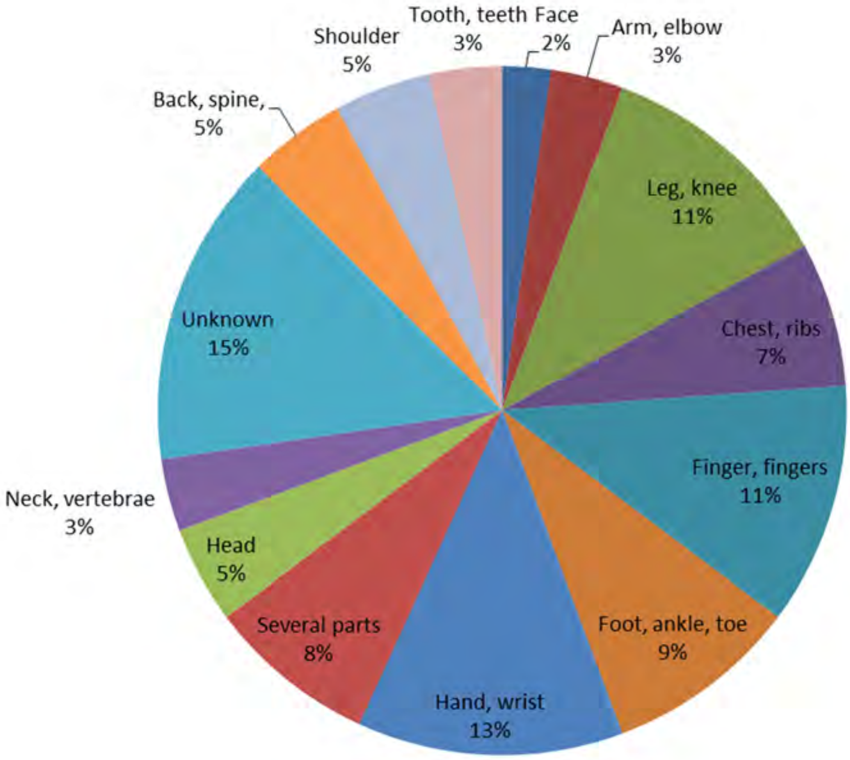


Figure 7. Injured body part in the accidents occurred during work with horse (a total of 88 cases).

Discussion and conclusions

The results of this study showed that the number of accidents in agriculture steadily increased in the period from 2009 to 2013. The accidents were most associated with milking, moving/sorting of cattle, other cattle management and work with the horse. Close to one in five accidents was also related to horses. Horses made up a large and growing business in the agricultural enterprises and working with horses was largely female dominated. Feeding and cleaning/strewing were also the operations with relatively much accidents and high proportion of animal-related accidents.

The most common accidents that occurred in milking, moving/sorting of cattle, other cattle management and work with the horse, had a higher proportion of cases that led to a sick leave longer than 14 days. Work with horses had a twice the proportion of work-related injuries that led to medical disability, compared to the three work phases with cattle. Nearly

one in five who was injured when working with horses got permanent physical disabilities, however the detailed information about these cases are still missing in the database.
Because of the high proportion of animal-related injuries, the preventive measures should focus primarily on this group of injuries. The analysis of these injuries will be continued to gain the more detailed information of the underlying causes and suggest the more specific measures.

The young women were particularly affected by accidents at work, then more than a quarter of those injured were under the age of 25 years and 46% of them were under the age of 35 years. The question is whether this is due to the fact that young women are exposed to greater risks, or if the allocation simply mirrors the age distribution of women employed in agriculture? A possible reason for young women at higher risk of being involved in an accident at work can be that they have less experience and professional knowledge, but it can also be explained in that they are exposed to greater risks when it is common that they are working with cattle and horses. 82% of accidents for young women < 25 years affected women in professions related and horse trades attesting this interpretation. It is also possible that there is a greater tendency of young women to report an accident.

Acknowledgements
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Psychosocial condition and mental health of Swedish farmers and rural entrepreneurs

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Introduction

The expansion of small family farms often implies increased financial responsibility, risk taking, employer responsibility and long working hours. Agriculture represents a profession whose success is highly dependent on uncontrollable external conditions such as weather, legislation, disease outbreak, environmental changes and negative societal attitudes. Moreover, farmers' face normative and market pressures and are expected to maintain high production standards, a stable economy and to act in socially conscious and environmentally responsible ways. The combination of uncontrollable external factors, increased expectations and weak social support may cause poor psychosocial working conditions and ultimately a decreased mental health.

Aim

The objective of this study was to examine the psychosocial working conditions and mental health of farmers' operating small size Swedish farms with different production sectors such as crop, dairy, beef and pig.

Methodology

The study was conducted in 2010-2011 among 470 farmers comprising 177 crop farmers, 139 dairy and beef farmers and 154 pig farmers. The General Nordic Questionnaire for Psychological and Social Factors at Work (QPSNordic) was administered to assess subjective perceptions of the psychosocial work conditions and mental health.

Results

The three groups reported general well-being regarding their psychosocial work conditions and health, however, dairy and beef farmers perceived their psychosocial work conditions and mental health as worse compared to crop and pig farmers. This was characterized by higher work demand, more negative impact regarding work and leisure time, less contentment concerning how the dairy and beef farmers dealt with the physical and psychosocial work demands, worse general health and more exhaustion after a work day. The participants were asked about the extent to which they felt stressed by various external factors. The external factors that especially crop farmers and dairy and beef farmers experienced as most stressful was the EU legislation, comprehensive subsidy regulations, lots of governmental and EU-related controls and delayed payments, and the Swedish authorities' attitude towards farmers. Increased demands on environmental issues, from society and consumers, weather conditions, animal welfare legislation, varying market prices, increased crime in rural areas, agro-terrorism, disease outbreaks among plants and animals and concerns for the future of the farm were other external factors that were stressful for the farmers. Based on the results, an action plan for improvement of the psychosocial working conditions, mental health, and social support in rural areas should be the next step to be developed.

Sustainable health and safety of Ugandan farmers

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Introduction
'Sustainable agriculture' and food security requires 'sustainable health' and safe working conditions for farmers and farm families. Farmers in good health will be able to provide for their families and contribute to the local farm community. There is limited or almost non-existing research available regarding health and safety of farmers in Africa and data is essential to understand and change patterns of human health and safety. In Uganda, these issues are not considered from an agricultural aspect although the majority of risk factors regarding human health and safety are related to agriculture.

Aim
The objective of the study was to interview Ugandan farmers and family members regarding their attitudes towards health, safety and risk factors in an agricultural context, and how it affected their daily lives and livelihood.

Methodology
The study was conducted in Uganda May 2014 and comprised interviews with seven male and female farmers, and transects walks on each farm.

Results
In general the level of knowledge and awareness of agricultural health and safety risks, disease and injury prevention among the farmers was low. The farmers claimed few agricultural related complaints, injuries or diseases. It was obvious from the farmers' responses that health and safety concerns (e.g. diarrhea, cough, fever), cuts while using the machete in the plantation, bruises when handling the animals and symptoms of poisoning from using insecticides on the
animals were nothing worth talking about and considered as part of the occupational hazard. The most important topic mentioned by the farmers was the use of chemicals and drugs related to livestock. Once a week the farmers sprayed the animals with an insecticide to prevent tics, lice, tsetse flies and other biting nuisance flies using a back or hand sprayer. The spraying was conducted without personal protection equipment (PPE) which was considered too expensive and difficult to obtain. The farmers explained that they usually felt unwell, dizzy, vomited, and had pain and burning feeling in the face and eyes after spraying. Sometimes the symptoms were so severe that they needed treatment and bought medication without prescription at the local drugstore where the storekeeper often had limited or non-existing knowledge about the chemicals or drugs, except for dosage.
The availability of agricultural health and safety training in the region was non-existing and the farmers expressed the need for information and practical training in agricultural health and safety, disease and injury prevention.

A survey on occupational injuries in tree climbing in Italy

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Abstract

The aim of this work is to know how many injuries occur to tree climber arborists, during their pruning and felling work on tall trees, both to know what kind of accidents and the reason why them happens. This study was made by means of "INFORMO", an INAIL's database which contains a list of serious and fatal injuries occurred from 2002 to 2012 counted by INAIL's Prevention Service. From such list Authors extracted only accidents related to operators who was working on tall trees, at least 2 meters above a stable ground, without using lifting platform. In these case operators would have to use ropes and harness. The result of the study consists in understanding common triggers of injuries, knowing if there are technical problems that can be solved, or other problems that can be addressed to decrease the number of accidents and their severity.

Keywords: Arboriculture, Work at Height, Safety And Health

Introduction

The presence of trees within the city, private gardens and parks is now recognized as a necessity and added value to the quality of life for the assimilative capacity and store carbon, oxygen emission, mitigation summer heat, thanks to the shadow produced by the foliage and water vapor caused by evapotranspiration, not taking into account the high landscape value. These benefits, however, entail the burden of maintenance, including:

- a proper assessment of the needs of the trees (airspace, radical);
- control of diseases (fungal, bacterial, insect infestations);
- the pruning.

The latter, which allows to reach the best compromise between the tree growth and the traffic's needs and safety along with the space limitations, must be done by green areas management professionists, because of their knowing about plants biology and the reactions of various types of pruning to the tree, depending on its species and age. Besides the professional green they must know the operating procedures to perform the pruning, in order to work efficiently and safely.

In this work accidents occurred in this workplace in Italy have been investigated, especially for pruning of tall trees, or during operations on trees that provide movements of the operator above two meters in height from a stable work plan, without the aid of a lifting platform but only through the use of ropes and safety harnesses.

Such technical work in canopy is called "tree climbing": due to its characteristic it is used all those times when you can't reach the target tree with a lifting platform, or when pruning or consolidation of branches is required to be executed from within the crown, and it is only feasible with this working technique. The aim of this survey consists in understanding what are the most common injuries in this kind of work and consequently what are the measures to limit the occurrence or diminish the severity of the consequences.

Methods

The data subject of this paper have been extracted from the database INFORMO, made by INAIL ('Istituto Nazionale per l'Assicurazione contro gli Infortuni sul Lavoro'), available on the web at *"http://www.ispesl.it/getinf/informo/"*. Inside it there are over 3800 dynamic of accident, which took place between 2002 and 2012, analyzed by the prevention services with a shared analysis model. In the "Archive of cases" you can search for areas of interest using the available filters; you can also make a free search with keywords using a search engine. With the said method, all injuries related to the word "tree" have been researched, and the search engine generated a list of 166 cases, which were analyzed individually to find the correspondence with the type of work investigated. Of these, 21 cases were eligible to the survey, because about pruning or felling of tall trees (else working over two meters height from the stable ground) without the use of platforms and using a positioning system with ropes and harnesses.

The INFORMO database classifies accidents with an alphanumeric code. Each event is associated to a brief description and different cards: the first one consists in the detailing of the accident. It lists the characteristic data of the incident's place, the injured, company and consequences. The second one shows the details of the injury factor. Finally there may be a third and a fourth table if together with the determinant there were one or more modulators factors that have influenced the development of the accident.

Results

From the data obtained in this analysis, looking at the modal data of each category (table 1), the profile of the standard worker more susceptible to injury comes out. It appears that falling from height is the most common trigger of injury, always with fatal consequences. Other data are reported in the table.

The profile shows that the operator more prone to injury is an Italian male, with a low level of education, working independently in agriculture, with experience in his work. The problem lies in the fact that pruning or felling of tall trees, even if present in agricultural environments, cannot be carried out by agricultural operators. They are specialized and normed by law (D.Lgs. 81/08 in Italy) activities that can be performed only after completion of enablers training. In fact, the determining factors are always procedures errors: the operator did not know what exactly he was doing, or how best to do, nor what were the consequences in case of failure. It also results from the risk assessment carried out by the injured: "factor not assessed".

Also aggravating modulator factor (but also in the background among the determinants) is the non-use of protective equipment such as helmets and restraint systems with ropes and harnesses.

Conclusions

In conclusion, there are laws that clearly establish who can perform work on ropes on trees (treeworkers), there are technical texts that refer to the safest working techniques and many safety devices dedicated to this type of work are available on the market.

The problem behind these accidents is the lack of training, and even before the issue of Italian culture, where everyone can do everything, but actually you have to have specific skills to perform complex jobs.

Even the assessment of the difficulty of operations must be performed by a technical expert in the sector, able to recognize specific problems.

The first point to be developed to reduce accidents and their severity is definitely the spreading of the safety culture, followed by proper training.

Table 1. Summary of modal value obtained from the survey in the INFORMO database

Categories	Modal data
Summary description	Fall from height
Ordinal working time	2-3
Collective accident	No
Place of injury (body)	Skull
Nature of injury	Fracture
Time off days	7500
Education	Middle school diploma or start training
Gender	Male
Nationality	Italian
Employment	Independent without wmployees or holder Without employees
Task	Farmers end specialized agricultural workers
Length of service	> 3 years
Number of employees present on the site with the patient	1
Business activies	Agricultural crops, horticulture, floriculture, breeding
Place of injury (location)	Agricoltural site, orchard
Subcontract Y/N	No
Task of the injured at the moment of accident	Own work activities
Parts of the environment that have impacted to body	Ground
Type of accident	Energy variation
Material cause	Plants
Determinant 1	Activity of the injured
Safety problem (Det. 1)	Error of procedure - Improper practice tolerated
Comparison with standard	D.Lgs. 81/2008
Risk assessment	Factor not assessed
Determinant 2	PPE
Safety problem (Det. 1)	Error of procedure
Modulator Factor	PPE and clothing

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Health and Safety Challenges among Dairy Workers in the United States

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Abstract
Dairy farming is among the most dangerous agricultural settings. The purpose of this study was to describe the work experiences of dairy workers in the United States (U.S.) to design appropriate safety training programs. The long-term goal of the work is to eliminate occupational injuries among a vulnerable (primarily Latino) workforce in industrialized dairy operations.
Focus groups were conducted before or after work shifts. Workers were asked to describe their work experience at the dairy, quality of relationships with their coworkers and manager/s, as well as safety policies and procedures, and training experiences. Focus groups were conducted in Spanish and required approximately one-hour. Discussions were recorded, transcribed and translated into English, and analyzed for themes. Forty-four dairy workers participated.
The workers described their jobs as highly stressful, characterized by strenuous manual labor and time pressures. Participants reported many equipment issues and environmental hazards on the dairy, including exposure to unsafe conditions and numerous harmful substances. Relationships with co-workers were generally described as positive and team-oriented, while relationships with managers were more varied and negative. Participants reported limited knowledge regarding safety policies and procedures and made numerous suggestions for how to improve safety training.
The participants identified individual, organizational and environmental points of intervention that can be used to inform management and training programs in order to promote and maintain a higher level of safety within the U.S. dairy industry.

Keywords: Occupational Health, Dairy Workers, United States

Introduction
The dairy industry in the U.S. produces a substantial amount of the world's milk supply (International Dairy Federation, 2010). In recent decades, the industry has been shifting toward a high efficiency model with growing herd sizes driven by advances in milking technologies (Douphrate et al., 2013). With the trend towards large-scale industrialized operations, U.S. dairies are increasingly relying on immigrant, primarily Latino, workers (Schenker & Gunderson, 2013).

The dairy industry has been recognized as one of the most dangerous agricultural settings, with high rates of occupational injuries and illnesses (Hagevoort et al., 2013). The promotion of health and safety are high priorities for dairy industry leaders, yet there has been very little research to date on the determining factors of these outcomes among immigrant Latino dairy workers (Hagevoort et al., 2013). In order to advise the development of culturally sensitive training programs, the present study conducted focus group interviews to better understand dairy worker perceptions of the barriers to and facilitators of enhanced safety.

Materials and methods

Dairy owners from three U.S. dairies were recruited and agreed to allow their workers to participate. Owners announced the opportunity to workers and encouraged them to participate by posting recruitment flyers in both English and Spanish. Eligibility was restricted to Latino/a dairy workers.

Focus groups (approximately one-hour in duration) were conducted on-site at each dairy before or after work shifts. Participants were asked questions about their previous and current work experiences. They were also asked to describe the quality and nature of relationships with their manager/s and co-workers. The interview closed with a discussion of safety policies, procedures and training. All focus groups were conducted in Spanish by a bilingual member of the research team. An interview guide was used to lead the discussion, while also maintaining flexibility to allow the workers to bring up other topics perceived as important. Confidentiality and anonymity were assured, and no demographic information was collected. However, some basic demographic and background information, such as gender, length of time working in the dairy industry, and country of origin, was gathered anonymously during the interviews. All participants provided written consent before initiation of the focus groups. Workers were incentivized to participate with a small gift certificate to a local store.

All discussions were audio-recorded, translated into English and transcribed verbatim with the help of a bilingual research assistant. Transcripts were analyzed by the first and third authors to identify themes. All discrepancies were discussed until consensus was achieved on the final list of themes.

Results

A total of 44 dairy workers (9% female) participated in the study. Participants were primarily from Mexico, but there were also representatives from Puerto Rico as well as South and Central America. The prevailing themes identified were grouped into the following categories: the nature of the work, equipment issues, environmental hazards, relations with coworkers and managers, and safety policies, procedures and training.

The workers' jobs involved manual labor, time pressure and stress. Participants reported numerous equipment issues (e.g., broken machinery, lack of personal protective equipment) as well as various environmental hazards (e.g., exposure to electricity, chemicals, manure, dust, polluted water) that influenced safety and health outcomes. Participants described relations with co-workers as positive and team-oriented, although some noted tensions due to poor irresponsible behavior and poor performance. Participants described the quality of relationships with their managers as anywhere from positive to negative to non-existent. Participants reported limited knowledge regarding safety policies and procedures, perceived safety training to be insufficient, and made numerous suggestions for enhancements.

Conclusions

This study provides novel and in-depth insights into the attitudes, beliefs and experiences of immigrant Latino workers on U.S. dairy farms, with a particular focus on safety. The participants identified numerous points of intervention—across individual, organizational and environmental levels—for better organizing, managing and training immigrant dairy workers in order to creating a more safe working environment.

Overall, the workers expressed a desire for more respect and acknowledgement as well as better integration across the different areas of the dairy. High workload and scheduling issues were acknowledged as especially stress-inducing aspects of the job, suggesting considerable effort should be invested into reducing these stressors. Participants highlighted the importance of more quickly addressing environmental hazards and equipment issues to avoid putting animal and human health at risk. There was a shared belief among participants that dairy management tended to prioritize cow health and safety over that of workers. This belief has been found in other studies involving immigrant Latino dairy workers in the U.S. (e.g., Arcury et al., 2010). It is essential that dairy management work to promote a strong safety culture. Many participants requested additional personal protective equipment, particularly in the milking parlor and other high-risk areas of the dairy. It is important that the introduction of new personal protective equipment be accompanied by instructions and training regarding proper use.

The increasing reliance on an immigrant, primarily Latino, workforce within the U.S. dairy industry, calls for the development of culturally-relevant and evidence-based safety programming. It is important such programs be guided by workers' attitudes, beliefs and behaviors in order to ensure maximum effectiveness (Blancero, 2014). These findings serve as an initial step toward better understanding how to improve safety outcomes among immigrant dairy workers.

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A Certificate Course for the Agricultural Safety & Health Profession

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Aims

In 1996 a Certificate Course in Agricultural Medicine was designed by a multidisciplinary consensus group in the U.S., primarily for health care providers. This course has expanded to 9 states in the U.S., Australia, and Turkey. A similar course for agricultural safety and health professionals has not existed. The objectives of the Agricultural Safety and Health Certificate Course were to: 1) Identify subject matter appropriate as core knowledge for practicing agricultural safety and health professionals; 2) Develop learning objectives for the core subject matter; and 3) Offer a pilot Agricultural Safety and Health Certificate Course.

Methodology

A task force of the International Society for Agricultural Safety and Health (ISASH), in exploring enhancement of professional development activities for members and others, used the agricultural medicine course as a starting point and decided upon a 3-day course taught by highly respected instructors focused on the following subject matter content areas: 1) History of Safety and Health in Production Agriculture; 2) Agricultural Operations and Workers; 3) Injury and Illness in Agriculture; 4) Agriculture Injury Hazards; 5) Agricultural Illness Hazards; 6) Methods and Approaches to Hazard and Risk Management; 7) Personal Protective Equipment; 8) OSHA and Other Safety and Health Regulations; 9) Developing Safety and Health Management Plans; 10) National Approaches to Agricultural Safety and Health; 11) International Approaches to Agricultural Safety and Health; and 12) Resources and References for Hazard and Risk Management.

The specific target audiences for the course were determined to be: 1) Beginning agricultural safety and health extension specialists, researchers, rural health care providers, administrators, loss control specialists, risk management specialists, and those with similar titles; 2) Farm and ranch operators, managers and supervisors responsible for worker safety and health; and 3) Practicing safety and health professionals missing formal training in agricultural safety and health.

An online course evaluation, operated by the University of Nebraska Medical Center, was devised. Students are required to pass a 50 item individually-randomized test with a score of 70% or higher. The exam was open-book and students may take the exam up to three times but must wait at least one week between each attempt. Financial support from the Agricultural Safety and Health Council was obtained to minimize the course fee.

Partial Results

Twenty-four students have completed the pilot course. Testing and course evaluation is in-progress on the due date of this extended abstract. Final results, evaluations and conclusions will be presented on the poster.

All 24 students (100%) opted to take the exam to obtain a certification by examination which indicates competency in core knowledge in agricultural safety and health. A copy of the certificate to those passing the exam is shown in Figure 1. To date, 8 of 24 students

(33.3%) have completed the exam with 8 (100%) successfully meeting requirements for certification. Sixteen of 24 students (67%) have completed the course evaluation. Of those completing the evaluation, 14 of 16 (87.5%) were practicing professionals with the other 2 (12.5%) particiapnts identifying as graduate students.

A sliding scale (0-100) was used to evaluate several specifics of the course. A mean of 77 (52 min; 98 max) was received when asked if the course achieved its overall purpose of establishing a core level of knowledge in the agricultural safety and health profession. To the question about how well the course achieved its objectives to enable the participants to recognize and understand the major occupational health and safety issues in agriculture, a mean of 78 (40 min; 98 max) was received. When asked if the course helped the student anticipate, recognize, and prevent occupational, environmental and community health and safety problems unique to the rural and agricultural populations, the mean was 77 (56 min; 97 max). For the question about the course providing multidisciplinary and community oriented prevention solutions to health and safety problems, the results show a mean of 75 (50 min; 99 max).

Students were asked to evaluate the value and usefulness of the specific subject matter taught in the course by asking them to use the sliding scale. Evaluations to-date on the major topics is summarized by mean, minimum and maximum scores.

Topic	**Mean**	**Minimum**	**Maximum**
History of Safety and Health in Production Agriculture	80	57	97
Agricultural Operations and Workers	79	60	95
Injury and Illness in Agriculture	75	50	95
Agriculture Injury Hazards	78	55	95
Agricultural Illness Hazards	79	55	95
Methods and Approaches to Hazard and Risk Management	81	21	100
Personal Protective Equipment	87	65	100
OSHA and Other Safety and Health Regulations	73	0	100
Developing Safety and Health Management Plans	83	35	100
National Approaches to Agricultural Safety and Health	75	13	95
International Approaches to Agricultural Safety and Health	70	13	100

Students were asked to indicate if their background was primarily safety, health, or a combination of both. Six students (37.5%) indicated a safety only background while 10 students (62.5%) indicated their background included both safety and health. No one indicated a health only background. When asked if the instructors tried to cover too much material in a 3-day course, the responses were evenly split between Yes (8, 50%) and No (8, 50%). Students were asked how important it was to have an opportunity to obtain a certificate based upon successful completion of an examination. The mean response was 86 with a low value of 17 and a high value of 100. Student were also asked if they would recommend this course to a colleague in the agricultural safety and health field with 15 of 16 respondents (94%) saying Yes.

Fewer students (8 of 24, 33.3%) have completed the examination as this time. A score of 70% is required to pass the examination. All have students have successfully passed the exam for certification with a mean score of 84. The low score to-date is 76 and the high score is 90.

Overall, it appears that the Agricultural Safety and Health Certificate Course meet the expectations of a large majority of participants. The number of students enrolled in the pilot test and their interest in completing the examination for certification suggests that professionals are interested in certification in agricultural safety and health. All students highly recommend that other professionals take this certificate course. Additional evaluation results will be included on the poster. Evaluation results, once completed, will be utilized by the course instructors to revise future course content and structure.

Figure 1. An image of the Certificate of Examination for the Agricultural Safety and Health Certificate Course.

Community Engagement in the Prevention of Injuries and Deaths from Agricultural All-Terrain Vehicle Use

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Introduction

All-Terrain Vehicles (ATVs) have become an essential aspect of efficient agricultural work but have led to many injuries and deaths. Since 1982 over 12,000 people have been killed in the United States riding ATVs for occupational and recreational uses (CPSC, 2014). ATVs are used in farm and ranch operations with increasing popularity resulting in 65% of all occupational related deaths occurring in the agricultural sector (Helmkamp et al., 2012). Occupational use of ATVs (Figure 1) is on the rise in many sectors because of their versatility, adaptability and affordability but has led to a nearly 200% increase in work-related fatalities reported in the U.S. between 1999 and 2008 (Helmkamp, 2011).

Practice Innovation

During challenging economic climates, it has become necessary for researchers and agricultural associations to work together as partners in the prevention of injury and deaths related to occupational ATV use. Using social marketing concepts and methods (Kotler et al., 2002), we developed a series of projects to increase the number of certified ATV safety trainers serving rural agriculture communities throughout the state of Montana. We designed participatory, community partner led projects for successful translation of ATV safety training through the Agricultural Extension Model to serve end users. The Agricultural Extension Model has been identified as one of the most successful approaches to translation of science to practice and adoption of research results (Rogers, 2003). Within this framework, theories work behavior (Campbell et al., 1993), planned behavior (Ajzen, 1991), the organization of work model (NORA Organization of Work Team, 2002), as well as social marketing principles were incorporated to enhance effective translation and dissemination of agricultural health and ATV safety knowledge, skills and abilities to end users. University researchers partnered with 11 agricultural Extension Agents in Montana. The partnership resulted in training and certification (by the ATV Safety Institute - ASI) for all 11 Agents located in rural areas throughout the State. The Agricultural Extension Service is made up of effective 'change agents' from communities throughout Montana. These agents live and work in the rural communities and provide support services for Agricultural operation success, they enjoy unique personal and professional relationships with operators and are perceived to be credible. Agents routinely promoted safe ATV use became certified to teach the five-hour ASI hands-on training in their communities with a focus on safe use for ranching work as opposed to recreational use. The Extension Agents were able to recruit agricultural producers through local communication channels for hand-on training in their communities. A series of trainings was launched in 2014 and continues throughout rural locations in Montana with increasing numbers of agricultural producers researched.

Figure 1. ATV used in ranching for tasks associated with fencing building, spraying weeds and herding animals.

Results

Certified Agricultural Extension Agents have trained over 75 producers to date. Evaluation of training sessions have enabled researchers to understand more about the specific needs of the producers, barriers and facilitators related to safe ATV use, and perceptions about ATV use in agricultural operations. ATVs among Montana ranching operations are used for general transportation, cattle handing, fence mending and weed control. Barriers exist to adoption of formal training and helmet use. We have found that the 5-hour ASI training overcomes many misperceptions and barriers about training and helmet use. Our data revealed that 88% of agricultural producers reported the training definitely increased their awareness of ATV safety issues and will alter their behavior. Using a pre/post test design with the trainees in the ATV safety program, we found 15% measurable gains in ATV safety knowledge and 100% of trainees reported the issues taught were applicable to their work. Producers indicated that they were likely to recommend the hands-on training to other producers as a result of their experience.

Additional outreach partnerships with Montana agricultural producers have resulted in ATV safety information Tip Sheets containing safety information aimed at the four primary uses of ATVs on cattle ranches, see Exhibit 1. These Tip Sheets were developed using participatory research to practice (R2P) model with community partners to enhance local messages about safe ATV use and to increase adoption of ATV the 5-hour hands-on field training. The Tip Sheets were disseminated throughout rural Montana. Feedback from Agricultural producers indicated an increase in safety knowledge and 74% would change the way they operated their ATVs as a result of information on the Tip Sheets.

Agricultural Extension Agents were interested in additional portable tools for ATV safety field training. Durable ATV Safety Training Kits were developed for Agricultural Extension Agents that had taken the 5-hour hands-on training and/or obtained ASI certification. Thirty ATV Safety Training Kits were produced and disseminated to 30 Agricultural Extension agents to use under variable environmental conditions. The kits contained posters, placards, flip cards, tip sheets, slide presentations, additional handout and evaluation forms. Data is being collected on the effectiveness of this tool for ATV safety training.

An additional partnership between media and web technology professionals at the university has resulted in the development a culturally appropriate, 60 minute, web 2.0 interactive training/education experience conceived and designed by certified Agricultural Extension Agents. This training/education is aimed at increasing awareness of risk and hazards associated with ATV use in ranching operations and the need to be knowledgeable about safe vehicle use and operations: 1) pre-ride vehicle safety check, 2) personal protective equipment, 3) starting and stopping, 4) driving on uneven terrain, 5) navigating obstacles and 6) riding up, down and across hill sides. The training and education are also reinforcing the need to take the 5-hour hand-on ASI training to achieve maximum learning, competency and safe vehicle operation.

The most recent project will deliver Public Service Announcements (PSAs) about ATV risks, hazards and available training in the local community. The PSAs will be disseminated throughout communities using multiple communication platforms while promoting a culture of adoption for ATV safety training and safe use in agricultural operations.

Figure 2. ATV used for herding cows.

Conclusions
The effective partnership between university researchers and agricultural partners has led to Agricultural Extension Agents earning ASI certification in safe ATV use on the farm and significantly increased capacity and access to high-quality ATV safety training for ranchers in rural Montana. Certified Agents must provide two training sessions per year to sustain their certification. Each session trains between six and eight producers resulting in a guarantee of 132 – 176 producers being trained each year in safe ATV operations throughout Montana. The success and sustainability of this project was only possible due to the strong collaboration and resources that that each partner contributed to the project

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TOPIC 6

"Environment Safety, People Health Protection and Welfare"

Italian Potential Biogas and Biomethane Production from OFMSW

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Abstract
This work is aimed at predicting the potential biogas and biomethane production, using the Organic Fraction of Municipal Solid Waste (OFMSW), in Italy, where 1388 Anaerobic Digestion (AD) plants (power of 7.4 TWh, equal to 640.4 ktep) are nowadays available.
In order to compute the potential biogas and biomethane production in the 20 Italian regions, the data about OFMSW production in 2010-2013 period have been evaluated.
The Italian production of OFMSW, that was 5.2 million tons in 2013 (18% of MSW), could be used inside bioreactors for producing biogas and digestate, that must be aerobically composted into a biofertiliser. In 2013, the Italian potential biogas production from OFMSW was 739 million m^3, that is equal to 444 million m^3 of biomethane. The highest biogas production from OFMSW was in Lombardy region (143 million m^3), having a potential biomethane production of 86 million m^3. The highest OFMSW production per inhabitant was in Emilia-Romagna region (142 kg). Yet, if OFMSW was 37% of MSW, the potential biogas and biomethane production should be increased: the biomethane production increase would be 486 million m^3, of which the maximum would be in Sicily region.
The biogas produced can be used for generating heat and electricity or upgraded into biomethane, distributed at dedicated stations and useful as biofuel for powering means of transport. This biofuel would replace natural gas, and, therefore, allow a reduction of GreenHouse Gas emissions of 200 g of CO_2 kWh^{-1} (5.5 times lower) and the import of fossil fuels from abroad.

Keywords: Organic Waste, Anaerobic Digestion, Biofuels, Biofertilisers, Greenhouse Gas Emissions

Introduction
The Anaerobic Digestion (AD) is the technology that can convert food industry by-products and/or the Organic Fraction of Municipal Solid Waste (OFMSW) and/or sewage sludge into renewable energy inside a bioreactor (Molino et al., 2013). AD process consists of a series of metabolic reactions (i.e. hydrolysis, acidogenesis, acetogenesis and methanogenesis), performed by a wide range of microorganisms in low or no oxygen environments and producing biogas and a digested substratum, called digestate, that must be aerobically composted into a biofertiliser (Comparetti et al., 2013a; Molino et al., 2013).

The biogas produced from AD process contains mainly methane (60% ca.) but also carbon dioxide, hydrogen, hydrogen sulphide, ammonia, siloxane and other substances that may inhibit the AD process itself or cause corrosion problems in plant pipelines or in distribution networks (Karatza et al., 1996; Lancia et al., 1997; Chen Ye et al., 2008).

The biogas produced can be used for extracting biomethane, that can be transferred to the national natural gas distribution grid or distributed at dedicated stations (to be built in the same area of each AD plant) and used as biofuel for powering means of transport. Another option is to transform the above biogas into electric and/or thermal energy inside a CHP

(Combined Heat and Power) plant, in order to contribute to replace fossil-oil based energy sources with renewable ones (Molino et al., 2013; Comparetti et al., 2013b).
Several authors have summarised technologies for biogas purification, aimed at extracting biomethane, by removing hydrogen sulphide, ammonia and siloxane. At the end of this process the biogas still contains hydrogen, carbon dioxide and traces of sulphidric acid and ammonia (<100 ppm), that must be removed from the stream, in order to produce biomethane (IEA, 2007).

The above process of upgrading biogas is a carbon negative balance, because the biomethane replaces the fossil natural gas and the carbon dioxide can be captured and used in industrial processes (Nova Energie, 2015).

OFMSW can be treated together with other organic wastes (co-digestion), e.g. animal manure, sewage sludge and wastes of slaughterhouses, in order to minimise the problems related to the collection of all co-digested wastes, i.e. bad smell (due to the concentration of proteins and sulphuric compounds, that become lower after AD) and high concentration of nitrogen (Comparetti et al., 2012).

The effective management and treatment of biodegradable waste is a topic of increasing importance for municipalities all over the world (Browne and Murphy, 2013).
OFMSW, which is dominated by food waste, is problematic as it is putrescible: it contaminates recyclable materials in combined waste collection methods and releases methane to the atmosphere, when it is deposited in landfill sites. Methane has a Global Warming Potential (GWP) 23 times that of carbon dioxide in 100 years (IPCC, 2012) and significantly contributes to climate change. The Landfill Directive 1999/EC (Directive 1999/31/EC, 1999) has established significant targets for reducing the biodegradable waste conferred to landfills, while the Waste Framework Directive 2008/EC has introduced more demanding waste recycling and energy recovery targets (Directive 2008/98/EC, 2008). Many EU countries have introduced landfill taxes, while some countries, including Germany, have established an outright ban on dumping untreated OFMSW.

The Landfill Directive 1999/EC permits, by 2016, landfills having a maximum storage capacity of 420,000 t/year of biodegradable municipal waste (based on 35% of 1995 amounts), so that alternative waste treatment methods are required for approximately 530,000 t/year of this waste (Directive 1999/31/EC, 1999).
AD is an environmentally effective waste treatment, whose added benefit is energy recovery in the form of biogas (Mata-Alvarez, 2003). The EU Renewable Energy Directive 2009/EC indicates that biomethane from OFMSW has a nominal GreenHouse Gas saving of 80% rather than the displaced fossil fuel (Directive 2009/28/EC, 2009), when it is used as a compressed gaseous biofuel. This saving is higher than other first generation liquid biofuels (Korres et al., 2010).

This work is aimed at predicting the Italian potential biogas and biomethane production, using OFMSW in a country where 1388 AD plants (total power of 7.4 TWh, equal to 640.4 ktep) are nowadays available (GSE, 2015).

Materials and methods

In order to compute the potential biogas and biomethane production in the 20 regions of Italy, the data of ISPRA (Higher Institute for the Environmental Protection and Research) Waste Register about OFMSW production in 2010-2013 period (2015) have been evaluated.

The potential biogas production per year from OFMSW (B_{OFMSW}) was determined according to the following equation, based on the biogas yield (bw) and the mass of this fraction produced per year (m_w) (Marangoni et al., 2013) :

$B_{OFMSW} = b_w\ m_w$ (Eq. 1)
where : b_w is the biogas yield of OFMSW ($m^3\ t^{-1}$);
m_w is OFMSW mass (t).

The potential biomethane production per year from OFMSW (BM_{OFMSW}) was determined according to the following equation, based on the biomethane content of OFMSW (mc_w) and the potential biogas production per year from this fraction (B_{OFMSW}) (Marangoni et al., 2013) :

$BM_{OFMSW} = mc_w\ B_{OFMSW}$ (Eq. 2)
where : mc_w is the biomethane content of OFMSW (%);
B_{OFMSW} is the potential biogas production per year from OFMSW (m^3).

Results

The Italian production of OFMSW, that was 5.2 million tons in 2013 (18% of MSW), could be used inside bioreactors, eventually together with other raw materials, in order to produce biogas and digestate. In 2013, the potential biogas production from OFMSW in Italy was 739 million m^3, that was upgraded into 444 million m^3 of biomethane. The highest biogas production from OFMSW was in Lombardy region (143 million m^3), having a potential biomethane production of 86 million m^3. The highest OFMSW production per inhabitant was in Emilia-Romagna region (142 kg) (Table 1).

Yet, if OFMSW was 37% of MSW, as it should be, the potential biogas production would be 1550 million m^3 (Table 2), that is similar to 1330 million m^3, estimated by Marangoni et al. (2013). Therefore, the MSW transferred to landfills would be reduced by 19% and also this amount could be converted into biogas and digestate.

Table 1. Italian potential biogas and biomethane production based on the actual OFMSW mass in 2013 (ISPRA, 2015)

N.	Region	Inhabitants (10^3)	MSW (10^3 t)	OFMSW (10^3 t)	OFMSW per inhabitant (kg/person year)	Potential biogas production (10^6 m^3/year)	Potential biomethane production (10^6 m^3/year)
1	Abruzzi	1334	600	119	89	17	10
2	Basilicata	578	207	17	29	2	1
3	Calabria	1981	833	35	18	5	3
4	Campania	5870	2545	618	105	87	52
5	Emilia-Romagna	4446	2780	631	142	89	54
6	Friuli-Venezia Giulia	1229	546	131	107	19	11
7	Lazio	5870	3160	279	47	39	24
8	Liguria	1592	890	54	34	8	5
9	Lombardy	9973	4595	1012	101	143	86
10	Marche	1553	764	196	126	28	17
11	Molise	315	124	8	27	1	1
12	Piedmont	4437	2004	382	86	54	32
13	Apulia	4090	1928	133	32	19	11
14	Sardinia	1664	742	194	116	27	16
15	Sicily	5095	2391	167	33	24	14
16	Tuscany	3751	2234	370	99	52	31
17	Trentino-Alto Adige	1052	495	122	116	17	10
18	Umbria	897	470	88	98	12	7
19	Valle D'Aosta	129	73	5	42	1	0
20	Veneto	4927	2213	662	134	94	56
	Italy	**60783**	**29595**	**5224**	**86**	**739**	**444**

Table 2. Italian potential biogas and biomethane production based on a theoretical OFMSW mass in 2013, that should be 37% of MSW (ISPRA, 2015)

N.	Region	Inhabitants (10^3)	MSW (10^3 t)	OFMSW (10^3 t)	OFMSW per inhabitant (kg/person year)	Potential biogas production (10^6 m^3/year)	Potential biomethane production (10^6 m^3/year)
1	Abruzzi	1334	600	222	166	31	19
2	Basilicata	578	207	77	133	11	7
3	Calabria	1981	833	308	156	44	26
4	Campania	5870	2545	942	160	133	80
5	Emilia-Romagna	4446	2780	1029	231	146	87
6	Friuli-Venezia Giulia	1229	546	202	164	29	17
7	Lazio	5870	3160	1169	199	166	99
8	Liguria	1592	890	329	207	47	28
9	Lombardy	9973	4595	1700	170	241	144
10	Marche	1553	764	283	182	40	24
11	Molise	315	124	46	146	6	4
12	Piedmont	4437	2004	741	167	105	63
13	Apulia	4090	1928	713	174	101	61
14	Sardinia	1664	742	275	165	39	23
15	Sicily	5095	2391	885	174	125	75
16	Tuscany	3751	2234	827	220	117	70
17	Trentino-Alto Adige	1052	495	183	174	26	16
18	Umbria	897	470	174	194	25	15
19	Valle D'Aosta	129	73	27	209	4	2
20	Veneto	4927	2213	819	166	116	70
	Italy	**60783**	**29595**	**10950**	**180**	**1550**	**930**

Also the difference between the potential biomethane production from the theoretical OFMSW (37% of MSW) and that from the actual OFMSW was computed for each region of Italy (Fig. 1).

The potential biomethane production should be increased by 486 million m^3 for the whole Italy, while Sicily resulted the region having the highest possible increase (61 million m^3) (Fig. 2).

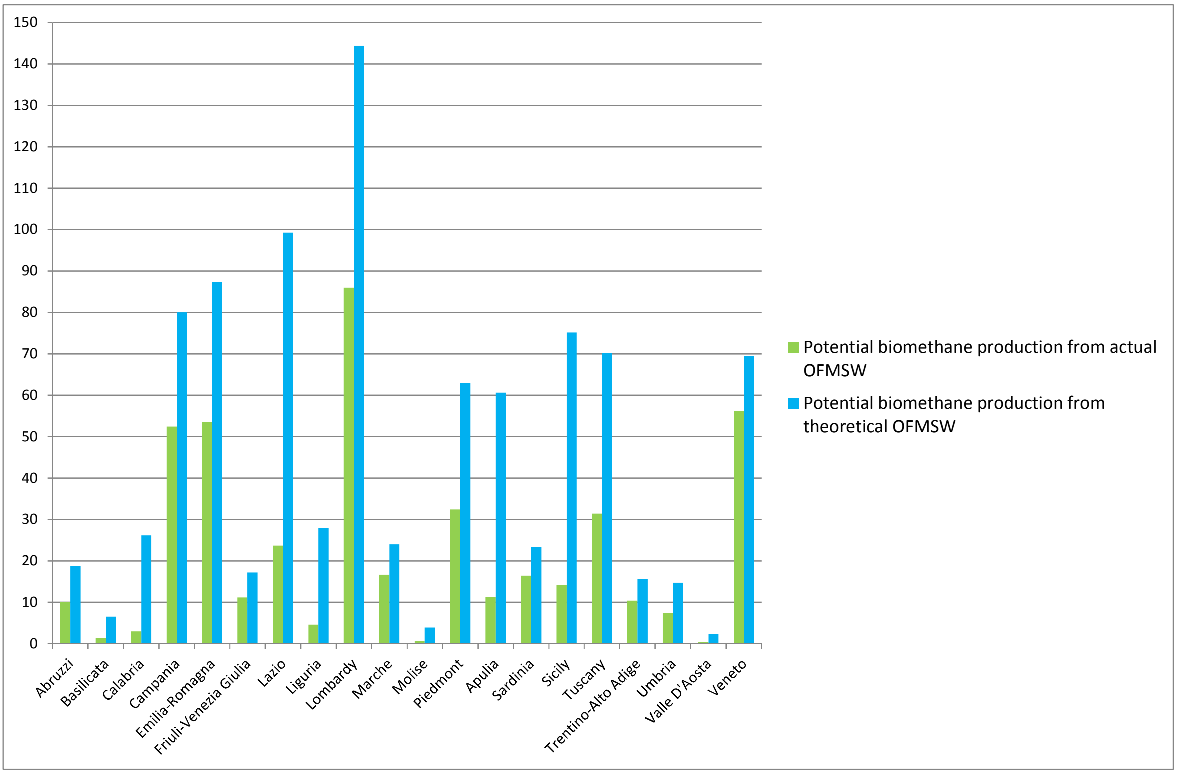

Figure 1. Potential biomethane production based on the actual OFMSW mass in 2013 and that from the theoretical OFMSW mass (37% of MSW) for each region of Italy (10^6 m^3/year)

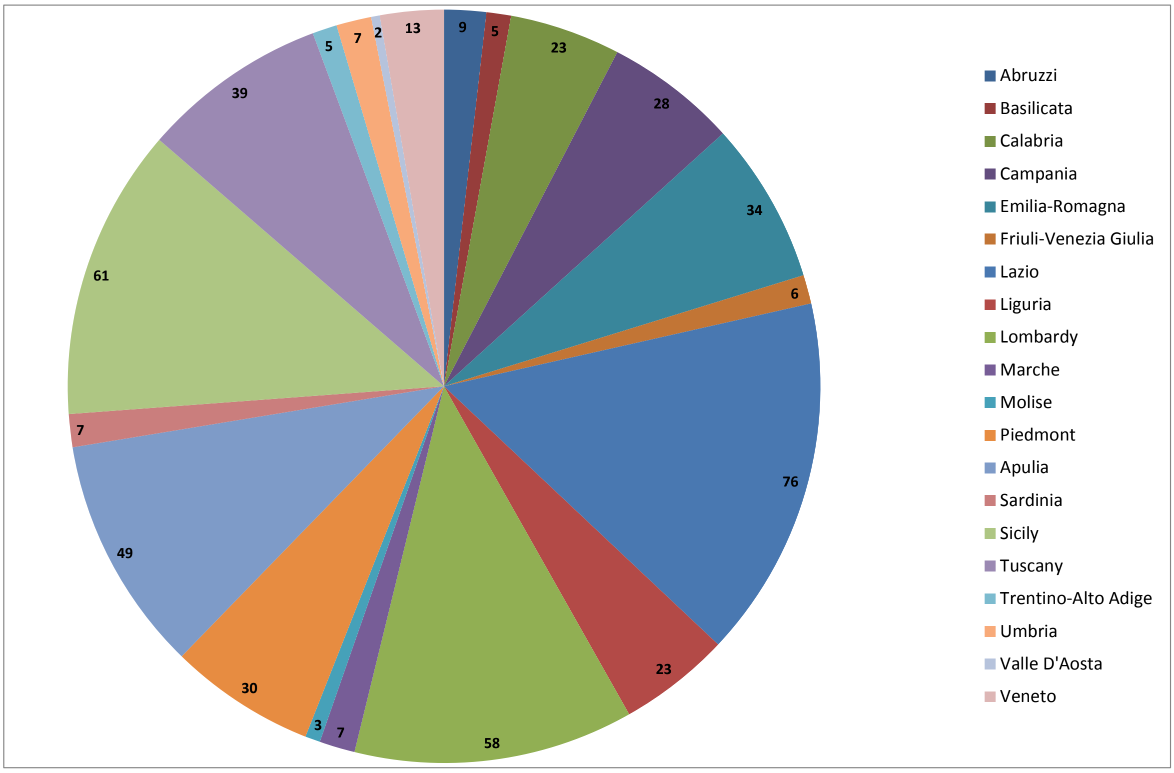

Figure 2. Difference between the potential biomethane production based on the theoretical OFMSW mass (37% of MSW) and that from the actual OFMSW mass in 2013 for each region of Italy (10^6 m^3/year)

Conclusions

The results of this work, showing the possibility of highly increasing the Italian potential biogas and biomethane production through the AD process of organic wastes, e.g. OFMSW, must be included in the perspective of achieving the targets of EU policies about waste, energy, environment and climate.

In fact, the EU Directive 2003/55 has authorised the connection to the natural gas grid: it is possible to inject biomethane, that is a refined biogas having a methane concentration higher than 95% and a quality comparable to that of natural gas. In order to produce pipeline quality biomethane starting from the biogas generated through AD process, it is needed to remove water, sulphur compounds, halogenated organic molecules, carbon dioxide, oxygen and metals (Molino et al., 2013).

Among the possible applications of biogas, if it was upgraded into biomethane, this biofuel would replace natural gas and, therefore, allow a reduction of GreenHouse Gas emissions of 200 g of CO_2 kWh^{-1} (5.5 times lower) and the import of fossil fuels from abroad (Marangoni et al., 2013) for transportation and network applications (Molino et al., 2013). Several authors have shown that the production unit cost of biogas is 8-10 €cents/m^3 (depending on the organic matter source), while the upgrading cost is 7-8 €cents/m^3, so that the total cost for producing biomethane compressed into the gas grid at 30 bar pressure is 20-22 €cents/m^3. The Italian market price of natural gas, fixed by the National Authority for the Electrical Energy and Gas Use, is equal to 40 €cents/Nm^3 (referred to January 2010) and, therefore, justifies the industrial feasibility of the above process (Molino et al., 2013).

Following the Decree of the 5th December 2013 of the Italian Ministry of Economic Development (2013) about the ways to promote the injection of biomethane into the natural gas grid, this biofuel will play a paramount role in the fuel market in the next five years.
Moreover, as a poor energy balance is associated with many first generation liquid biofuels (e.g. rape seed biodiesel) and the public concern towards biofuels displacing food production is increasing, the concept of using biomethane from organic wastes as a biofuel is very attractive (Mata-Alvarez, 2003; Directive 2009/28/EC; Korres et al., 2010).

Furthermore, fossil fuels are limited resources, concentrated in a few geographical areas of the Earth. This generates, for the countries outside these areas, a permanent state of dependency on imported energy. Most European countries are strongly dependent on fossil fuels, imported from regions rich in fossil fuel sources, e.g. Russia and the Middle East. The development and implementation of renewable energy sources, such as biogas from AD, based on national and regional biomass, will increase the security of the national energy supply and reduce the dependency on imported fuels.

Fighting against global warming is one of the main priorities of European energy and environmental policies. The production and use of biogas from AD has the potential to comply, at the same time, with all the three main goals of the EU climate and energy package for 2020: to reduce GreenHouse Gas (GHG, e.g. CO_2) emissions by 20%; to improve energy efficiency by 20%; to generate 20% of energy consumption from renewable energy sources. A major part of renewable energy will be produced from European agriculture and forestry, through biomass conversion into gaseous, liquid and solid biofuels (Comparetti et al., 2013a).
In this perspective politicians should promote the valorisation of organic wastes (e.g. OFMSW) through AD process. In fact, whether OFMSW was anaerobically digested, it would highly reduce the amount of this waste that is nowadays aerobically composted or, even worse, landfilled (Comparetti et al., 2013c).

If the Italian towns, that support a high cost for OFMSW transportation to landfills or composting plants and the subsequent treatment, would implement AD, could achieve a high saving. At the same time the environmental benefits for all citizens would be the reduction of GHG emissions, as well as soil and ground water pollution by leachate.

The limitation of implementing the results of this work is "ecomafia", that is the mafia involved in environmental business and, therefore, controlling the waste management. The "criminal systems" (as defined by the judge Roberto Scarpinato) are complex illegal networks including policy makers, entrepreneurs, professionals and traditional mafia men. Therefore, a cultural change is needed, firstly in citizens and secondly in policy makers, entrepreneurs and professionals, in order to optimise the separate waste collection and the subsequent recycling, as well as valorise OFMSW through biogas and digestate production (Comparetti et al., 2014).

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Analysis of the braking performance of counterbalanced forklift truck at varying of the tread wear

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Abstract

The market provides tires for counterbalance forklift trucks with different kinds and depths of tread: the level of tire wear opens issues about the related safety level, in particular during braking. This research aims at verifying the effect of rubber solid tire wear on counterbalance forklift truck braking performance to verify braking performance compliance with regulations as well as standard requirements.

One counterbalance forklift truck was equipped with three different sets of rubber tires characterized by different wear levels provided that within the legal limits (new, wear, almost completely wear) evaluating its braking performance according to ISO 6292/2009 standard. Experimental activity was carried out driving the counterbalance forklift truck in two ballast conditions on three different kinds of surfaces: dry asphalt (according to ISO 6292/2009), wet asphalt and one low friction flooded surface. Different loads were applied on the brake pedal to evaluate the related braking behaviors (stopping distance and deceleration). Acquired data underwent statistical processing by means of Minitab 17.0 statistical package.

According to preliminary investigations, the kind of surface and the ballast the counterbalance forklift truck is subjected to, turn out to be the factors significantly affecting the braking performance while tire wear level does not seem to have a significant role. Further studies are nevertheless required to deepen the knowledge about the interaction between tire wear level and surface/ballast.

Keywords: Safety, Slick Rubber Tire, Wheel Locking.

Introduction

Different kinds of tires for counterbalance forklift trucks can be found on the market: all of them can be basically divided into pneumatic and solid ones (these furtherly divisible in other subcategories). The guidelines of the Italian National Institute for Insurance against work accidents (INAIL, the public non-profit board safeguarding workers against physical injuries and occupational diseases), specifies which controls have to be carried out for the different kind of tires (pneumatic, superelastic and cushion) to confirm the importance of the influence of tires regarding safety. In particular, resilient solid tires are characterized by a depth of tread that can be completely smooth at the end of its life: the technical indicator of complete wear tire is called 60J and is not related with the depth of the tread. The tire wear level opens issues about the related braking performance in particular on wet surface.

This research aims at verifying the effect of rubber solid tire wear on the braking performance of counterbalance forklift truck to check the braking performance compliance with regulatory and standard requirements.

Test were conducted to evaluate the influence of three solid tire different wear levels (0%, 50%, 95%), all of them within the law limits, with braking tests.

Material and methods

The standard we referred to is the ISO 6292:2008, titled *“Powered industrial trucks and tractors -- Brake performance and component strength”*, that specifies the performance and test methods for brake systems fitted to powered industrial trucks of all capacities, industrial tractors with rated capacities up to and including 20 000 N drawbar pull, burden carriers and industrial trucks handling freight containers. Three different sets of resilient solid tires, whose main technical and geometric specifications are reported in tab. 1, were adopted.

Table 1. Main characteristics of the tested tires.

Measure (ETRTO standard)	Rolling circumference	Test code
	2053/2053	T_0
7.00-12	1913/1914	T_50
	1744/1747	T_95
	1639/1639	T_0
6.00-9	1524/1524	T_50
	1362/1374	T_95

The tested tires have been fitted on the counterbalance forklift truck shown in fig. 1 whose main characteristics and the test conditions are reported in tab. 2

Table 2. Main characteristics of the tested truck.

Type	Internal combustion
Nominal load (kg)	2500
Mass without ballast(kg)	4070
front (kg)	1765
rear (kg)	2305
Mass with ballast* (kg)	5270
front (kg)	3695
rear (kg)	1575

*the chosen ballast was 1.200 kg

Figure 1. The forklift truck during one of the tests carried out on asphalt with the T_95 set of tires.

Braking tests were carried out on asphalt and concrete, in both wet and dry conditions (fig. 2), and on a low friction surface. To this last purpose, one sheet of polyvinyl chloride (PVC) constantly kept wet was adopted (fig. 3) choosing the ballast and the pedal load so that the testing conditions could be as close as possible to those adopted for asphalt and concrete surfaces. Therefore, the complete set of surfaces and conditions turned out to be the following:

- Asphalt dry;
- Asphalt wet;
- Concrete dry;
- Concrete wet;
- PVC wet.

Figure 2. The tested forklift truck during one test on wet asphalt with the T_0 set of tire.

The friction between the tires and the PVC sheet (fig. 3) has been assessed measuring the force required to pull the forklift truck both up to incipient tire locking and locked tires.

These values, dimensionless, resulted respectively of 0.15 ± 0.01 e 0.21 ± 0.02.

Figure 3. Example of the equipment layout of the test on PVC.

Despite the followed methodology is based on ISO 6292/2008 requirements, given the experimental aim of the test (as a matter of fact, the different tread wear and the wet surface are not cited in the standard), further test settings, described in detail in the paper, were required. The term "wet surface" means that during the braking performance assessment, the surface was constantly kept wet by the presence of a water film (fig. 4).

Figure 4. Example of wet surface condition.

The ISO standard requires the maximum speed set at maximum the forklift truck is capable of. Nevertheless, the different tires tread wear gave rise to different rolling circumferences determining different maximum forward speeds at varying of the fitted set of tires. Therefore, to compare the results, it was necessary to adopt a common value of maximum forward speed. This was achieved adopting, at the beginning of the brake test, the lowest of the maximum forward speed (15 km h-1) corresponding to that of the T_95 set.

The chosen ballast was a mass as to prevent the rear tires from losing the contact of with the surface during the braking by placing the forks as low as possible without touching the surface also during the test.

The test conditions and the adopted test codes are reported in detail as follows:

- Forward speed at starting braking: 15 km/h;
- Maximum force on the brake pedal:
  - Runs on asphalt and concrete: max 45 kg;
  - Runs on PVC: 45 kg or tire locking;
- Surfaces:
  - Asphalt:
    - dry: AD
    - wet: AW
  - Concrete:
    - dry: CD
    - wet: CW
  - PVC:
    - wet: PW
- Ballast:
  - not ballast: N
  - ballasted with 1.200 kg: Z
- Repetitions:
  - asphalt and concrete: at least 5;
  - PVC: at least 5 and pedal load/deceleration correlation;
- Direction: only with forward speed (not in rearward);
- Starting measurement: at reaching of the 0.3 kg defined load on pedal brake.

The measurements of the mass of the forklift truck was carried out by means of a weighing platform of 20 tons. The forward speed has been measured adopting a fifth wheel. The details of the used instruments are reported in table 3.

Table 3. Instruments and materials adopted

Instrumentation	Make/model	Measurement
Weighing machine	Bulgari 20 t	Mass
Fifth wheel	Peiseler	Forward speed Distance
Load cell	Leane 2361 e Leane CPF Disp	Pedal load

Acquired data were processed by means of analysis of variance (ANOVA) followed by the means multiple comparisons (Tukey’s test) to point out possible significant differences between test settings ($p<0.05$).

Results

Tables 4 and 5 display the results of the breaking tests carried out on asphalt and concrete surfaces. With reference to these two surfaces, the analysis of variance followed by multiple comparisons of means did not show the three tire sets (T_0, T_50 and T_95) to significantly affect the braking performance ($p=0.68$). On the contrary, the “surface” factor showed to be significant ($p < 0.05$) and the mean deceleration on asphalt (4.08 m s-2) is significantly different from the one on concrete (3.95 m s-2). In the same way the results obtained at varying of surface condition (dry or wet) were found to be significantly different with the mean deceleration value of 4.23 m s-2 in dry conditions and 3.78 m s-2 in case of wet surface.

As far as ballast is considered, its presence turned out to be significant for deceleration values: as a matter of fact deceleration values of 4.26 m s-2 and 3.78 m s-2 respectively in case of ballast and non-ballast condition. Table 6 reports the homogeneous groups of means resulting from ANOVA and Tukey’s test.

Table 4. The results on the asphalt surface (data are expressed as arithmetical mean of the repetitions in each condition)

Surface code	Tire Set	Ballast code	Forward speed (km/h)	Pedal load (kg)	Braking distance (m)	Deceleration (m/s^2)
AW	T_0	Z	15.1	41.2	2.16	4.05
		N	15.1	35.8	2.38	3.72
	T_50	Z	15.2	39.1	2	4.33
		N	15.1	40.2	2.64	3.32
	T_95	Z	15.1	37.4	1.96	4.63
		N	15.0	37.2	2.50	3.44
AD	T_0	Z	15.1	41.2	2.20	4.10
		N	15.1	38.1	2.16	4.00
	T_50	Z	15	40.2	1.76	4.95
		N	15	39.7	2.02	4.24
	T_95	Z	15.1	38.8	2.00	4.40
		N	15.0	36.1	2.20	3.94

Table 5. The results on the concrete surface (data are expressed as arithmetical mean of the repetitions in each condition)

Surface code	Tire Set	Ballast code	Forward speed (km/h)	Pedal load (kg)	Braking distance (m)	Deceleration (m/s^2)
CW	T_0	Z	15.1	39	2.2	4
		N	15	37.7	2.3	3.81
	T_50	Z	15	37.7	2.26	3.87
		N	14.9	40.8	2.62	3.31
	T_95	Z	15	39.9	2.16	3.97
		N	14.9	42	2.58	3.3
CD	T_0	Z	14.9	39.9	2.02	4.22
		N	15.1	39	2.14	4.12
	T_50	Z	15	38.3	2.02	4.35
		N	15	39.8	2.08	4.16
	T_95	Z	14.9	40.4	1.94	4.37
		N	14.9	40.1	2.1	4.04

Table 6. Results of the ANOVA of the braking test on asphalt and concrete

Set	Test conditions							
	AD_N	AD_Z	AW_N	AW_Z	CD_N	CD_Z	CW_N	CW_Z
T_95	b	b	b	a			b	
T_50	a	a	b	b	ns	ns	b	ns
T_0	b	b	a	b			a	

The “a” indicates higher values of deceleration

As far as braking tests on PVC wet surface are concerned, table 7 and figure 5 report the deceleration (m s-2) and braking distance (m) average values.

As expected, increasing the pedal load leads to increasing values of deceleration and decreasing values of braking distance and, in the framework of the pedal loads reported in table 6, only some trends can be pointed out so that further investigations should be carried out.

With reference to deceleration and braking distance values obtained with pedal loads resulting in tire locking (higher than 20 kg and lower than 45 kg), the ANOVA followed by Tukey’s test (table 8) showed that T_0 set of tires significantly affects the lift fork truck braking performance resulting to be the one with the higher deceleration (1.42 ± 0.068 m s-2) and the lower braking distance (6.17 m s-2). The braking performance of the other tire sets resulted to be each other significantly different only with reference to deceleration while braking distance did not show any homogeneous group.

Table 7. The results on wet PVC surface till brake locking

Surface	Set	Ballast	Forward speed (km/h)	Pedal load (kg)	Braking distance (m)	Deceleration (m/s²)
		Z	14.8	14.3	11.9	0.71
		Z	14.9	15.6	10.5	0.81
	T_0	Z	15	18.8	8.3	1.04
		Z	15	20.6	6.4	1.36
		Z	14.9	23.4	5.6	1.54
		Z	15	14.3	11.9	0.76
		Z	15.1	16.5	8.4	1.05
PW	T_50	Z	15.2	20.2	6.6	1.34
		Z	15.1	23.4	6.9	1.27
		Z	14.9	25.3	5.8	1.49
		Z	15	13.8	10.5	0.83
		Z	14.9	16.6	7.7	1.11
	T_95	Z	14.9	19.7	6.6	1.3
		Z	14.7	21.7	6.8	1.22
		Z	14.9	24	6.7	1.28

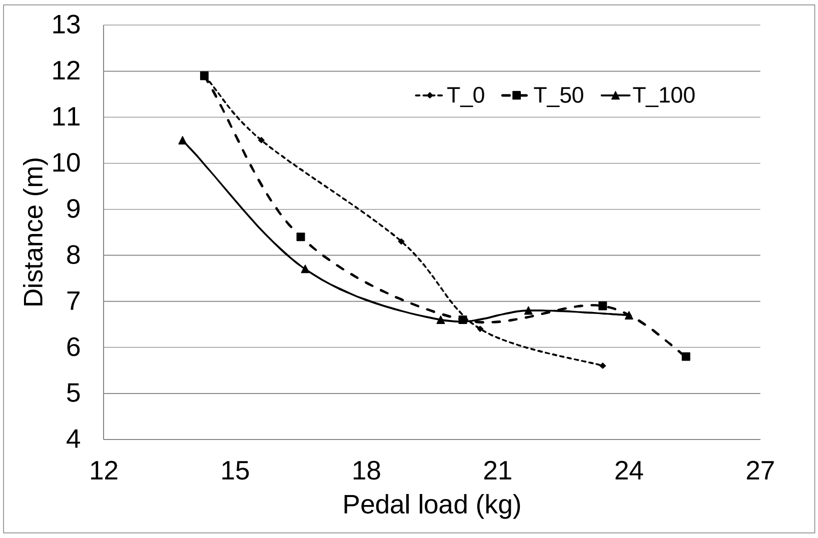

Figure 5. Trend of the correlation pedal load/braking distance on the wet PVC.

Table 8. Tukey's test and mean values of the braking distance and deceleration obtained on PVC with pedal load between 20 and 45 kg*.

Set	Deceleration ($m\ s^{-2}$)		Distance (m)	
	Mean value and group.	Standard Deviaiton	Mean value	Standard Deviation
T_95	1.18 c	0.079	7.23 a	0.485
T_50	1.30 b	0.077	6.83 a	0.433
T_0	1.42 a	0.068	6.17 b	0.315

* Testing conditions (ballast and pedal load) as close as possible to those adopted for asphalt and concrete surfaces.

Conclusions

The forklift truck doesn't present significant differences of braking performance at varying of the set of tires on concrete and asphalt test.

The set wear at 95% (T_95) presents, meanly, a lower deceleration of the new tire if the truck is not ballasted but higher if ballasted.

The difference of deceleration between the set new and the wear at 95% on wet PVC surface resulted significant with a difference between mean values (1.18 and 1.42 m s-2) of 0.24 m s-2 (1.06 m).

Acknowledgements

The research was carried out in the frame of the "Us. Pre." Project (Analisi dell'influenza di differenti ruote per carrello elevatore sugli aspetti prestazionali del veicolo) funded by Trelleborg Wheel Systems Italia S.p.A.

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ISO 6292:2008 Powered industrial trucks and tractors -- Brake performance and component strength.

Summary of U.S. Agricultural Confined Space-Related Injuries and Fatalities and Comparable International Findings

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Abstract
Purdue University's Agricultural Safety and Health Program has been documenting injuries and fatalities associated with agricultural confined spaces for over 30 years. To date, nearly 1,800 U.S. incidents/cases have been documented and findings entered into a database. In addition, cases outside the U.S. have been documented, but not included in summary data reported to date. Findings from the U.S. cases have been summarized and reported on an annual basis for the past decade. These findings have been used to promote enhanced safety measures designed to reduce the severity and frequency of agricultural confined space-related incidents.
This presentation summarizes all documented incidents including those identified outside the U.S. It is believed, based upon the frequency of non-U.S. incidents, that the problem of worker injuries and fatalities while working inside agricultural confined spaces is an international safety issue. This is especially true for incidents involving the transport, storage, and processing of agricultural grains.
Findings regarding causative factors such as type of grain and structure, worker characteristics, and the role of out-of-condition grain on increased risk of entrapment will be presented. Recommended preventative measures will be discussed.

Keywords: Grain Entrapment, Agricultural Confined Spaces, Grain Engulfment, Toxic Environments

Introduction[2]

As part of an effort to gain a better understanding of U.S. grain-related entrapments[3] and engulfments, Purdue's Agricultural Safety and Health Program (PUASHP) has published, over the last decade, an annual summary of these incidents[4] (www.agconfinedspaces.org). These summaries are based on data gathered, documented and entered into Purdue's Agricultural Confined Space Incident Database (PACSID). With support from the U.S. Department of Labor's Susan Harwood Training Program, over the past four years, the surveillance effort was expanded to include not only incidents of entrapments in grain, but also asphyxiations, entanglements, falls, fires and electrocutions in and around all forms of

[2]Partial support for this material was provided under grant number *SH24885SH3* from the Occupational Safety and Health Administration, U.S. Department of Labor. It does not necessarily reflect the views or policies of the U.S. Department of Labor, nor does mention of trade names, commercial products, or organizations imply endorsements by the U.S. Government.
[3] Flowing grain entrapments include both fatal engulfments and partial entrapments that require assistance in order for the victim to be extricated.
[4] An incident may involve multiple victims that are recorded in the database as individual cases.

agricultural confined spaces.[5] This annual summary, based upon 2014 incidents continues to reflect this expanded effort and hopefully adds additional light on a problem that poses significant risk to agricultural workers. Thought not aggressively investigated, a brief summary of incidents documented outside the U.S. is included.

As the result of using the broader definition for agricultural confined spaces to identify cases of interest, no fewer than 70 U.S. cases were documented in 2014. Of these, approximately 54% were directly related to grain entrapments. To ensure continuity of the data record involving entrapments in grain and other free flowing agricultural material, and due to the high percentage of past fatal cases involving grain entrapment, special attention continues to be given to these incidents.

In addition to the cases documented in 2014, approximately 50 cases that occurred in previous years were added to the database due to ongoing discovery efforts. Also, 11 cases were removed from the database as they, upon further investigation, no longer met the criteria for having occurred in an agricultural confined space, or occurred outside the U.S. The total number of U.S. cases documented to date and entered in the PACSID is nearly 1,800. The identification of additional cases can be attributed to the increased surveillance efforts allowed by the support from the U.S. Department of Labor as well as increased public awareness of the problem leading to greater media exposure and voluntary reporting.

As noted in past summaries, the data presented do not account for all incidents involving agricultural confined spaces. There continues to be no comprehensive or mandatory incident/injury reporting systems for most of agriculture, and there is reluctance on the part of some victims and employers to report non-fatal incidents, even where extrication was required, and therefore no public record is available. Based upon prior research, it is estimated that the documented annual cases represent approximately 70% of the total cases that actually occur annually in the Corn Belt where most U.S. Grain is produced.

2014 Summary of All Agricultural-Confined Space-Related Cases with Comparisons to Previous Years

In 2014, there were no fewer than 38 U.S. grain entrapment cases, 12 falls, 8 equipment entanglements (including augers), 9 fire related injuries and 3 asphyxiations that were identified as occurring in an agricultural confined space (Figure 1). Grain entrapments accounted for 54% of the documented cases. For incident types with more than one case, asphyxiations due to toxic environments, constituted the most dangerous with a reported 67% fatality rate, while grain entrapments ranked fourth with a 45% fatality rate. Again, it is believed that most confined space incidents are under-reported especially those resulting in non-fatal grain entrapment and involving being overcome by toxic gases such as found in manure storage facilities.

The 70 confined space cases represent a 4% increase in number of cases from 2013 when 67 cases were recorded. The previous three years (2010, and 2011, 2012) experienced 100, 64 and 46 documented cases respectively (Figure 2). The five-year average continues at a relatively high level of 69.4, slightly below the peak of 74.8 in 2011. Since 2002, the five-year average has increased steadily from 36.8 cases per year to an average of 52.6 cases per year in 2008, 61.2 in 2009, and 70.8 in 2010, and peaking in 2011 with 74.8 cases.

[5] The definition used to identify an agricultural confined space in this study is: Any space found in an agricultural workplace that was not designed or intended as a regular workstation, has limited or restricted means of entry or exit, and has associated with it potential physical and/or toxic hazards to workers who intentionally or unintentionally enter the space.

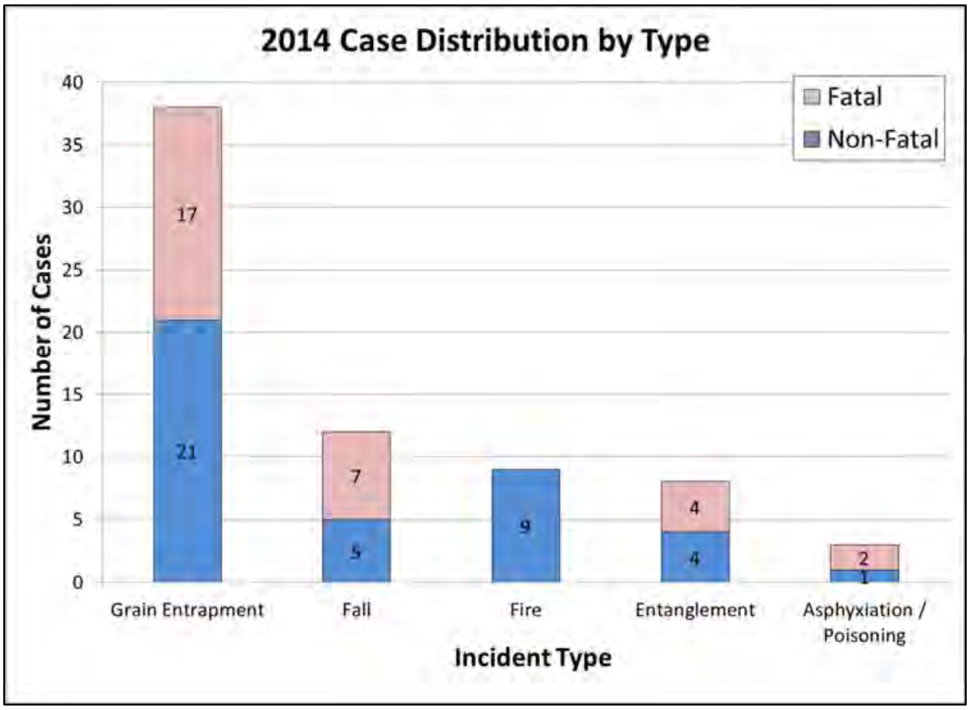

Figure 1. Distribution of 2014 agricultural confined space-related cases by type of incident.

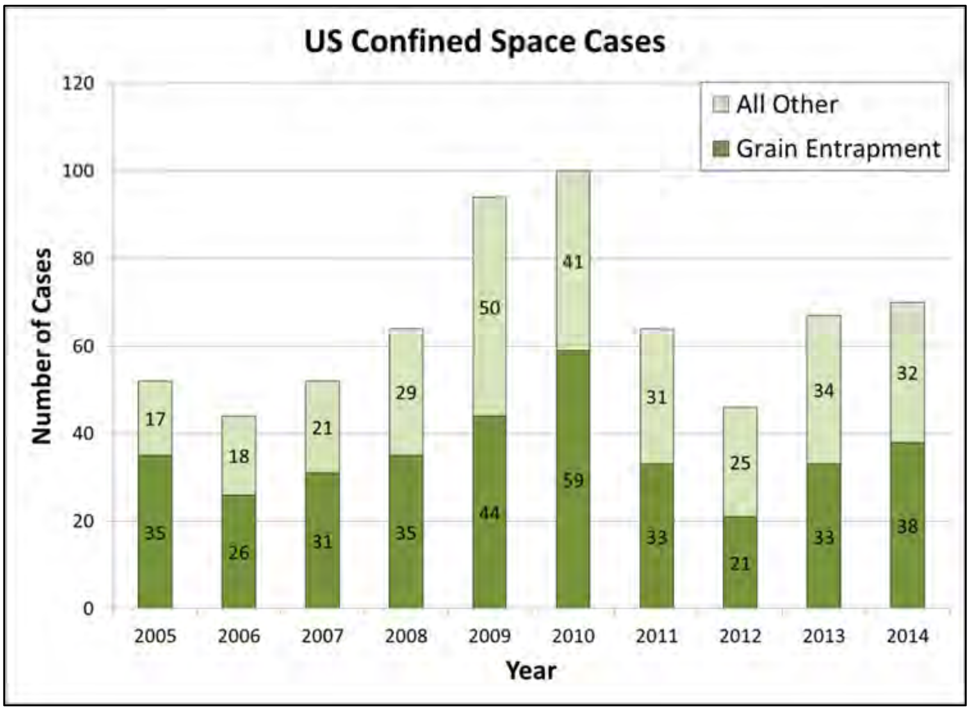

Figure 2. Number of annual confined space cases recorded between 2005 and 2014.

In 2014, the states with the most documented confined space cases, of all types, including fatal and non-fatal, were Minnesota (9) and Ohio (9). Seven of Ohio cases involved one incident in which a fire injured seven workers while attempting to extinguish a fire inside a grain storage structure. There were five cases each for Indiana, Nebraska, Illinois, and

Wisconsin. There were four cases each for Michigan, Iowa and Pennsylvania. Overall, incidents were documented in 20 states in 2014, three states less than 2013. Figure 3 provides a geographic distribution of all documented cases in the PACSID, where the location was known, and the sites, where known, for 2014. It should be noted that the high number of cases identified in Indiana reflects a more aggressive surveillance effort historically.

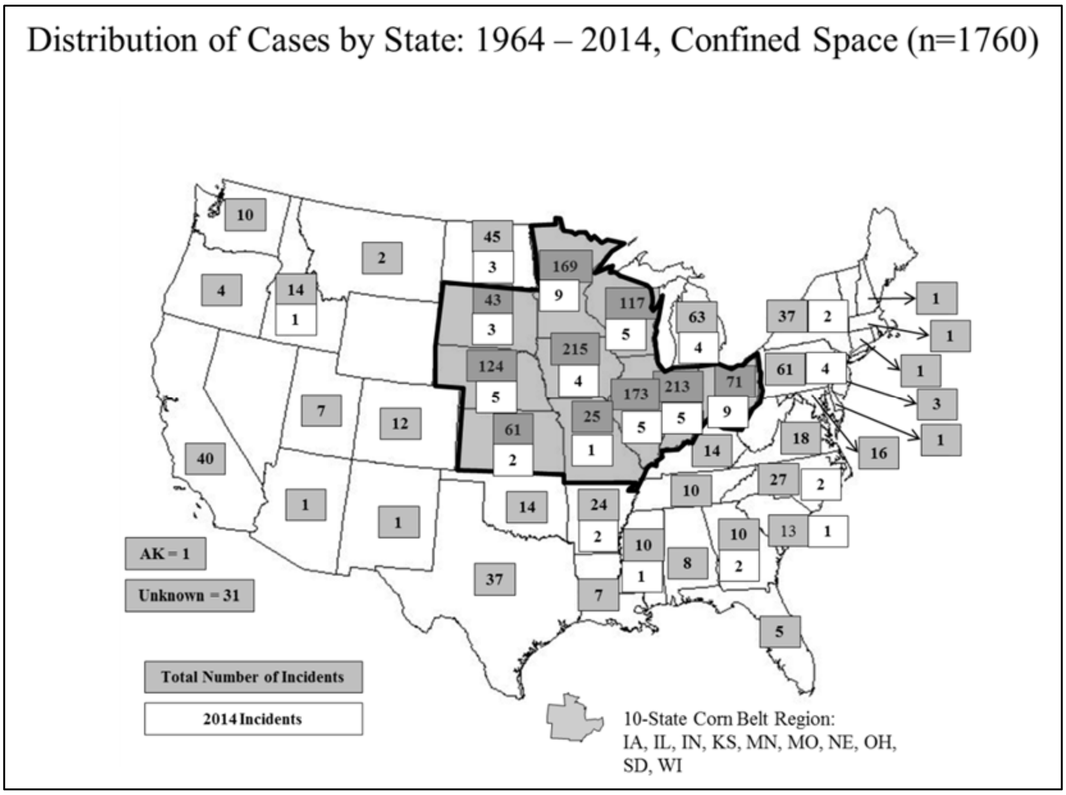

Figure 3. Geographic distribution of confined space cases for 2014 and previous years.

There was only one case in 2014 involving a female. Also, there were six cases involving a child or youth under the age of 20, as shown in Figure 4. Overall, a specific age was known for 46 of the 70 victims in 2014, with the oldest victim being 81, and the youngest 5 years old. The average age was 45 years old, and the median age 51.5 (Figure 4), which is significantly lower than the current average age of 58 for U.S. farmers. As can be noted, a large number of the cases documented did not include a specific age of the victim.

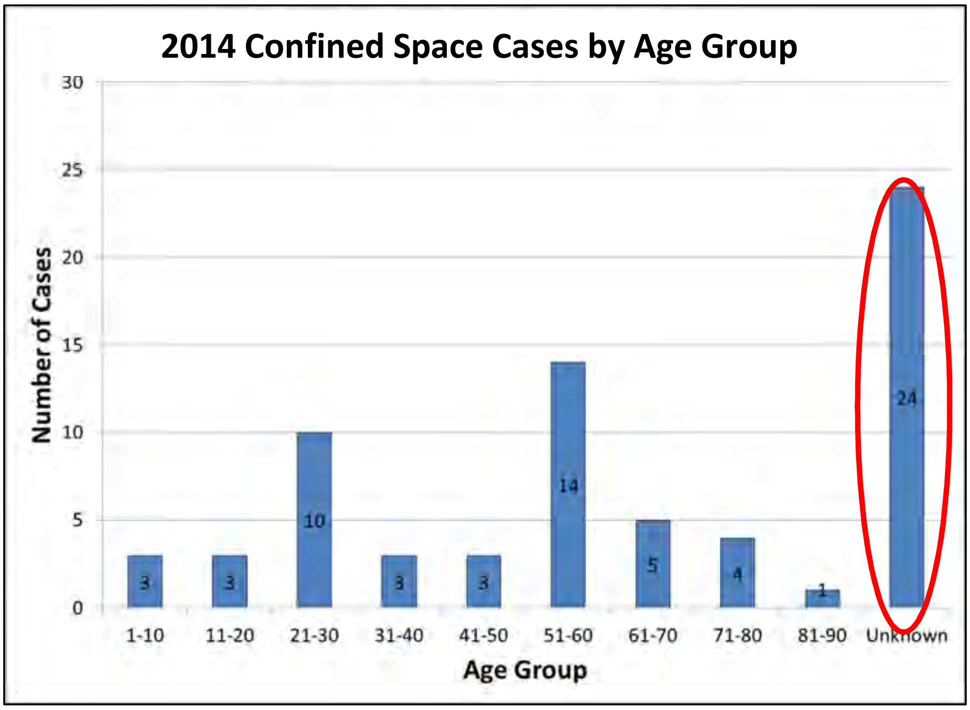

Figure 4. Age distribution of 2014 agricultural confined space victims by number of cases recorded.

2014 Summary of Grain Entrapments with Comparisons to Previous Years

The 38 grain entrapment cases in 2014 represent a 15% increase in entrapments from 2013 when 33 entrapments were recorded. The previous three years (2010, and 2011, 2012) experienced 59, and 32 and 21 documented cases respectively. The five-year average continues at a relatively high level of 36.8, below the peak of 40.4 in 2011 (Figure 5). In 2014, the state with the most documented grain entrapments, fatal and non-fatal, was Minnesota (6) (Figure 6). There were four cases each for Indiana and Iowa, and three cases each for North Dakota, Wisconsin, Nebraska, South Dakota, and Illinois. Overall, entrapments were documented in 16 states in 2014. The majority of grain entrapment cases occurred in the Midwest (87%), in the region known as the Corn Belt in contrast with 2013 in which only 61% of the cases occurred in the Midwest. Figure 5 provides a geographic distribution of all documented grain entrapment cases contained in the PACSID where the location was known.

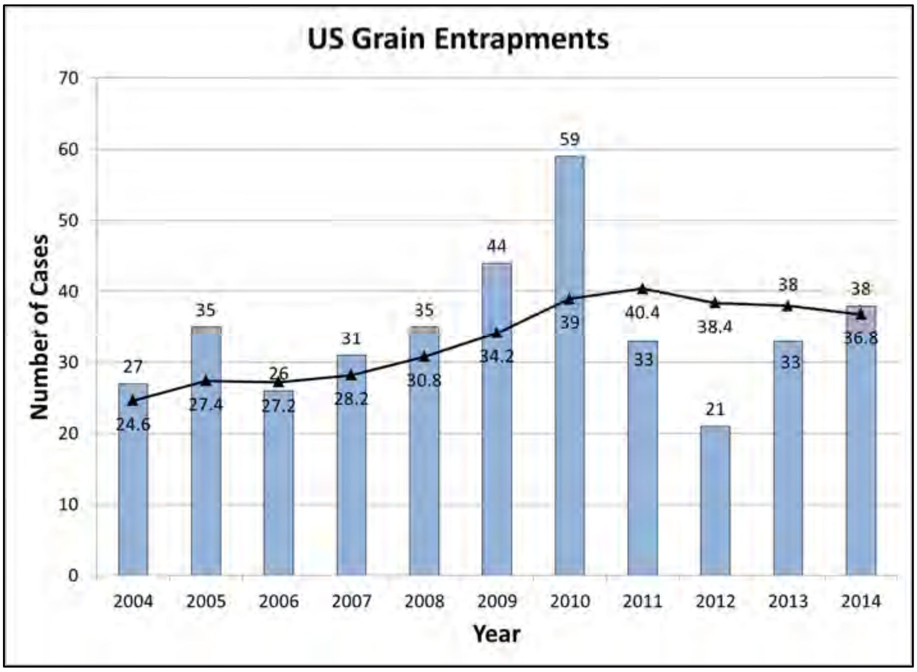

Figure 5. Number of annual grain entrapment cases recorded between 2004 and 2014.

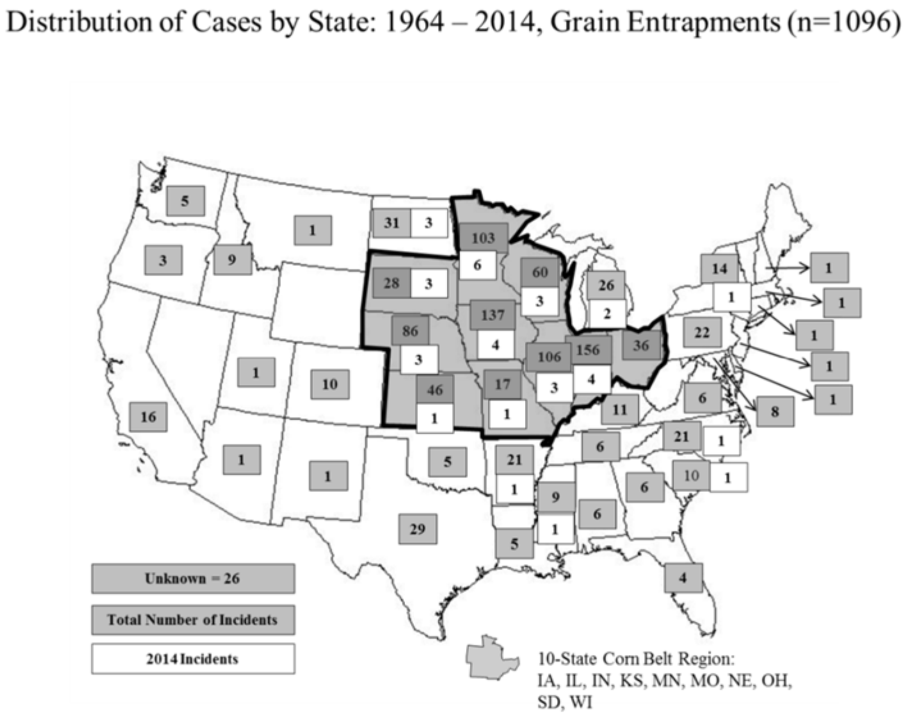

Figure 6. Geographic distribution of grain entrapment cases for 2014 and previous years.

In 2014, there were 36 cases where the exemption status[6] of the facility with respect to Federal Occupational Safety and Health Administration (OSHA) regulations was known. Of those, 31 (82%) occurred on farms or other locations currently exempt from the OSHA Grain Handling Facilities Standards (29 CFR 1910.272), with the balance of 5 (13%) taking place at non-exempt commercial grain facilities. This is in strong contrast to 2013 and 2012 when 70% and 35% of all cases occurred on exempt farms. It is important to note that there were only 2 unknown cases this year and it is believed that the majority of the unknown cases, based on historical data, have OSHA exempt status.

All documented victims were male except for one case. Also, there were 4 documented cases involving a youth under the age of 20 in contrast to 2013 in which there were no child/young adult cases (Figure 7). Overall, a specific age was known for 26 of the 38 victims in 2013, with the oldest victim being 81, and the youngest 8 years old. The average age was 49 years old, and the median age 53. In contrast to previous years, three of the grain entrapments occurred in grain transport vehicles. The last time a grain entrapment in a grain transport vehicle was documented was in 2011.

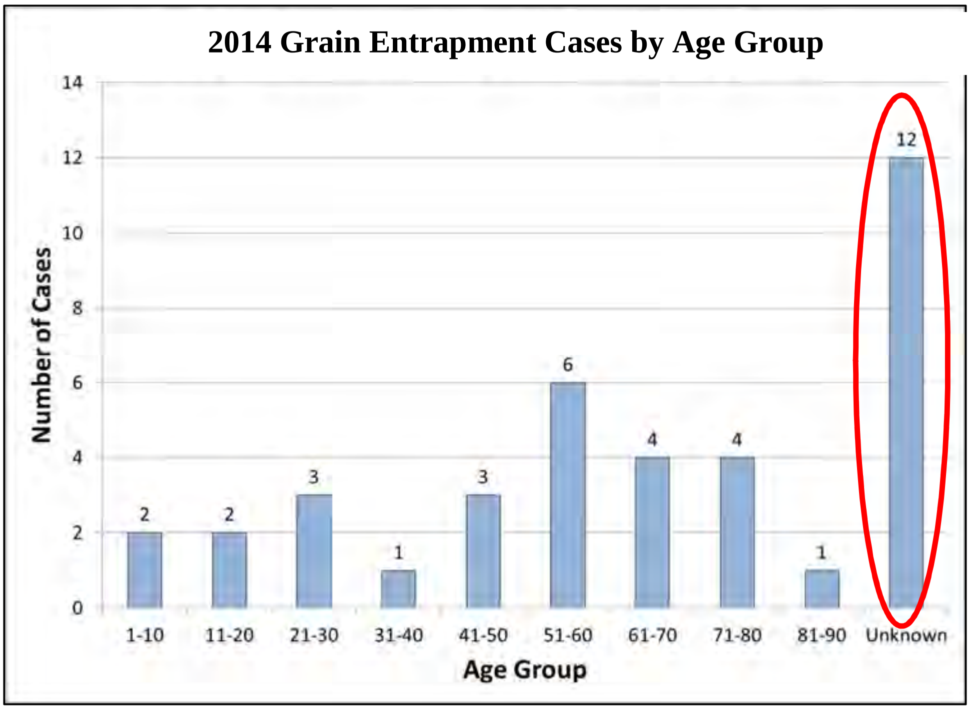

Figure 7. Age distribution of 2014 grain entrapment victims by number of cases recorded.

During 2014, the primary medium, or type of grain, of entrapment, when identified, was corn (19 cases, 50%). Soybeans were the second most common grain with four cases (11%). Unlike previous years the ratio of fatal to non-fatal cases actually rose to 45% in comparison to last year's 39%. This number is still relatively low in comparison to 1964-2008, during which 73% of documented entrapments resulted in a fatality. As in past years, it should be noted that this summary does not reflect all grain-related entrapments, fatal or non-fatal that have occurred. Currently over two-thirds of grain storage capacity in the U.S. is

[6] Under the current provisions of the two OSHA workplace safety and health standards most relevant to agricultural confined spaces, most agricultural worksites, including most farms, feedlots, and certain seed processing operations are exempt from compliance.

found on farms that are exempt from the current OSHA injury reporting requirement standards.

Summary of Documented Falls in and Around Agricultural Confined Spaces

Falls in and around U.S. agricultural confined spaces represent the third largest group of confined space-related cases after grain entrapments with a total of 180 cases documented to date. However, documented cases for falls have only been continuously recorded since 1990 (177 cases recorded; 13% of all cases). When comparing other categories over the same timeframe, falls are the second highest injury type after grain entrapments. It is believed that the majority of non-fatal falls involving agricultural confined spaces go unreported (Figure 8).

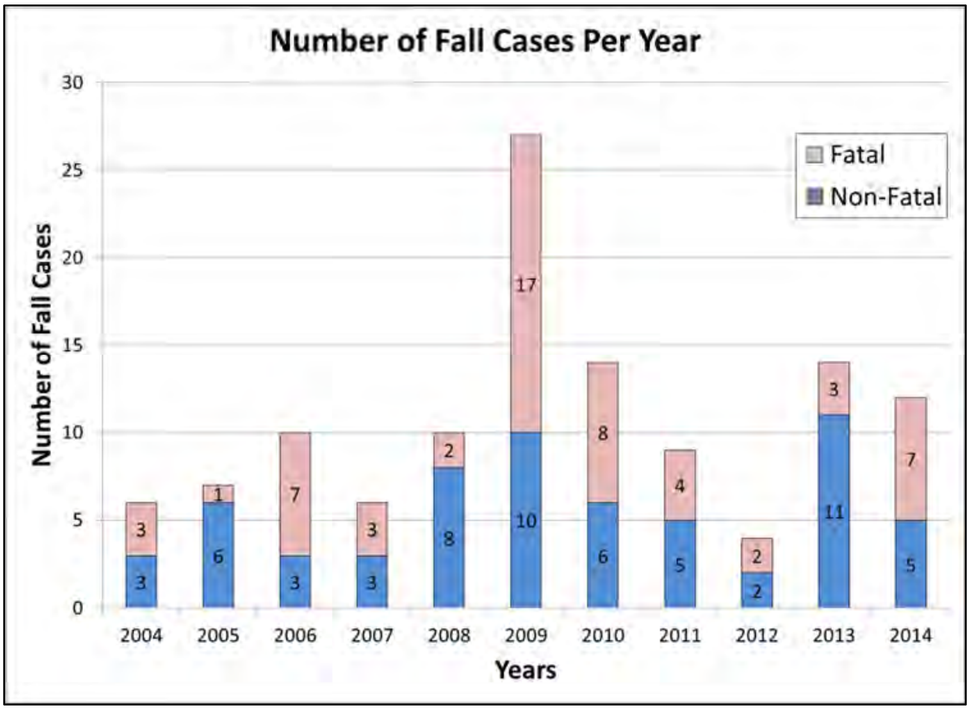

Figure 8. Number of annual fall cases recorded between 2004 and 2014.

Incidents Outside the U.S.

A review of the literature did not identify any ongoing surveillance efforts outside the U.S. to document deaths or injuries in agricultural confined spaces. The fact that numerous countries have published safety resources related to the hazards of these work spaces provides an indication that this is an international problem. In addition, there have been a sufficient number of international cases identify by the Purdue effort to confirm that there are many similarities between the cases documented in the U.S. and the rest of the world.

A review of published farm injury data from several of the Canadian provinces found incidents involving several types of agricultural confined spaces with a prevalence of cases involving grain handling and manure storage. For example, a recent case in 2015 in Nova Scotia involved a 20 year old worker buried to his chin in a corn bin. He was successfully rescued by emergency personnel after several hours of being entrapped.

A case was documented in Bagworth, Leicester, England in which an 8 year old boy was engulfed and suffocated in a corn bin. Another case in Sussex, England involved a 13 year old male entrapped in a bin of Linseed. He was successfully rescued by a tactical rescue team using ropes to lower rescuers to the surface of the grain and attaching a safety harness to the boy. In Brookton, England an 18 year old male farm family member suffocated while attempting to remove corn from a grain bin.

Several cases were documented in Australia, including a case in 2013 in which a total of 10 people, including farm workers, police officers, and paramedics, who were overcome in a farm silo containing fermented corn syrup. These first responders were attempting to rescue a farmer who had become overcome by the toxic environment while working in the silo. There were no fatalities, but the number of first responders injured during the rescue was unusual.

In 2013, four employees at a grain facility in Brazil suffocated in a bin of soybeans while attempting to break up crusted grain. The unloading system was apparently operating while the workers were in the bin.

Verbal accounts of incidents have also been received from literally around the world including Ireland, Finland, Sweden, Poland, China, Argentina, and Mexico. Since documentation from original or verifiable sources was not possible these cases are not included in the PACSID.

The evidence is clear that workers, worldwide, are dying or being injured on a regular basis while working in or around agricultural confined spaces, and during efforts to rescue the primary victim.

New Website

As part of the plan of work for the U.S. Department of Labor's Susan Harwood Grant, a new website on agricultural confined spaces has been developed and is currently accessible (www.agconfinedspaces.org). This website is intended to be a resource for those conducting safety and health training in the area of agricultural confined spaces with a special focus on grain storage handling, and processing. Training resources are provided that are relevant to farm operators, youth and beginning workers, current workers in the commercial grain industry, and emergency first responders. The site includes an extensive bibliography of resources, frequently asked questions, and related links.

For additional information on this report, contact Professor Bill Field at 765-494-1191 or field@purdue.edu. In addition, refer to these sources for more information on this topic:

- www.agconfinedspaces.org
- www.grainsafety.org
- www.grainsafety.us
- www.grainentrapmentprevention.com
- http://apps.npr.org/buried-in-grain/

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Determination of bystander exposure to pesticide spray drift: methodology proposal.

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Abstract

The potential spray drift exposure of bystander and residents from orchard pesticide applications is likely to be higher than from boom sprayers, especially in Italy where the close interconnection between urban and rural areas amplify this phenomenon. On request of European Commission the European Food Safety Authority (EFSA) established a working group (WoG) for revising all available data and procedures to perform the operator, worker, resident and bystander pesticide risk assessment (EFSA, 2014). For orchard crops and vines, the most used dataset is Lloyd et al. (1987). The WoG recommended that further data shall be produced to refine the proposed assessment. Besides having limited data available at present there is no standardized method for collecting data on resident and bystander pesticide contamination. The aim of this work was to assess the efficiency of different collectors types and the different test layouts, in order to evaluate the better solution for detecting the pesticide exposure of bystanders during plant protection product (PPP) application and to propose a test methodology that may be combined with the existing ISO22866 standard methodology for arable crop pesticide drift measurement. The proposed methodology has been applied in field experiments undertaken in 2013 and 2014 measuring spray drift deposits on mannequins (coveralls and synthetic filter clothes collectors) and airborne spray drift (Petri dishes, vertical polythene line collectors). The results obtained have underlined a lacking relationship between different type of collectors, underlining the need of an appropriate experimental framework able to define the most suitable collectors type and layout to be used.

Keywords: Pesticide Bystander Exposure, Airborne Spray Drift, Collector Types, Test Methodology.

Introduction

According to ISO22866 -Crop protection equipment e Methods for field measurement of spray drift-, spray drift is defined as “the quantity of plant protection product that is carried out of the sprayed (treated) area by the action of air currents during the application process”. During and immediately after spray application non target receptors including water, plants and animals can be exposed acutely and may therefore face the risk of adverse effects. Thus drift may cause damage to non-target plants, contaminate water courses, result in illegal residues in food and feed commodities and cause adverse human exposure. The potential spray drift exposure of bystanders and residents from tree plantation as vineyards and orchards pesticide applications is likely to be significantly higher than that from boom sprayers applications. In Italy the close interconnection between the urban and rural areas underline the real phenomenon of spray drift bystander acute exposure and contamination in these conditions. For orchard crops and vines, the most used dataset is Lloyd et al. (1987). The European Food Safety Authority (EFSA) established an *ad hoc* working group (WoG) for revising all available data and procedures to perform the operator, worker, resident and bystander risk assessment, in order to prepare the "Guidance on the assessment of exposure of operators, workers, residents and bystanders in risk assessment for plant protection products (PPP)" (EFSA, 2014). Besides having limited data available at present there is no standardized method for collecting data on resident and bystander pesticide contamination. In order to use the full range of available bystander and airborne spray drift data obtained using different collectors and layout Butler Ellis *et al.* (2014) try to link one collector type to another type. In this way a new methodology must start from the definition of the collector type most suitable between the collectors normally used. Actually for the evaluation of bystander exposure is possible use a standardized shape collectors (eg. Polythene line used in different layout, Petri dishes, filter material of different nature, etc.) or collectors that simulate a human figure (eg. coveralls wear by mannequins or volunteers); few work debate about the comparison and correlation between these two types of collectors. At present, the most used collector types are likely those standardized; this is due to the easier use in field trials, analysis and data management. The aim of this work was to assess the efficiency of different collectors types and the different test layouts, in order to evaluate the better solution for detecting the pesticide exposure of bystanders during PPP application and to propose an appropriate test methodology that may be combined with the existing ISO22866 for arable crop pesticide drift measurement because actually is the only official standard procedure for drift measurement.

Methods

Two field trials were undertaken (24 October 2013 and 24 October 2014) at a vineyard (espalier training system, row spacing 2,5 m and full leaf growth stage) located near DiSAFA facilities in Grugliasco (TO). Tests were made applying a water solution of Tartrazine E102 tracer at a concentration of about 5 g l^{-1}. Four type of collectors were selected from those normally used for spray drift measurement as defined in Table 1. The first field trial was aimed to study the bystander potential dermal exposure comparing the efficiency of synthetic filter (CAMFIL) and coveralls (TYVEK®) collectors; in this case collectors were placed on three adult mannequins (Figure 1 and Table 2) aligned at 1, 2 and 3 meters from the middle of sprayer's wheel track while spraying the last tree row of the vineyard. The second trial assessed the airborne spray plume drift and compare the recovery efficiency of Petri dishes (70 mm diameter), placed on a vertical support, and vertical polythene line (Figure 2); the collectors were aligned at 5 and 10 meters from the middle of sprayer's wheel track while spraying the last tree row of the vineyard.

Table 1. Spray drift collector used.

Trials	2013		2014	
Collector	**Synthetic filter**[1]	**Coveralls (adult)**[2]	**Petri dish**[3]	**Vertical Polythene line**[4]
Characteristic	10 cm X 20 cm	non defined	diameter 7cm	10.0 m X 1.98 mm
Dimension	0.020 m^2 (200.00 cm^2)	≈1.943 m^2 (19429.73 cm^2)	0.015 m^2 (153.938 cm^2)	0.006 m^2 (62.172 cm^2)
Location eight	Placed on the adult mannequins (1.80 m approx) according to the Figure 1	Adult 1.8 m (approx) sectioned according to the Figure 1	Every 0.5m from 0.5 m to 4.0 m according to the Figure 2	On 7 m vertical masts sectioned into 1.0 m pieces according to the Figure 2

[1]Synthetic filter - CAMFIL SPA

[2]Coveralls Tyvek® - DuPont

[3]Petri dishes - AppenLab

[4]Portex Fine Bore Polythene line - Smiths Medical International Ltd

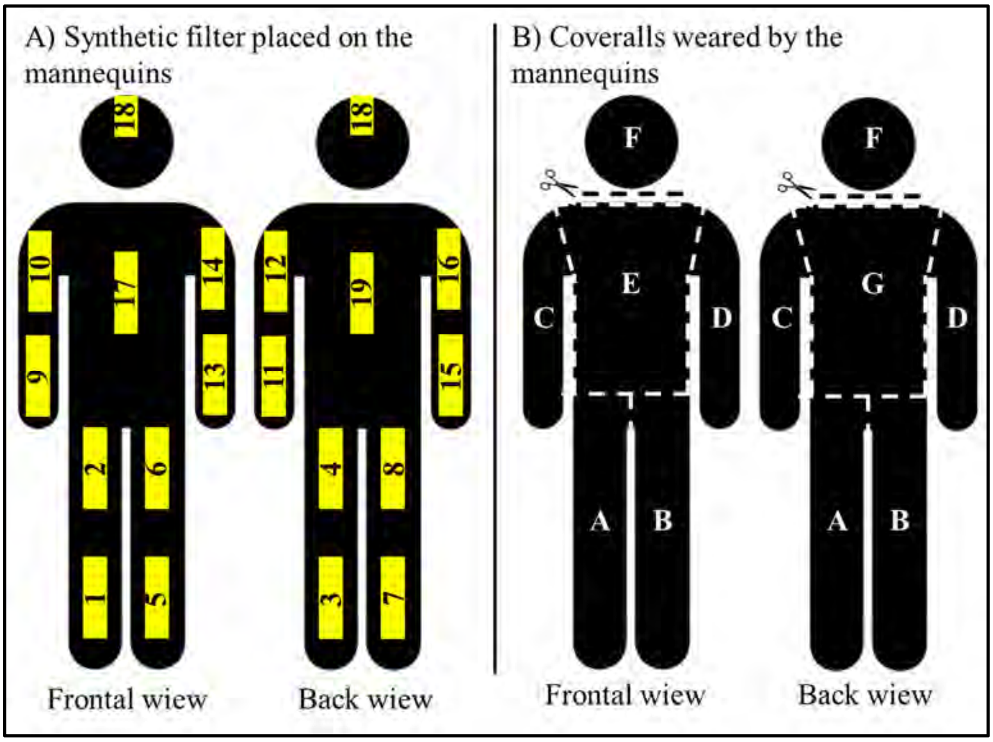

Figure 1. Artificial collectors used in the trials with mannequins: A) synthetic filter placed on the mannequins B) coveralls weared by the mannequins.

Table 2. Correspondance between synthetic filter and coveralls collectors: shared body parts.

Shared body parts	Synthetic filter collectors [ID number]	Coveralls collectors [ID letter]
Leg right	1 - 2 - 3 - 4	A
Leg left	5 -6 - 7 - 8	B
Arm right	9 - 10 - 11 - 12	C
Arm left	13 - 14 - 15 - 16	D
Chest	17	E
Head	18	F
Back	19	G

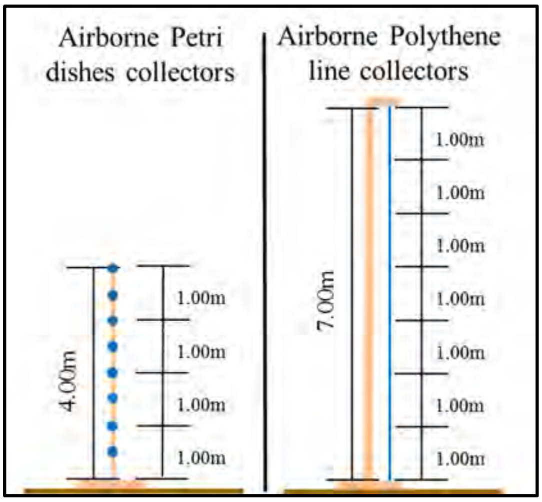

Figure 2. Airborne spray drift collectors: A) Petri dishes B) Polithene line.

Wind speed and direction during the tests were measured and recorded by means of a sonic anemometer (Gill Windsonic), placed at the edge of the downwind area where the collectors were disposed, at a height of 4 m from the ground, linked to a datalogger (Campbell Sci CR200X). Data were acquired and recorded every one second. Air temperature and humidity during the tests were measured by means of a thermo-igrometer (Allemano Testo 400).

Two different axial fan sprayers has been used. The main operative parameters are shown in Table 3.

Table 3. Maine operative parameters of the sprayers used in the trials.

Trials		2013	2014
Sprayer		Fede Qi90	Tifone Storm
Nozzles type		ATR 80 red hollow cone nozzle	ATR 80 orange hollow cone nozzle
Droplets size (test pressure of 1.0 Mpa)	**D_{V10} [µm]**	38	33
	D_{V50} [µm] (VMD)	102	80
	D_{V90} [µm]	264	164
Active nozzles [N°]		4+4	7+7
Operatin pressure [Mpa]		1.0	1.0
Forward speed [m s^{-1}]		1.39	1.39
Volume rate [l ha^{-1}]		737	934
Fan air flow rate [m^3 h^{-1}]		28800	30000

For each trial three replicates were made. At the end of each test the sprayed artificial collectors were recovered in closed boxes to prevent light degradations (coveralls were sectioned into 7 parts according to Figure 1 and Table 2, and then recovered). For each test carried out a sample of the spray liquid applied was taken from the sprayer tank to have a reference of the concentration of the tracer in the test liquid.

Afterwards, at laboratory, samples were analyzed washing the sprayed artificial collectors, measuring the amount of deionized water used for wash them and analyzing the obtained liquid by means of a spectrophotometer (Biochrom Lybra S11) set at 434 nm wavelength, corresponding to the peak of absorption of the Tartrazine dye.

Statistical analyses were done using IBM SPSS Statistics (Statistical Package for the Social Sciences) for Windows (Version 22.0., Armonk, NY: IBM Corp.). For each trials, a bivariate Pearson correlation was performed between the different type of collectors.

Results

All tests were conducted with a wind speed of more than 1 m s^{-1} and a wind direction between 60° and 120° respect to the sprayer travel direction. Temperatures during the tests were around 19.4°C (Min 17.3 and Max 21.6°C) and relative humidity between 70.3% and 76.4%. All the environmental parameters resulted in line with the requirements of ISO 22866.

First trial, years 2013 - Tracer recovered on the mannequins (synthetic filters VS coveralls)

The means of the tracer specific amount (µl/cm^2) recovered on the synthetic filters placed on the different mannequins positions and on the coveralls different parts are shown in in Table 4. In Figure 3 is reported the relationship between the specific amount of tracer recovered by the filter collectors and by the different part of the coveralls. For this analyses the amount of tracer detected on the sectioned coveralls were related to the mean of the quantity of tracer detected on filter collectors gathered by shared coverall sectioned part body in accordance to that shown in Table 2.

The mean quantity of deposit on whole mannequins detected with synthetic filter (19 collectors for a total surface of 0.38 m^2) was 3650.4 µl, 457.8 µl and 238.3 µl respectively at 1, 3 and 5 meters from the treated area; the quantity detected using a coveralls (total surface of was 1.943 m^2) was 92.4 µl, 7.8 µl and 1.5 µl respectively at 1, 3 and 5 meters. Comparing the two type of artificial collectors the specific quantity recovered in synthetic filter was 40, 59 and 159 superior respectively at 1, 3 and 5 meters from the treated area. This differences are due to their nature: the filters have small dimensions (200 cm^2) and could only be completely exposed (collectors placed in front side mannequins) or fully hidden (collectors placed in back side mannequins); on the other side the coveralls have a larger surface area (about 5 times greater) and while also having a part fully exposed (front side) and a part completely hidden (back side) is characterized by a continuum of surfaces which vary between the two extremes. Table 4 show that more variability of results was found using a synthetic filter (in some cases CV more than 100%) and that variations in deposition tracer detected in the different body parts, at all distances, are less marked using coveralls (the highest CV was 32%). Figure 5 shows that there is not a relationship between the deposition on mannequins measured using filters and coveralls collectors at 3 and 5 meters of distances from the sprayed area. At 1 meter from the treated area there is a significant correlation ($p=0.033$); however this tendency is explained by the values obtained in back body part (fully hidden) with very low deposition values.

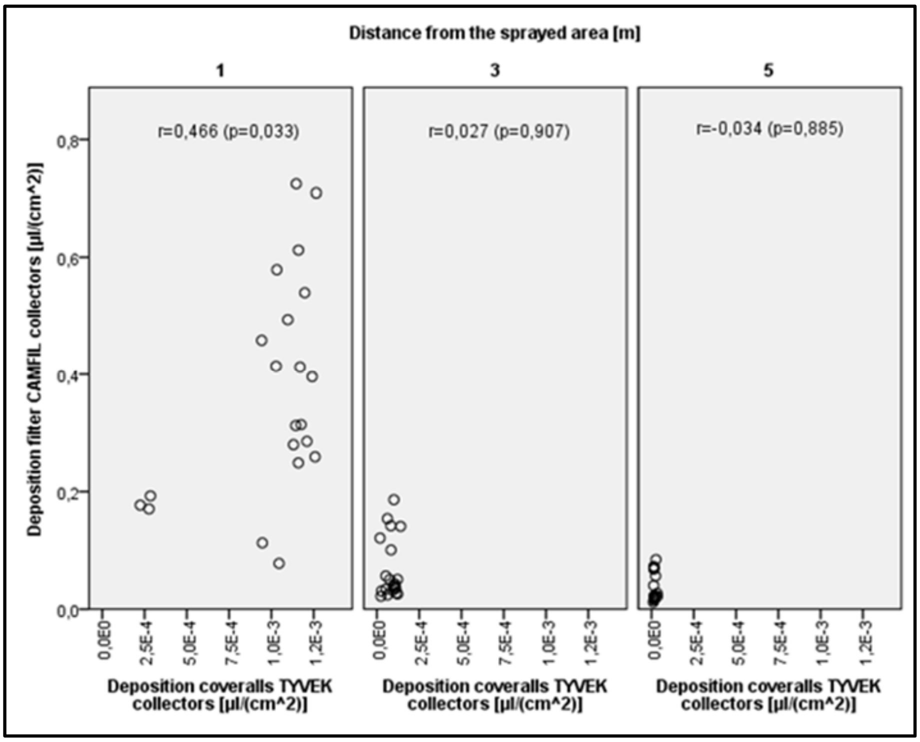

Figure 3. Relationship between the amount of tracer recovered by the filter collectors and coveralls collectors at the different sampling distances (1, 3 and 5 meters).

Table 4. Amount of tracer recovered by the synthetic filter and coverall collectors placed on the adult mannequins at the different sampling distances (1, 3 and 5 meters).

Shared body parts	Synthetic filter collectors							Coveralls collectors						
	ID number according to the Figure 1	Distance from the treated area [m]						ID letter according to the Figure 1	Distance from the treated area [m]					
		1		3		5			1		3		5	
		Deposition [µl/cm^2]	CV [%]	Deposition [µl/cm^2]	CV [%]	Deposition [µl/cm^2]	CV [%]		Deposition [µl/cm^2]	CV [%]	Deposition [µl/cm^2]	CV [%]	Deposition [µl/cm^2]	CV [%]
Leg right	1	0.176	36	0.062	77	0.037	100							
	2	0.851	37	0.084	63	0.026	85							
	3	0.192	29	0.051	99	0.049	50							
	4	0.972	22	0.092	100	0.040	87							
	average	**0.548**	**29**	**0.072**	**84**	**0.038**	**78**	**A**	**1.23E-03**	**3**	**9.40E-05**	**12**	**1.66E-05**	**21**
Leg left	5	0.133	4	0.058	77	0.045	85							
	6	0.654	63	0.099	58	0.044	103							
	7	0.127	62	0.049	62	0.028	63							
	8	0.608	38	0.157	128	0.022	75							
	average	**0.380**	**46**	**0.091**	**92**	**0.035**	**85**	**B**	**1.12E-03**	**7**	**1.11E-04**	**10**	**1.56E-05**	**13**
Arm right	9	0.973	28	0.076	110	0.032	65							
	10	0.406	31	0.042	62	0.020	106							
	11	0.671	34	0.100	110	0.060	77							
	12	0.282	51	0.075	81	0.037	85							
	average	**0.583**	**27**	**0.073**	**96**	**0.034**	**80**	**C**	**1.16E-03**	**1**	**9.64E-05**	**32**	**1.70E-05**	**13**
Arm left	13	0.074	48	0.061	63	0.032	45							
	14	0.150	49	0.065	91	0.033	106							
	15	0.819	20	0.079	107	0.029	26							
	16	0.537	10	0.069	101	0.041	57							
	average	**0.395**	**19**	**0.068**	**92**	**0.037**	**58**	**D**	**1.04E-03**	**10**	**1.21E-04**	**14**	**2.06E-05**	**17**
Chest	**17**	**0.346**	**6**	**0.063**	**52**	**0.027**	**43**	**E**	**1.19E-03**	**7**	**8.46E-05**	**12**	**1.48E-05**	**16**
Head	**18**	**0.157**	**69**	**0.038**	**43**	**0.044**	**78**	**F**	**1.04E-03**	**9**	**5.64E-05**	**10**	**3.18E-05**	**15**
Back	**19**	**0.180**	**37**	**0.058**	**94**	**0.033**	**95**	**G**	**2.62E-04**	**13**	**2.29E-05**	**18**	**1.25E-05**	**18**
Total deposition amount of all collectors placed on each mannequins [µl]		**3650.448**	**46**	**457.807**	**22**	**238.306**	**10**		**92.428**	**3**	**7.812**	**9**	**1.500**	**12**

Second trial, years 2014 – Airborne spray drift collectors (Petri dishes VS Polythene lines)

Table 5 shows the amounts of airborne spray drift recovered by Petri dishes and Polythene line (used previously by Cross et al., 2001 and Butler Ellis et al., 2014) at different sampling heights on the ground and at two distances (5 and 10 meters) from the treated area. The sampling height for the Petri dishes stops at the height of 4 meters and for the vertical Polythene line stop at 7 meters.

The data of deposition on the collector used for the assessment of the airborne spray drift point out a greater collection using the Petri dishes mounted on vertical mast. The quantity intercepted by the two type of artificial collectors are different, especially at 10 meters from the treated area, due to the different collector surface (153.938 cm^2 for Petri dishes against 62.172 cm^2 for polythene line). The quantity detected at different heights from the ground has the same trend for both sampling distances 5 and 10 meters. The Figure 4 shows the relationship between the quantity of spray drift recovered from the petri dishes and portion of polythene lines placed at the same height (only shared data used for correlation). At distances of 5 m there is not a relationship between the deposition on Petri Dishes and polythene lines. A significant correlation was detected between the two types of collectors at 10 meters from the treated area (p=0.028). Table 5 show that more variability of results was found using a Petri dishes collectors, especially at 10 meters from the treated area (highest CV 65%). Sometimes the CV values of tracer deposition detected on polythene lines show a high value (CV 70%) but overall are broadly less marked (CV between 8 and 20%).

Table 5. Amount of tracer recovered by the airborne drift collectors (Petri dishes and Polythene lines) at the different sampling distances (5 and 10 meters).

Height collectors on the ground according to the Figure 2 [m]	Petri dishes collectors				Polythene line collectors			
	Distance from the treated area [m]				Distance from the treated area [m]			
	5		10		5		10	
	Deposition [μl/cm^2]	CV [%]	Deposition [μl/cm^2]	CV [%]	Deposition [μl/cm^2]	CV [%]	Deposition [μl/cm^2]	CV [%]
0.5	2.196	13	0.888	44				
1.0	2.248	13	1.115	26	2.522	18	0.291	16
1.5	1.534	19	0.970	37				
2.0	1.412	31	0.572	54	1.670	17	0.091	8
2.5	1.575	29	0.413	61				
3.0	2.234	40	0.398	65	0.922	70	0.063	15
3.5	1.835	42	0.307	60				
4.0	2.440	39	0.411	54	0.717	8	0.069	17
4.5								
5.0					0.438	14	0.069	15
5.5								
6.0					0.086	8	0.055	15
6.5								
7.0					0.013	20	0.012	20

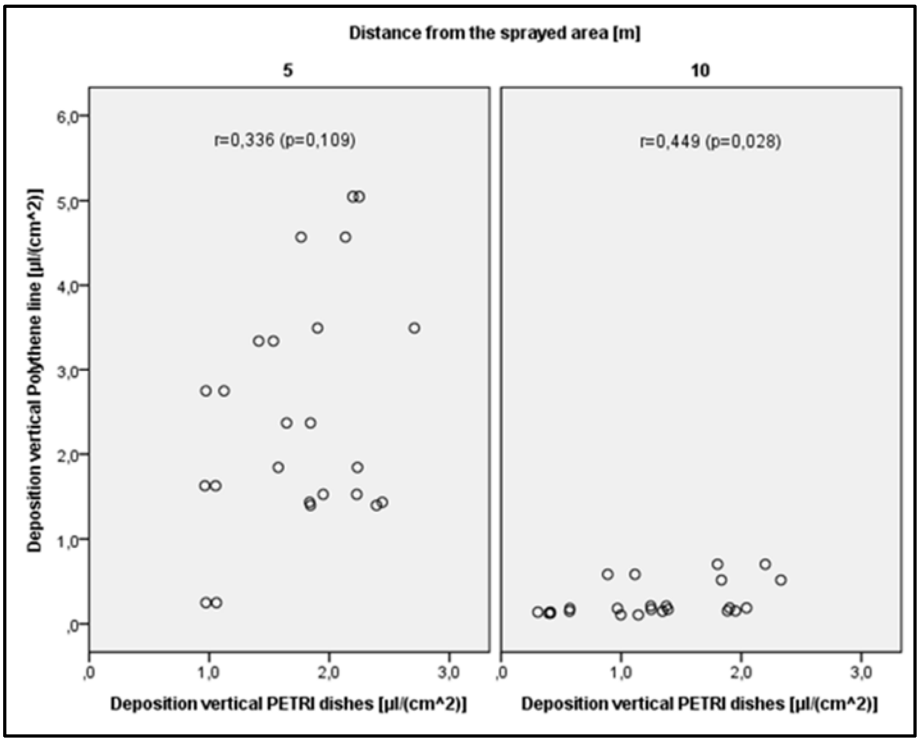

Figure 4. Relationship between the amount of spray recovered by the Petri dishes and Polythene vertical line at the different sampling distances (1, 3 and 5 meters).

Conclusions

Different artificial collectors types used in trials for the measurement of the potential bystander exposure due to vineyard pesticide applications have been studied and shown to be hardly comparable. The collection surface area and efficiency of collection play a fundamental role in the assessment of airborne spray drift and bystander exposure but for the assessment of dermal exposure (bystander) the shape of the collector used it is the main issue. For the before mentioned explanations there is the need to work in a standardized manner using the same type of collectors and test layout. On the basis of the experimental experiences, a visual pattern for propose a test methodology layout combined with the existing ISO22866 is showed in the Figure 5.

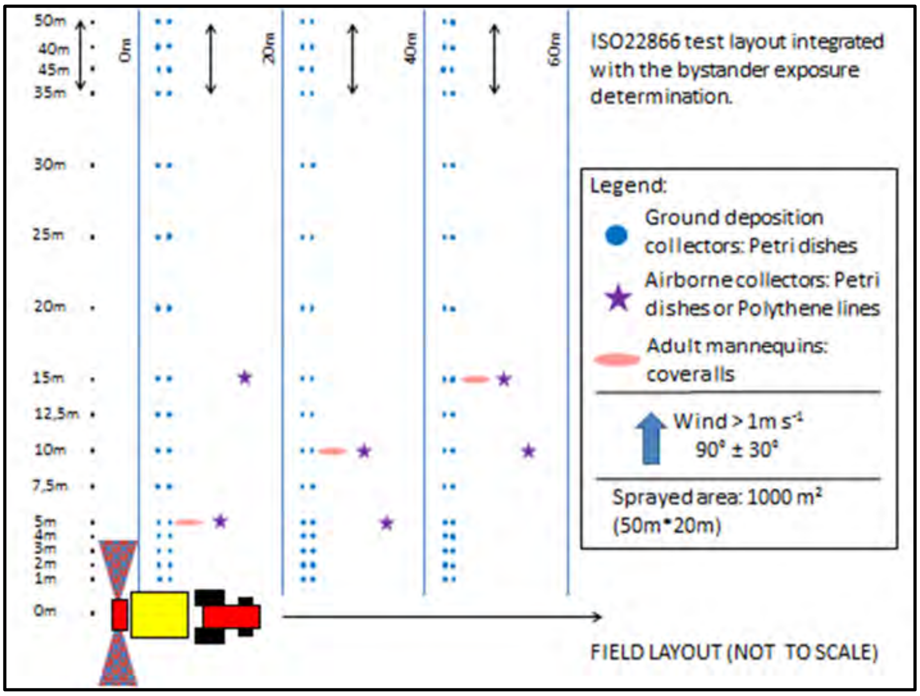

Figure 5. Combined ISO22866 methodology for the evaluation of bystander exposure, airborne spray drift and ground sediment depositions.

This is a preliminary proposal that requires further study regarding the suitable types of collectors and the suitable layout.

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A survey on work safety in 103 agricultural farms in Friuli Venezia Giulia

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Abstract
The objective of this study was to investigate current levels of work safety in agriculture, based on interviews conducted in a composite sample of 103 farms located in the region Friuli Venezia Giulia (North-East of Italy). The survey has outlined a number of patterns that were consistently found across all types of farms and only slightly varied depending on farm size, type of production and location. The results were used to define guidelines for safety experts on the field with new, updated approaches for risk assessment and accident prevention in the farms.

Introduction
Agriculture is one of the most hazardous sectors of economic activity in Italy, in relation both to injuries at the workplace and occupational diseases. More important, the frequency of fatal accidents is particularly high, although not well recognized since many of them involve unprofessional conditions such as retired persons or young people. This makes it very important to properly assess work safety conditions.

Specific surveys on health and safety conditions of working people have been conducted at both European and national level. Recently, the Ministry of Health has promoted a Research Programme on occupational safety and health. One of the priorities has been to establish a national, permanent infrastructure to monitor how workers awareness about risks at the workplace, consistently with the objectives of the National Health Service (Servizio Sanitario Nazionale; Inail, 2014). This kind of investigation is based on telephone surveys involving both the workers and their employers. Another survey was conducted in the agricultural sector (Rete Rurale Nazionale, 2014) based on face-to-face interviews conducted by specialists.

The legal framework in Italy has evolved in recent years, following the adoption in 2008 of Decreto Legislativo (Decree) n. 81 of April 9, 2008, on the regulation and enforcement of workplace health, safety and welfare. This fundamental text (Testo Unico), modified by Decreto Legislativo No. 106 of 2009, contains 306 articles and 51 attachments and introduces the principle of organisation in risk prevention, since both the employers and the workers are committed to safety management practices.

Unlike other European legal standards (e.g. for food safety, environment protection of animal welfare), work safety standards are not part of the common rules for direct support schemes under the European common agricultural policy. However, compliance with work safety rules and national guidelines is required by many Italian Regions as a mandatory condition in order to apply for public support schemes, including those of the Rural Development Plans.

As indicated by previous work, risk prevention and safety rules, while representing substantial requirements for any agricultural farm, are often difficult to introduce and partly still unattended in many cases (Cividino et al., 2010, 2012, 2013). Thus, the first objective of this study was to investigate current levels of work safety in a sample of 103 agricultural farms located in the region Friuli Venezia Giulia (North-East of Italy). Another objective was to define guidelines for safety experts on the field with new, updated approaches for risk assessment and accident prevention in the farms.

Materials and methods

The data used in this study derived from two separate surveys, conducted to assess safety levels in the Animal husbandry sector and in the Vine growing – Wine producing sector in the Region Friuli Venezia Giulia. In the second case, a number of other farms with different specialisation or mixed production were also included. For the purpose of the present study, this made up a sample of 103 agricultural farms, with a prevalence of dairy farms and farms with vineyard and/or horticultural crops (Table 1).

Table 1. The farm sample.

Type of farm	No.	%	Average size (ha)
Dairy farms	36	35.0	67.5
Other livestock	17	16.5	89.9
Vineyard and winery	24	23.3	55.6
Horticulture and nursery	12	11.7	9.4
Other	7	6.8	14.9
Mixed	4	3.9	240.5
Cereal crops	3	2.9	42.3
All farms	103	100.0	63.9

These farms were located in all of the six Health Districts in Friuli Venezia Giulia, each controlled by the respective District Agency (Azienda per l'Assistenza Sanitaria, AAS). Part of these farms (56.3%) employed hired personnel, while 43.7% were family farms, allowed by the law to use a simplified safety management scheme.

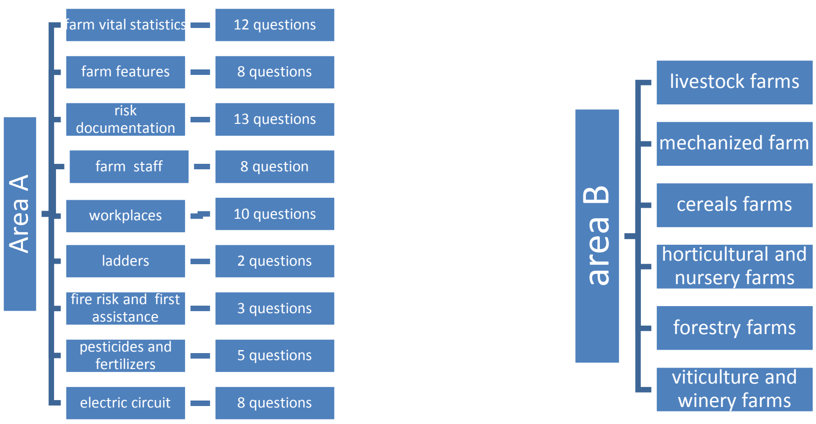


Figure 1. Areas A and B.

Each of the farms was visited by one evaluator and all data were recorded following a specific questionnaire. This was divided in two areas (Figure 1):

- area A, including general information about the farm;

- area B, which varied depending on farm specialisation, and was further divided into three profiles: B1: farm machinery; B2: personal protective equipment (PPE); B3: specific risks.

Results

To the purpose of the present study, we analysed:

- whether official documents and records were actually present at the farm;
- how safety management was organised;
- the presence of protection devices on tractors;
- the use of prevention and protection equipment.

Table 2. Official documents at the farm.

Type of document	Missing or inadequate (% of farms)
Risk assessment document	34.5
Risk assessment update	44.8
Medical watch	34.5
Emergency procedures	41.4
Regular inspection record (lifting equipment)	44.8
Compliance certificate of equipment	10.3
Book of use and maintenance	8.6
Pesticide license	24.1
Pesticide safety sheet	25.9
Equipment maintenance plan	36.2

Table 2 includes only the 58 farms with external personnel, which are subjected to full application of Decreto 81/08 including official documentation. The main document required, i.e. the Risk assessment document, was absent or inadequate in 34.5% of the farms; other required documents were missing even more often, including a scheme for medical surveillance of workers (34.5), the scheme for emergency procedures (41.4%), and the record of periodic inspection of lifting equipment (44.8%). Only those documents provided by third parts were mostly present, such as the Compliance certificate (lacking in 10.3% of farms), the Book of use and maintenance of equipment (8.6%), the Pesticide safety sheet (25.9%), or those required for purchasing pesticides (Pesticide license: 24.1%). Particularly remarkable was the absence of a plan for machinery and equipment maintenance (36.2%), because of its great importance for accident prevention.

The law also requires every farm with hired personnel to officially appoint a number of figures in charge of the different protection and prevention services (Table 3). While a safety manager (or head of the prevention and protection service, PPS) was mostly present (82.8% of the farms), other figures were often missing, including a doctor designated for periodic medical surveillance (48.1% of farms), or the supervisors for fire prevention (33.3%), first aid (34.6%) and workers' safety during actual work (63.0%). Additionally, 38.3% of the farms were not providing the workers with sufficient training and information services, while 44.3% did not have any special training for the various managers and supervisors.

Table 3. Managers and services.

	Not present (% of farms)
Safety manager	17.2
Medical doctor	48.1
Fire prevention manager	33.3
First-aid manager	34.6
Workers' supervisor	63.0
Training and information service (workers)	38.3
Special training service (managers)	44.3

Most of the farms had adequate toilet and shower services and dressing rooms for the workers (Table 4). The width of the main entrance to the farm (minimum: 5 m) was mostly in line with the law. Protections on gaps or trenches were, however, missing in 28% of their farms. Most remarkable was the absence of any Interference risk analysis, i.e. a plan to avoid risks owing to the presence at the farm of external personnel, especially contractors for cereal or grape harvesting. Only 8.6% of farms had conducted a proper analysis of such risks.

Table 4. Situation of buildings in the farm.

Building services	Yes (%)	No (%)
Toilets	93.9	6.1
Showers	87.2	12.7
Dressing room	86.4	13.5
Main entrance to farm > 5 m	81.3	18.6
Railing on hole, trench	71.8	28.1
Interference risk analysis	8.6	91.4

In approx. one half of the farms, a specific analysis was made to assess the main features of the tractors (Table 5). The average nominal power was 63 kW, and the average age was 20.9 years. The average annual usage (328 h/year) was related with the small average land area (63.9 ha, Table 1), and was far from the level suggested for profitable management (at least 600 h/year). These data offer some clues as to the current difficult economic situation in most of the farms: the reasons are many, which cannot be fully discussed here. Anyway, this makes even more difficult for these farms to bear the costs involved by current requirements for risk prevention and protection.

Table 5. Tractors at the farms.

	no. of tractors	Power (kW)	Age (years)	Usage (hours)	Usage (hours/year)
Dairy farms	54	76.6	20.7	7339	355
Other livestock	18	65.6	21.6	7078	328
Viticulture	62	57.1	15.3	4444	290
Horticulture and nursery	26	50.3	27.8	3610	130
Other	2	40.4	24.8	1750	71
Mixed	29	61.8	26.1	15329	588
Cereal crops	5	64.7	20.0	6958	348
All farms	196	63.1	20.9	6873	328

In fact, missing protection devices are mostly related to the tractor's old age. In most of the sample farms, tractors were equipped with roll over protection structures (ROPS), protection of moving parts such as belts and fans, and of hot surfaces (Table 6). Remarkably, however, a safety belt was missing at the driver's seat in 55.1% of the tractors (it is compulsory since 2005); PTO guards were also missing in 24.7% of the tractors.

Table 6. Protective devices.

Protective item	missing (% of tractors)
ROPS	5.2
Safety belt	55.1
Protection of belts & fans	7.6
Protection of hot surfaces	10.8
Safe access to driver seat	13.6
PTO guards	24.7
CE marking	37.6
Owner handbook	8.0

The relationship between the presence of protective items and the tractor's age is shown in Figure 2. All of the new tractors were in line with legal requirements; the only exception was a safe access to the driver's seat, which is often difficult to attain especially in small tractors for viticulture. This means that the main problem for these farms is the low investment capacity, that prevents them to replace old tractors with new ones.

Figure 2. Tractors with required protective items in place.

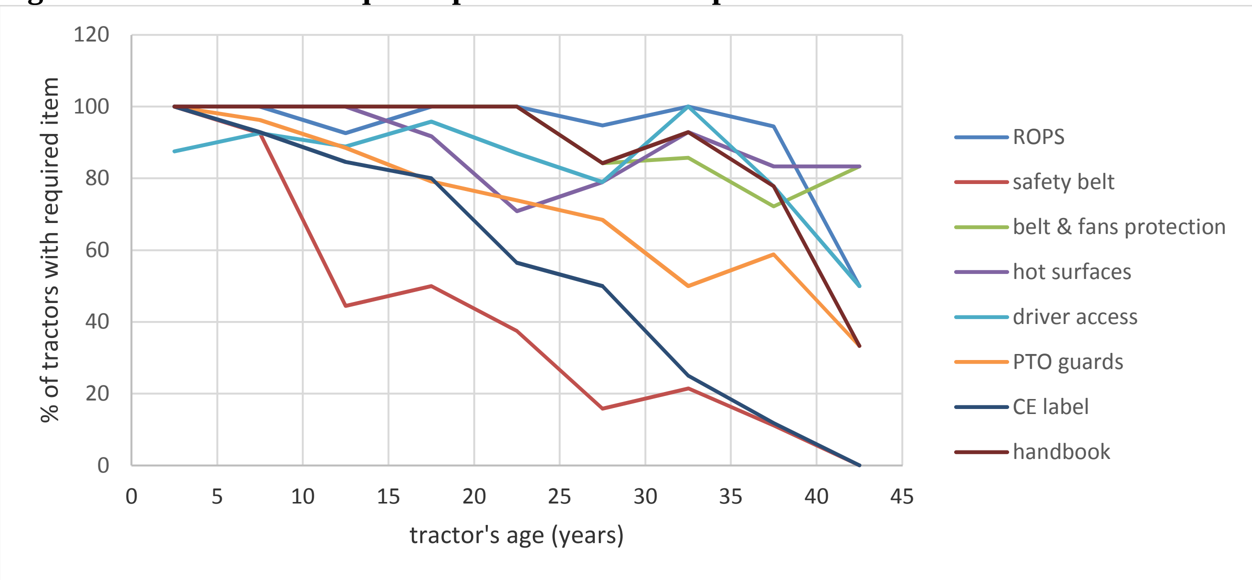
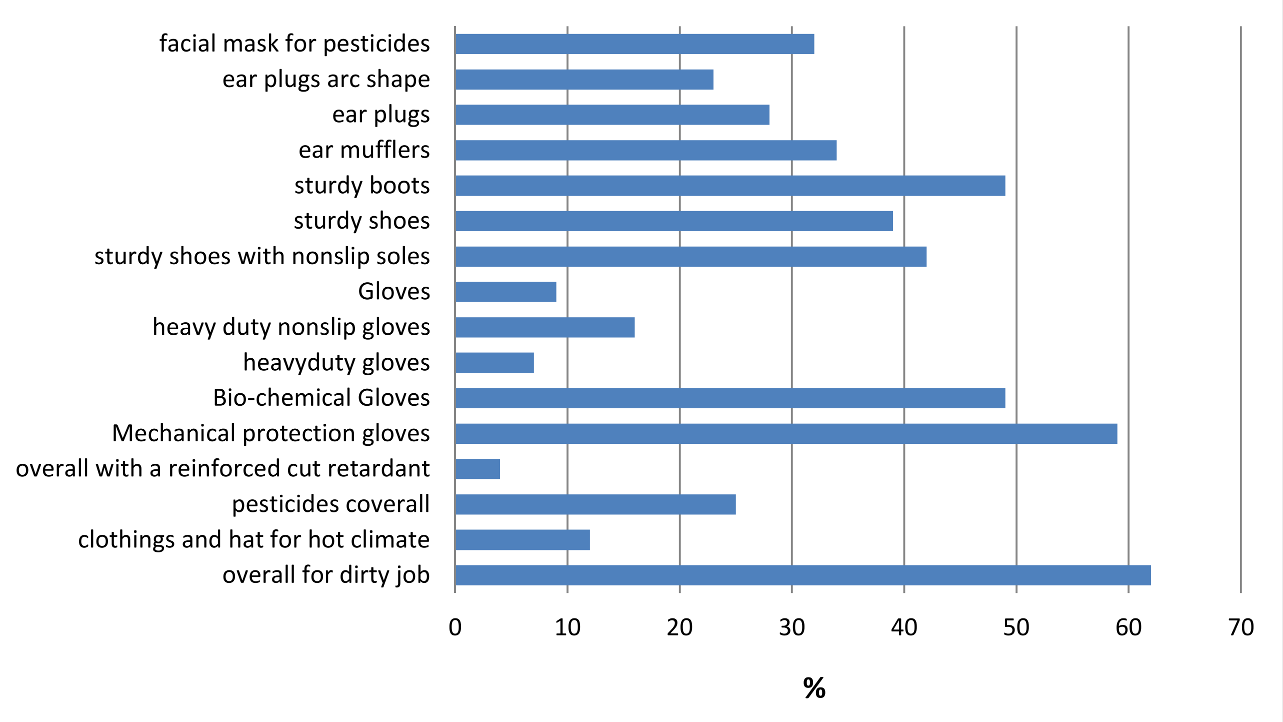


Figure 3 shows the percentages of farms that were providing their workers with personal protection equipment (PPE). In general, only basic PPE were present (like overalls in cotton and mechanical protection gloves), while specific PPE were seldom found (such as ear muffs, safety footware, chemical resistant clothing and gloves).

The main findings from the survey suggested that many agricultural farms were sufficiently aware of the risks associated with their specific production systems, or with the machinery used, but had a tendency to neglect them to some extent, particularly in order to avoid the related economic costs. More important, information about legal obligations was generally insufficient, as was the understanding of the possible cost, in terms of fines, damage compensations and similar, that failure to comply with the rules might cause.

Figure 3. Types of personal protective equipment (PPE) provided at the farms (% of farms where present).



This suggested that most farms would take advantage of some simple informative tool, e.g. in the form of a software, in order to quickly detect the most critical situations. This software, based on a Microsoft Excel® worksheet (Figure 6), enables the farmer to check all the legal requirements for tractors and the main agricultural implements, and suggests how to amend possible defects.

For example, it is possible to examine the existing ROPS on a tractor (Figure 7) and understand whether it fulfils legal requirements or needs changes or replacement; or, indications are given about how to install a ROPS on an old tractor.

Conclusions

The survey was important to improve current knowledge about work safety in agricultural farms, and was also useful to increase the farmer's awareness about the specific risks involved by the different production systems.

A further step will be to improve safety conditions through proper informative and self-assessment tools. Since the survey had shown that most of old tractors and machinery were defective in one way or another, we prepared a software to help the farmer check each machine and detect any improper or missing protective device, or to amend it in order to fulfil legal requirements.

Finally, this work was instrumental to building a data base about current situation of agricultural tractors and implements in use in the Region Friuli Venezia Giulia.

Figure 6. Software menu for check safety device in the tractors.

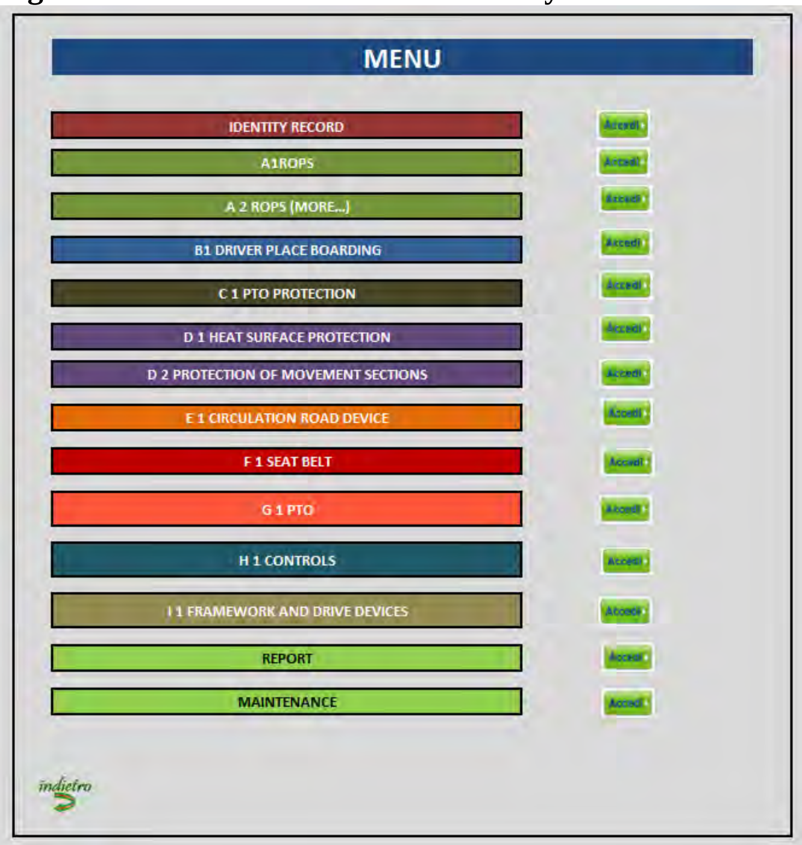
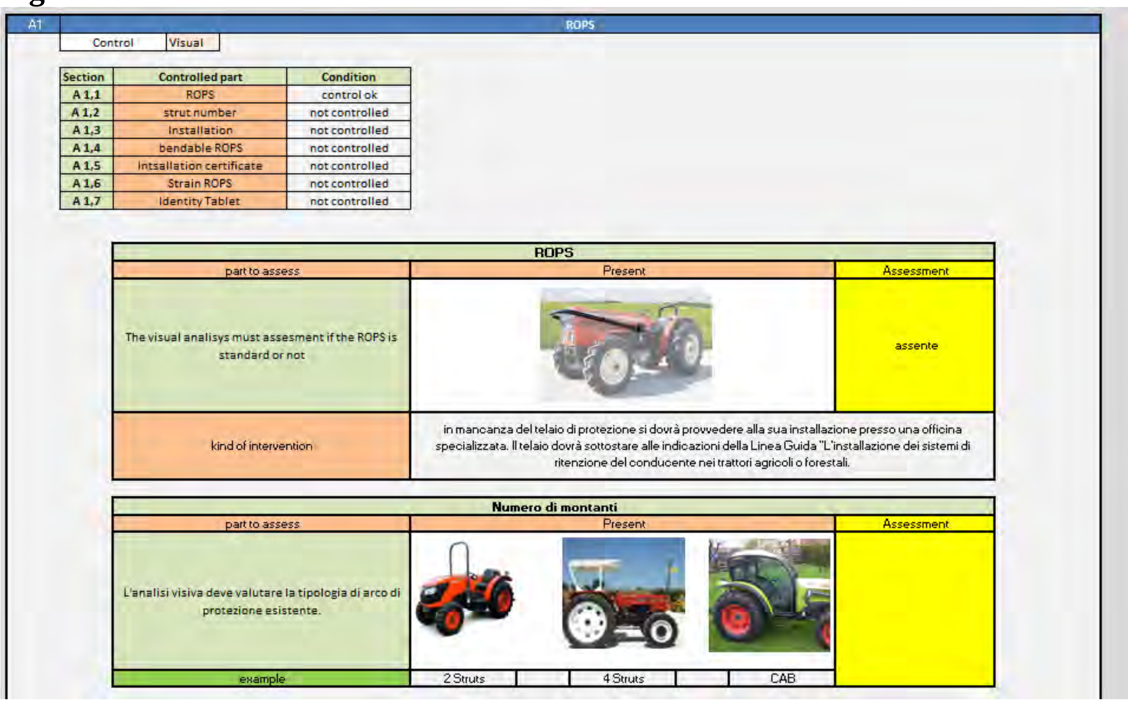


Figure 7. Menu section of tractor ROPS.



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A U.S. Approach Towards Safety Education for Youth in Agriculture

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Abstract
In 1968, the U.S. Department of Labor (DOL) initiated the Hazardous Occupations Order for Agriculture allowing youth employment on farms/ranches at the age of 16; students aged 14-15 years could also be employed provided they participated in a mandated tractor/machinery safety program. In the 47 years since legislation, serious deficiencies and variations occurred in the type/quality of training and the overall process for certifying young workers. While a considerable amount of effort and funding was given to update the training, no real changes have occurred. More recently, the DOL attempted to place stricter controls on youth employment and was met with much opposition from the rural community and their agricultural lobbyist organizations. With politics aside, the more important topic was how to safely involve youth in agriculture. The overall objective of this national project was to develop a sustainable and accessible clearinghouse of safety and health curricula for youth workers. A group of dedicated stakeholders received funding by the U.S. National Institute of Food and Agriculture to coordinate a national approach for youth safety education. This plan involved interactions, collaborations, and partnerships from a variety of public and private institutions. The ultimate result was to provide appropriate training to the youth workforce that increased their awareness for hazards and improved safe practices. Along the way, there was a need to build capacity within the system for teacher education and access to quality curriculum, including testing tools that met a national education standard. Likewise, enhancing public perception of legislation was needed before any success could be attained. This paper addresses the steps taken by the national project, and three results attained thus far: 1) a national symposium for stakeholders' input, 2) a national clearinghouse for curricula, and 3) training for school students in a supervised agricultural experience.

Keywords: Young Workers, Training, Public Policy

Introduction
In 1968, the U.S. Department of Labor (DOL) initiated the Hazardous Occupations Order for Agriculture (AgHOs) allowing youth employment on farms and ranches at the age of 16 (U.S. DOL, 2007). Students aged 14-15 years could also be employed provided they participated in a mandated tractor & machinery safety program. The AgHOs have been, and are currently regulated by the U.S. DOL. In the 47 years since legislation, serious deficiencies and variations occurred in the type and quality of training as well as the overall process for certifying young workers. Likewise, changes in agricultural production and the types of tasks youth are performing have changed. The U.S. Department of Agriculture, a federal core agency of the U.S. Cooperative Extension System, dedicated a national program to address trainings and certificate course programs that meet the AgHO requirements. This Youth Farm

Safety (YFS) Program supported national efforts to deliver timely, pertinent, and appropriate trainings to youth seeking employment or who are already employed in agriculture. While these training requirements do not apply to youth working on their family farm, the educational resources represent good agricultural work practices. Because of this, many parents and grandparents consider this training for their family-based youth workers.

Through the YFS program, land grant universities were provided grants to develop current, consistent, and evidence-based curricula. Over the years, some 23 projects were funded for this target audience. Despite these excellent efforts, no official directory or clearinghouse was developed to contain or market the availability of this material – which is generally offered at no cost to the students.

Safety education is just one approach for reducing injuries, illness, fatalities – engineering practices and public policy are two others (Murphy, 1992). However, in the agricultural workplace, engineering controls (i.e. shields, guards, safety interlock devices, and ROPS) can be removed by the user, and are often viewed as a nuisance rather than a protective factor. To compound to the problem, many youth learn to operate farm machinery using the farm's older equipment, where shields and guards, seat adjustments, and ROPS are completely void.

In 2011, the U.S. DOL proposed policy to strengthen the AgHOs for children working in agriculture. This proposal was met with great opposition from the community. In the U.S. farming is a culture; it is an occupation that enjoys limited controls and governmental oversight. Because of this culture, and the special interest groups that support it, it is difficult to implement and mandate occupational safety and health programs and trainings that may be common in other industries.

Leviton (1991) speculate that people will delay taking action to reduce risk until they first perceive the risk as a significant health threat. "Education can help individuals expand their awareness of risks and increase their skills for dealing with them" (p.233). Safety and health education has become a significant factor in injury intervention and control. Recognizing that prevention is the only sensible strategy in curbing unintentional fatalities on the farm, education provides a framework for increasing knowledge and skills. Education is also critical to inform target populations of public policy as well as benefits of engineering controls. In all aspects of the injury prevention model, there is a need for safety education.

Career Training and Work-Based Learning Programs

In the United States, youth desiring a career in agriculture have formal public school technical training provided through an approved agricultural education program. These programs offer supervised agricultural experiences (SAE), which are philosophically designed to provide guided experiential learning beyond typical school hours (Phipps, Osborne, Dyer, & Ball, 2008). Students completing SAEs as part of an agricultural education program apply concepts learned in the classroom or laboratory to real world applications (Dyer & Osborne, 1995; Phipps, Osborne, Dyer, & Ball, 2008; Croom, 2008). Learning activities are to be planned intentionally to develop students' skills and abilities that will culminate toward a career in agriculture (Barrick, Arrington, Heffernan, Hughes, Moody, Ogline, & Whaley, 1992).The number of agricultural education programs is estimated to be 610,240 students nationwide enrolled in 7,665 school-based agriculture programs (National FFA, 2014). Roberts and Dyer (2004) identified that developing SAE opportunities for students was among the highest professional development need for secondary school agricultural instructors. However, with the large number of students engaging in the SAE's, it is imperative to understand supervision strategies and safety guidelines provided by the agricultural education professionals.

When placed in an SAE, it is typical for students to work alongside the co-workers or supervisors. This could lead to exposing students to uncontrolled interaction with potential risks while supervisors are busy with their own work responsibilities. Sanderson, Dukeshire, Rangel, and Garbes (2010) concluded that as individuals progressed through childhood to young adult, they developed clear ideas about how to farm safely and that observational learning and modeling were key components of the apprenticeship process. There is a significant need to provide professional development and curriculum to assist SAE supervisors in protecting and shaping our future leaders in agriculture. An increased awareness about agricultural injuries and their prevention is essential in the development of culturally and geographically relevant safety instruction and supervision strategies.

Stakeholder input

During a public forum meeting conducted by the U.S. Department of Agriculture – National Institutes for Food and Agriculture (USDA-NIFA, 2012), stakeholders acknowledged the critical roles adults have in designing and implementing youth farm safety education programs. These stakeholders did more than express their concern over the lack of comprehensive training curricula available to young farm workers, they also reported a strong need for a youth farm safety curriculum that is ecologically sound, developmentally appropriate, innovative, time relevant, exceeds the minimum requirements of the current AgHOs, and reflects current approaches in pedagogy and knowledge of youth-related injuries in agriculture. Most stakeholders felt that creating a centralized source for educational and training materials would be helpful, and that a national curriculum should follow national education standards already being used in career pathways knowledge and skill sets.

Related to partnerships, the stakeholders also felt it beneficial to implement a comprehensive youth training program with coordinated collaborations from associations, schools, and organizations that are currently implementing safety programs, as well as partnerships with parents, health community educators, farm labor organizations, local farm & ranch organizations, Cooperative Extension, Future Farmers of America (FFA), National 4-H, agricultural equipment manufactures, commodity groups, the National Institute of Occupational Safety & Health (NIOSH), the U.S. Department of Labor and the Agricultural Safety and Health Council of America (ASHCA).

Another resource of the U.S. land grant system is eXtension (pronounced E-extension). This electronic system is integrated within the land grant universities as a partnership for shared knowledge and educational resources, delivered via the Internet through community-based educational programs. This collaborative effort provides public access to training materials and informational resources 24/7/365 via website (http://www.extension.org). A specific component of the eXtension network addresses farm and ranch safety and health topics (eXtension, 2011). At this time, a network of 90 Community of Practice (CoP) members use their expertise to develop site content through a peer reviewed process which requires a minimum of two reviewers per article. Content on this eXtension site includes articles by topic, educational and outreach materials, national reference documents and visuals, and national resource organizations. The mission of this electronic network is to become the primary resource library for all agricultural safety and health information for use by agricultural producers, professionals, educators and rural people.

With such a broad array of interest groups, educational opportunities, and politics, an opportunity existed within the United States to address a modern public health and safety problem regarding youth workers. The primary topic discussed within stakeholder groups was 'how' to safely involve youth in agriculture. The overall objective of this project was to develop a national strategy that would enhance awareness of, access to, and utilization of farm materials for youth workers and those adults who instruct or employ youth.

Methods

In 2013, a group of educational specialists from land grant universities received funding from the U.S. National Institute of Food and Agriculture to coordinate a national approach for youth safety education. The Safety in Agriculture for Youth (SAY) Project was funded as a collaboration between Pennsylvania State University, The Ohio State University, Utah State University, University of Kentucky, and Career Safe, Inc. (a private education corporation). The primary mission of the SAY Project was to develop a sustainable and accessible national clearinghouse for agricultural safety and health curriculum for youth in both formal and informal settings. Several secondary objectives were established to improve communication and collective cooperation from multiple stakeholders with similar interests. All curriculum efforts were to increase safety and health knowledge and reduce hazard and risk exposure to youth on U.S. farms and ranches. This national curriculum is not a 'curriculum' per se, but is an umbrella compilation that includes many different curricula, programs, projects, and activities that together have a common purpose. Additionally, this comprehensive national curriculum was developed to be sensitive to all types and scales of production agriculture and all ages and experience levels of youth audiences. It must include parents, employers, and other educators. It must be culturally appropriate. And it must be usable in both formal and informal educational settings.

Under this public funding, four specific aims guided the approach. Three results are collectively reported in this paper.

Specific Aim 1: Conduct a youth farm safety symposium to engage the various stakeholder groups and build synergy for the overall SAY program initiatives. This public symposium involved SAY National Steering Committee members and their root organizations, other interested organizations, government agencies, and commodity groups with youth educational resources.

Specific Aim 2: Create a centralized location (National Clearinghouse) of relevant educational materials that can be used in both formal and non-formal educational settings for youth.

Specific Aim 3: Establish a risk assessment protocol for developing supervision strategies and guidelines for formal secondary students' experiential learning activities (i.e. Supervised Agricultural Experiences).

Results

The ultimate results were to provide appropriate training to the youth workforce so that they could have increased awareness for hazards and improved work practices. At the onset of this process there was a need to build capacity within the system for teacher education and access to quality curriculum, including testing tools that met a national education standard. Likewise, enhancing public perception of legislation was needed before any success could be attained. Outcomes of three aims are reported here.

Outcome from Specific Aim 1: A National symposium of stakeholders' input

The national symposium provided interaction and discussion amongst stakeholder groups, educators, parents, and agricultural employers who provide and/or seek training opportunities for youth workers. The concise workshop-style format consisted of two half-day technical sessions, whereby the program started at 1pm on the first day and ended at noon on the second. An evening dinner and social was included on Day 1 to allow for informal discussion and networking opportunities. Forty-five stakeholders participated in the symposium, representing 7 academic institutions and 11 other agencies.

Four plenary sessions were developed with unified themes and national speakers. The purpose of each session was to evoke constructive dialogue to bring about ideas, share resources, identify gaps, and discuss best practices for safely involving youth on the farm or ranch. These discussions were not only important for employed youth, but also those who may work for family agricultural operations. The plenary sessions included: 1) Current Regulations, 2) Employment Options in Agriculture, 3) Age Restrictions versus Competence Standards for Involving Youth, and 4) Formal versus Non-Formal Training Resources. Each session was video recorded and available on the project's clearinghouse website.

Evaluation data was collected from participants, reflecting a 44% response rate. Using a 5-point Likert scale, 100% of the participants agreed that speakers were knowledgeable, content was presented with a good flow, and topics were reflective of the latest developments in agricultural safety for youth. Approximately 85% were in agreement with the panel-style sessions as an effective way to learn the information, and offered comments like: "I really liked the two-day format; it was intense, but helpful" and "Each speaker brought great information into the symposium." Fifteen percent of participants rated the Question/Answer sessions higher than the panel sessions with comments including: "The Q&A sessions were the most valuable aspect of the event." Over 95% of the participants reported the symposium met their expectations.

Outcome from Specific Aim 2: A National clearinghouse for curricula

Steps were put in place to develop a national clearinghouse specifically for agricultural safety and health curriculum. A national steering committee and three stakeholder groups were formed to offer the project team guidance, as well as assistance in identifying appropriate content to be submitted to the clearinghouse. A marketing and outreach plan was developed to ensure national awareness and easy access/utilization of those materials. Also, a website was established to serve as the central location for the training materials.

An online submission process was developed for easy submission of educational materials. Content could be cataloged by curriculum, education resource, or video link. It was important for the clearinghouse to be sustainable, so in that regard, steps were put into place that ensured 1) links were made to existing educational resources, 2) curricula included formal (school) and non-formal (home and agriculture) resources, and 3) resources were marketed for all audience groups, including youth workers, parents, educators and agricultural supervisors.

Outcome from Specific Aim 3: A supervised agricultural experience training program

Agricultural education teachers are in a prime position with SAE's to influence the safety culture and protect their students while working in the agricultural industry. Two approaches were taken within this aim.

1. Assess U.S. public school agriculture instructors' professional development needs and safety practices for protecting youth involved in supervised work based agriculture experiences.

2. Develop a professional development program for public school agriculture instructors

to monitor supervised work based agriculture experiences for hazards and implement safety interventions to reduce injury risks to students.

The first approach utilized the theoretical framework of the theory of reasoned action and planned behavior (Ajzen, 2005; Ajzen & Fishbein, 1980) which has been used to explain the significant association between health attitudes and risky behaviors. The purpose was to gather evidence of agricultural education teachers' beliefs towards supervision and planning practices for student safety during SAE activities.

Agriculture teachers rated 60 items on level of agreement (5 = "Strongly Agree", 1 = "Strongly Disagree"). A panel of five university agricultural education teacher educators with expertise in supervised agricultural experiences reviewed and determined the survey was content and face valid. Cronbach's coefficient alpha reliability estimates were used to determine the instrument reliability. A total of 263 surveys were returned with 232 surveys complete and useable for a response rate of 19.2%. Multiple contacts were made to encourage non-respondents to participate in the survey. Telephone follow-ups were conducted with a random sample of 300 non-respondents. All statistical tests were set at an alpha level of .05 a priori. There were no statistically significant differences between early and individuals responding to telephone follow-ups. IBM SPSS Statistics version 20 was used for data analysis. Research questions were analyzed descriptively with frequencies, percentages, means, and standard deviations. For items where the standard deviation exceeded the mean, the median (*Mdn*) and interquartile range (*IQR*) were reported.

The average age of agriculture teachers completing the survey was 41 years old (SD = 11.1). The majority of respondents (62.9%, n = 144) self-identified their gender as male. Over half of the respondents (56.5%, n = 130) indicated having completed a master's degree program at the time of the survey. The majority of agriculture teachers (65.2%, n = 150) indicated being a single teacher program. For the number of students enrolled in respondents' programs the median was 100 (IQR = 98). For the number of students enrolled with an active approved SAE in respondents' programs the median was 50 (IQR = 70). A total of 122 respondents (54.2%) indicated the most commonly completed SAE type was placement followed by 101 respondents (45.5%) who indicated entrepreneurship was the most commonly completed SAE type in their program. The construct "SAE Safety Procedures Perception" had the highest level of agreement (M = 4.12, SD = 0.50) among Agriculture teachers. "Professional Development Need" ranked second (M = 3.93, SD = 0.59) followed by "Mentor Involvement" ranking third (M = 3.72, SD = 0.63) and "Hazardous Work Perception (solitary student SAE tasks) ranking fourth (M = 3.37, SD = 0.78) in the level of agreement among respondents.

The second approach taken within Aim 3 included a professional development workshop conducted for secondary agricultural teachers regarding supervised agricultural experiences and student safety planning.

Using NIOSH FACE reports of childhood injuries as case studies, teachers were given a demonstration of how to utilize Haddon's Injury Model for evaluating work environments for uncontrolled interactions between a host, an agent, and the environment (Haddon, 1980). The demonstration guided teachers on pre-event phase and event phase supervision for following safety guidelines when working with agricultural machinery and livestock. The workshop instructed secondary school agriculture instructors on the development of informational resources that are meaningful, barrier-free, and culturally sensitive to their community members (Runyan, 1998). Secondary agriculture education teachers from Region I NAAE (N = 15) were surveyed at the NAAE Region I conference regarding the professional development workshop (α = .76, 10 items). The workshop survey was reviewed and deemed content and face valid by three agricultural education professional development experts. Teachers were asked to evaluate the workshop using a paper based questionnaire with 10 Likert-scale questions (1=Strongly Disagree; 2 = Disagree; 3 = Not Sure; 4 = Agree; 5 = Strongly Agree) and four open ended questions. Fifteen workshop participants completed the survey. The anonymous nature of participants responses precluded follow up of non-responding workshop participants.

The majority of teachers (87%) agreed the workshop was well organized and that main points were clarified, 53% strongly agreed the facilitators demonstrated a comprehensive knowledge about the subject, and 73% agreed that the facilitators conveyed ideas effectively and clearly. The majority of teachers (80%) would like further professional development in the area of supervised agricultural experience and student safety planning. Further, 93% agreed to strongly agreed that the material presented gained usable skills and will be able to apply them to their academic and/or personal life. Finally, 83% found the curriculum CD materials provided were useful. Responses to open ended questions identified the opportunity to share best practices, curriculum materials and the work being done in this area as being most useful, felt it was at the current skill level for teachers, and suggested the facilitators review the contents of the curriculum CD materials.

Through both of these independent assesssments, it was learned that agricultural education teachers were in a prime position with SAEs to influence the safety culture in agriculture to protect their students. Individuals participating in this study agreed that secondary agricultural education teachers should require students to follow SAE safety procedures during work. An outcome from these intitiatives will lead to the development of SAE supervision and safety “best practices” to assist agricultural education professionals in protecting and shaping our future leaders in agriculture.

Conclusions

The SAY Project was a multi-faceted approach to address a complex health and safety problem in the U.S. workplace. Cognizant that youth populations were at risk for injury and death while working in agricultural settings, a comprehensive strategy was formed and funded by the National Institutes for Food and Agriculture, a division of the U.S. Department of Agriculture (USDA) in Washington, D.C. An effort by multiple academic institutions was implemented to provide appropriate training to the youth workforce that would increase their awareness for hazards and improve safe practices when working in agriculture.

The three results reported in this paper, served as a foundation by which additional projects were implemented under the funding agreement. Having this framework in place, provided a means for centralized access to curriculum, learning activities, youth safety certificate courses, farm safety and health expertise, public policy reference documents, and applied research approaches for formal and non-formal learning arenas.

These results also serve as a means to document the feasibility for developing a culture of safety among youth and leaders in the agricultural industry. A recommendation for health and safety professionals is the consideration of an outreach strategy goal to address public outreach needs for the implementation of youth safety programs (like hazard identification and elimination and promotion of engineering controls). Outreach efforts will continue to involve substantive education, short training courses, live presentations, handbooks, posters with educational content and captioned illustrations, and web-based training modules, or websites for best practices. The USDA project encourages outreach activities that attempt to provide prevention information, education, risk reduction counseling, referrals, and safety options to populations who work with or supervise youth in agriculture.

A continuation project was funded for 2015-16 with full expectation that additional government dollars will be appropriated towards future projects under this umbrella SAY project structure. The initial project is a testament of the progress that can be made when stakeholder groups work together for the overall well-being of the young workers.

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Risks linked to the management of pressured hydrogen within a photovoltaic-electrolyzer-fuel cell power system located on a rural land[7]

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Abstract

A power system formed by photovoltaic panels, alkaline electrolyzer and fuel cell stacks was designed and realized to supply the heating system of an experimental greenhouse. The barometric alkaline electrolyzer produces pressured hydrogen (3 MPa), which is stored inside iron tanks. The aim of this paper is to emphasize the main safety aspects of the power system connected to the management of the pressured hydrogen. From the safety point of view the electrolyzer unit has been equipped with devices able to highlight the malfunctions before they cause damages to the operators and break off the process of hydrogen production. The system can be reactivated after the repair just if the cause of malfunctioning has been removed effectively. Nevertheless the management of the products of the electrolysis process involves forethought and trained operators. Starting from the study of international directives and through the Hazard and Operability (HAZOP) Study method, the standards of safety systems for the hydrogen equipment located on a rural land have been estimated.

Keywords: Hydrogen Hazards Assessment, Water Electrolysis, Rural Lands, Risks Analysis

Introduction

The geothermal heating systems with heat pump may be useful, environmental friendly and economically favorable to meet energy requirements of modern greenhouses for winter heating systems (Vox et al., 2010; Scarascia Mugnozza et al., 2011). The Authors are carrying out a research with the aim to investigate the suitable solutions of a power system, based on solar energy (photovoltaic) and hydrogen, supporting a self-sustained greenhouse heated with a geothermal heat pump. The study is going on at the experimental farm of the University of Bari sited in Valenzano (Bari, Southern Italy), latitude 41° N, where a power system integrated with a greenhouse, composed of photovoltaic panels, an alkaline electrolyzer bank, fuel cell stacks, a plastic greenhouse and a geothermal heat pump were set up (Fig. 1). The electricity coming from the solar photovoltaic source (PV) feeds the electrolyzer; the hydrogen gas produced by water electrolysis is then stored in a pressure tank and, when the photovoltaic is inactive (during night time or overcast sky), it is used by a fuel cell system producing electricity for the greenhouse energy demands (Blanco et al., 2014). The electrolyzer is supplied by a power rating of 2.5 kW at a voltage of 230 VAC and produces a hydrogen nominal rate (dry gas) of 0.4 Nm^3/h at 3 MPa. Hydrogen and oxygen bubbles that are generated in the cell stack of the electrolyzer are collected in two separate channels and flow into the gas separators. These are two cylindrical recipients made of stainless steel and half filled with electrolyte where the produced gases are bubbling and separate from the liquid they carry away. The two gases are then filtered, and cross final droplets separators before being delivered from the unit. Hydrogen is routed through a backpressure controller; oxygen

[7] *Each of the authors contributed in equal parts to this work*

is vented to the atmosphere. The produced pressurized hydrogen is stored in two steel tanks having a total capacity of 0.6 m^3. Furthermore the power system is equipped with pressured nitrogen hold inside metallic cylinders, employed to make unreactive the plant, that is to remove the air inside the system before each restarting of the electrolyzer and immediately after each system failure. The running of the power system and the management of the pressured gases have required a careful risks analysis to safeguard the farmer operators that must be trained to be aware of potential hazards and to take appropriate precautions. In this regard the hydrogen devices, pipes and systems observe the two ATEX directives for the manufacturers (directive 94/9/EC) and for the users (directive 99/92/EC) of the hydrogen equipment. The aim of this paper is to emphasize the main safety aspects of the power system connected to the management of the pressure hydrogen.

Materials and Methods

The entire power system has been designed so that any failure to its components does not compromise the safety of the plant. The different phases of the process (generation and purification of the produced hydrogen by the electrolyzer, hydrogen storage, electric production) are supervised by an automatic control system, designed to ensure reliable safe and efficient effectiveness. The logic underlying the controls has been realized according to a the Hazard and Operability Study (HAZOP) study (Trevor, 2006). As known, the HAZOP Study is a standard hazard analysis technique used in the preliminary safety assessment of new systems or modifications to existing ones; it consists in a detailed examination of components within a system in order to determine what would happen if a component were to operate outside its normal design mode. In the realized power system alarm situations are highlighted and the production process is cut off in safe conditions in the event that the operational parameters have an abnormal deviation from the design values. The reasons that have given raise to alarm are highlighted and the operator is called for an inspection. The system can be reactivated after the repair just if the cause of malfunctioning has been effectively removed.

The electrochemical reaction concerning the water splitting into hydrogen (H_2) and oxygen (O_2) takes place when a suitable DC electric current is applied to the electrodes of the electrolyzer. In an electrolysis cell, an electric current is passed between two electrodes separated by a conductive electrolyte, producing hydrogen at the negative electrode (cathode) and oxygen at the positive electrode (anode). As water is H_2O, twice the volume of hydrogen is produced over oxygen. The gases produced by this process are mutually impure, because of the diffusion phenomenon and this mutual mixing of the two gases, beyond specified limits, may lead to the formation of explosive mixtures. Really the technical standard (ISO 22734-1:2008) requires that the electrolysis process must be stopped at the fulfilment of 2% of H_2 inside O_2 and 1.6% of O_2 inside H_2, without detailing temperature and pressure values.

Results

The electrolyzer (Fig. 2a) has been equipped with an analyser (Fig. 2b) of oxygen and hydrogen on the production line, which gives an alarm signal when the concentrations of oxygen and hydrogen reach respectively 1.1% and 1.6 % and in this last case cut off the electrolysis process. However, in order to provide pure hydrogen to the fuel cell, the percentage of oxygen in the hydrogen in the working conditions is less than 0.01%. The electrolyzer has been located inside a metallic cabinet equipped with a system for the air extraction (Fig. 2b). Suitable openings have been made in the lower part of the cabinet to suck the outside air, which is then withdrawn at the top by a suitable fan. The cabinet has been also equipped with a H_2 gas detector to control if the atmosphere is able to explode. In this way, the area classified as dangerous has been limited inside the cabinet and has been considered as zone 2, i.e. a place in which an explosive atmosphere consisting of a mixture with air of dangerous substances in the form of gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only (ISO 22734-1:2008; Directive 94/9/EC).

Conclusions

The hazards assessment connected to the employment of the power system within the agricultural environment and executed through the HAZOP methodology has been very complicated due to its complexity but it is essential for the farmers' safety. The electrolyzer is the heart of this plant and it requires remarkable attention during its operation. The management of the products of the electrolysis process also involves forethought and trained operators. From the safety point of view the electrolyzer unit has been equipped with devices able to highlight the malfunctions before they cause damages to the operators and break off the process of hydrogen production. But the risk analysis of the power system is in progress because technical operations are being carried out for enhancing the plant functionality, making it more suitable to the designed task of supplying electrically the greenhouse heating system during cold periods.

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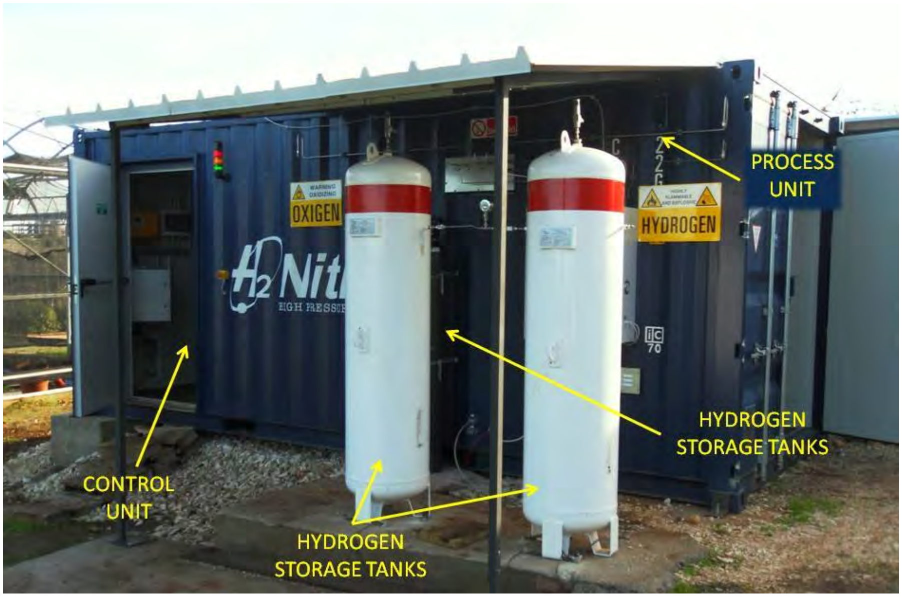

Figure 1. Plant external layout

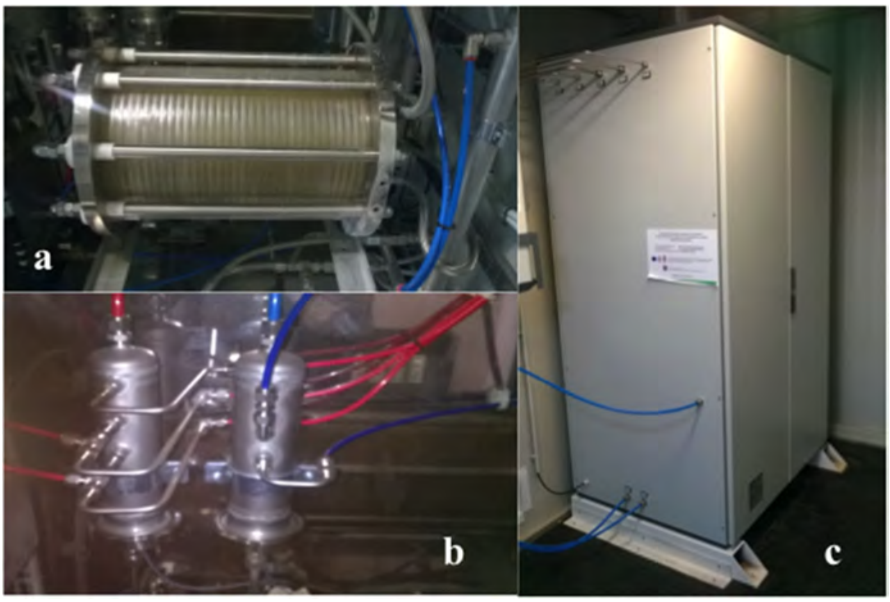

Figure 2. a. electrolyzer; b. analyser of oxygen and hydrogen; c. cabinet

TOPIC 7

"ROPS"

ROPS Design and Testing for Rigid and Foldable Structures

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Abstract

While Roll-over Protective Structures (ROPS) are prevalent on agricultural tractors in the United States, an estimated 1.6 million tractors are still not equipped with ROPS. Many of these tractors do not have ROPS commercially available although they were originally designed to support a ROPS. To meet this need, a computer-based ROPS design program was developed to quickly develop ROPS designs based on tractor weights and dimensions. The final product from the program is the ROPS design drawings with specifications that can be used to construct the ROPS. The constructed ROPS would then need to be tested to assure it meet the appropriate ROPS standard. Two ROPS designed with the program successfully passed the SAE J2194 static longitudinal, transverse and vertical tests.

Many ROPS being sold on new tractors use a foldable ROPS design. These ROPS are effective when the ROPS is raised and locked in place. But raising and lowering ROPS is a tedious and strenuous task, and many times ROPS are left down during tractor operations. Fatality reports are showing that operators are dying when tractor upsets are occurring with the mounted ROPS folded down. In one study the fatalities from tractor overturns with foldable ROPS down were 50% of the total tractor overturn fatalities examined. New OECD TAD/CA/WD(2014)8/REV1 defines the maximum forces to manually actuate a foldable ROPS. Forces measured on existing foldable ROPS far exceed those stated maximums. A simple mechanical foldable ROPS lift assist can ease in the raising and lowering of ROPS. A summary of foldable ROPS forces and the benefits of the ROPS lift assist will be presented.

Keywords: ROPS, Foldable, OECD

Evaluation of the stability of an articulated farm tractor using mounted implements on hillsides

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Abstract
When introducing a new farm tractor in the market, manufacturers undergo a tight homologation path under the supervision of the OECD centres technicians. Two of the most requested tests, although not mandatory for the commercialization of a tractor, are the individuation of the centre-of-gravity and of the lateral rollover angle on a tilting platform. The results of these tests are very interesting for the technical characterization of a vehicle but still far from its real working conditions, even if the tilting platform test forecasts, for example, the presence of fuel in the tank and the use of some weights to simulate the driver. Indeed, in this last test, no mounted implement (or equivalent mass) is connected to the tractor, hence limiting a lot the use of the results of the described tests.
Therefore, a numeric stability simulator was developed to overcome this problem, thus managing the variety of the possible implements to be connected to a tractor and giving the farmers effective indications concerning their vehicles' safety while working on hillsides. This simulator, based on a Newtonian approach, is able to compute the stability of a vehicle formed by a tractor and an implement.
It was used to verify the possibility of safety using some common mounted implements with a compact wheeled articulated tractor, specifically designed to work within terraced orchards/vineyards, common in mountain areas. This tractor was chosen because of its particular architecture: it gives the tractor a higher agility and a shorter turning radius than conventional tractors with the same dimensions, but also a very different stability behaviour, maybe not completely predictable in all situations by inexperienced drivers.

Keywords: Numerical Stability Simulator, Tractor + Implement Stability, Articulated Farm Tractor.

Introduction
The search for higher and higher safety and health conditions of agricultural workers is always a very important topic for manufacturers, engineers and scientists dealing with farm machines, having significant repercussions also for the whole society (Cecchini et al., 2013; Cividino et al., 2014; Cividino, Gubiani, Pergher, Dell'Antonia, & Maroncelli, 2013; Monarca et al., 2009). In particular, agricultural vehicles working on hillsides can easily reach critical conditions from the point of view of their stability (Gravalos et al., 2011; Hunter, 1993; Mazzetto, Bietresato, Gasparetto, & Vidoni, 2013; Mazzetto, Bietresato, & Vidoni, 2013; Previati, Gobbi, & Mastinu, 2014; Vidoni, Bietresato, Gasparetto, & Mazzetto, 2015) so one of the most interesting challenges is *predicting the possible rollover of a vehicle*, thus preventing the damages and the risks caused by an eventual overturning. For this reason, the mechanization of side-slope activities (Longo, Pennisi, Bonsignore, Schillaci, & Muscato,

2013) and, in general, the dynamic behaviour of off-road vehicles has been studying since the eighties and it is responsible for the continuous work of improvement which can be seen on the machines (e.g., the lowering of the centre of gravity or the introduction of active and passive safety systems).

The presence of an implement or a trailer connected to the tractor, is one of the most common causes of rollover on hill-sides especially if the vehicle is doing specific manoeuvres (e.g., tight turnings): the implement alters considerably the static and dynamic behaviour of the whole vehicle (tractor + implement/trailer) with respect to the behaviour of the same tractor alone (Ji-hua, Jin-liang, & Yan, 2011; Karkee & Steward, 2010; Popescu & Sutru, 2009). So, a tractor that is normally stable on a specific sloping ground could reach critical conditions if equipped with an implement.

Actual OECD homologation tests include only the search for the spatial position of the tractor's centre of gravity (even if with fuel in the tank and the some weights to simulate the driver). As a series of OECD-like experimental tests on the tractor connected with some specific implements could not be exhaustive of the whole market offer of the implements' makers, we proposed to integrate the OECD experimental results (performed on the tractor alone) with an ad-hoc developed numerical simulator. This tool, using a quasi-static Newtonian approach (Baker & Guzzomi, 2013; Guzzomi, 2012; Mazzetto, Bietresato, & Vidoni, 2013; Vidoni et al., 2015), is able to calculate the position of the centre of mass and the rollover angle of the vehicle "tractor + implement" with any implement and, therefore, to give an indication of the limit slope for safety operating with the tractor. More in detail, it quantifies the attitude of a vehicle "tractor + implement" to be stable in several slope and angular conditions by using a single number, the *Roll Stability Index (RSI)*, in a way similar to (Yisa, Terao, Noguchi, & Kubota, 1998) and (Liu & Ayers, 1999).

In particular, this approach has been used here to inquiry the stability performance of *articulated farm tractors*, i.e. wheeled agricultural tractors having a central joint used for steering (Mazzetto, Bietresato, Bisaglia, Vidoni, & Weger, 2013; Mazzetto, Gallo, Vidoni, Bisaglia, & Calcante, 2012; Mazzetto, Gallo, Vidoni, & Bisaglia, 2013). These tractors have a higher agility and a lower turning radius than conventional tractors with the same dimensions, but, due to the particular architecture, their supporting polygon varies with the steering angle (Vidoni et al., 2015) and their behaviour could be difficultly predictable by inexperienced drivers.

<u>*Aims of this work*</u>

The aim of this work is to propose a methodological approach for evaluating a priori the stability of an agricultural vehicle operating on hillsides and equipped with different (mounted) implements, with known dimensions and masses. This approach integrates effectively a numerical simulator with the results of the OECD tests.

We also want to show the capabilities of the numerical simulator, part of the approach, when it is applied to inquiry the stability of an articulated farm tractor.

Materials and methods

<u>*The studied articulated tractor*</u>

The agricultural tractor studied in this work is a very compact 4-wheel drive articulated tractor, designed to operate as an implement-carrier within vineyards and orchards placed on steep hillsides (Figure 8, Table 7). It presents a series of interesting features: a narrow track, a low centre of gravity (CoG), a central articulation (or "joint") of the chassis, the engine in the front part, a loading platform in the rear part, a reversible driving seat immediately above the motor, a hydrostatic transmission.

The central joint has two degrees of freedom (DoFs): one hydraulically-operated through a joystick (the *jaw*, used for making the tractor steer), the other passive (the *roll*, to allow the vehicle complying with the terrain). Hence, this vehicle changes its travelling direction by modifying the angle between the two parts composing the chassis: the consequent angulation of the axles individuates a centre of rotation for the vehicle on the horizontal plane, in accordance with the classical kinematics (Vidoni et al., 2015).

This architecture gives the tractor a superior flexibility of use and the driver a very high visibility from his seat but this steering modality, affecting the baseline dimensions and shape, the presence of a passive DoF of the joint and the equipment of the tractor with an implement in its front or rear part, modifying the balance, could be potentially critical for the vehicle's stability.

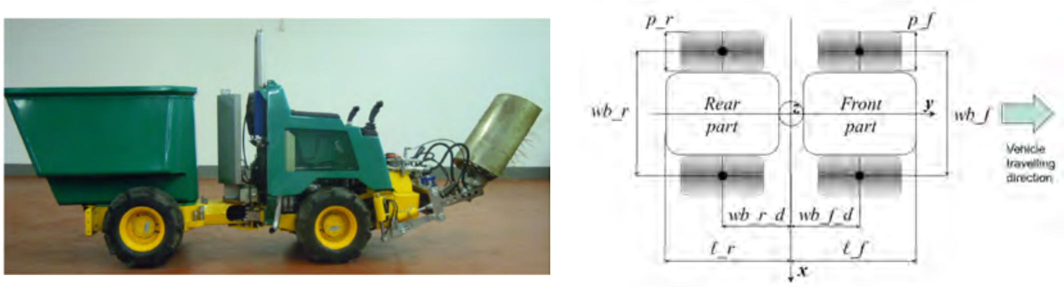

Figure 8. (left) Overview of one of the first prototypes equipped with a front-coupled mower and a rear dumper; (right) Main dimensions of an articulated wheeled tractor and used frame of reference (z axis is perpendicular to the supporting plane of the tractor and is pointing towards the observer).

Table 7. Main geometrical and mechanical parameters referred to the articulated tractor (*f*: front part; *r*: rear part; for other abbreviations refer to Figure 8).

Quantity	Value
CoG_f position (*)	[0.011, 0.621, 0.270] m
CoG_r position (*)	[0.000, -0.618, 0.159] m; [0.000, -0.500, 0.000]** m
ℓ_f; ℓ_r	1.226 m; 0.923 m
wb_f; wb_r	0.710 m; 0.685 m
wb_f_d; wb_r_d	0.669 m; 0.669 m
p_f; p_r	0.200 m; 0.200 m
Joint height	0.280 m
Mass(es)	650 (f) + 344*** (r) kg
Maximum steering angle	110° between the two tractor halves

(*) coordinates referred to a local coordinate system, placed as drawn in Figure 1; (**) without any ballast on the rear end; (***) when no implement is placed on the rear end (149 kg), a ballast (195 kg) is used.

The stability simulator

A Matlab® simulator implements the classical steering kinematics of a vehicle (Genta, 1997), allowing the user to insert the position of the implement's CoG and calculating the position of the CoG of the whole vehicle with respect to the stability baselines. Thanks to this simulator, it is possible to inquiry the different stability conditions for a tractor equipped with any implement and working on sloping terrains.

In particular, the positions of the wheels can be computed while the vehicle travels along a circumference with a set radius on a perfectly smooth inclined plane, neglecting the friction contributes in the advancement direction and the inertial terms (quasi-static approach).

The stability critical angle (*Type II stability*) is searched with respect to the slope and the angular position of the vehicle on the circumference, supposing that the vehicle never slips along the plane and its wheels stay always in contact with the plane.

If d is the distance of the projection CoG* of the CoG from the tractor line of symmetry along the maximum slope direction and d_l the critical stability condition, i.e. the distance corresponding to the scenario in which the CoG projection is on the baseline border (*Type II instability*; Figure 9), the *Roll Stability Index* (*RSI*) is defined as follows (Liu & Ayers, 1999):

$$RSI = \left(1 - \frac{d}{d\_l}\right) \cdot 100 \ \ with \begin{cases} RSI \in \left]0;100\right] \Leftrightarrow d \in \left[0; d\_l\right[: stable\, configuration \\ RSI = 0 \Leftrightarrow d = d\_l : incipient\, overturning \\ RSI < 0 \Leftrightarrow d > d\_l : unstable\, configuration \end{cases} \qquad (1)$$

The instability of each part (*Type I stability*) is also evaluated by checking if the projection of the front and rear centres of mass fall inside or outside the proper stability triangle (Baker & Guzzomi, 2013; Guzzomi, 2012; Vidoni et al., 2015).

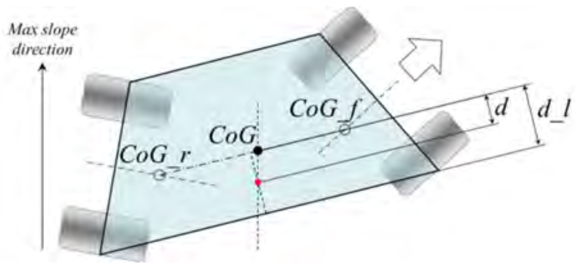

Figure 9. Top view of an articulated tractor while turning; in evidence: the positions of the CoGs on a perfectly horizontal ground (hollow/solid black points), the new position of the CoG projection along a line parallel to the max slope direction (solid red point, indicated as CoG*), the distances used for the calculation of the RSI and the support polygon of the vehicle (light blue).

<u>The proposed approach</u>

The prediction of the minimum value of the RSI or, in general, the forecasting of the equilibrium conditions of a generic tractor equipped with an implement (with known mass and CoG position) can be done by following the four-step approach presented here:

1. Experimental positioning of the centre-of-mass of a tractor in accordance with the current EU norms;
2. Input in the simulator of the data concerning the tractor (geometrical and mechanical parameters), the implement (mass and position of the CoG with respect to the linkage system) and the scenario to be simulated (slope and circumference radius to be travelled, also called "turning radius");
3. Calculation of the CoG of the whole vehicle in a perfectly horizontal plane and of the stability conditions (*Type I and II stability*) of the tractor in each angular position on a sloping ground;
4. Generation of graphical and numerical outputs.

While step 1 is performed once per tractor, steps 2-4 can be repeated many times, i.e. once per implement and per scenario (slope, turning radius) to be inquired. To give an effective aid to the farmers, the values of the slopes and turning radii to be inquired should be close or equal to the values which farmers can experiment within their fields.

Inquired scenarios

With regards to the presented articulated tractor, a generic mounted implement can be coupled to it according to one of the following schemes:

- implement *mounted frontally and operating centrally* with respect to the tractor's longitudinal axis; the connection of the implement to the tractor is made through a properly-designed front lifter equipping the tractor;
- implement *mounted frontally and operating laterally* (i.e., not centrally) with respect to the tractor's longitudinal axis; the implement is at the external/internal side of the turn; the connection of the implement to the tractor is made through a properly-designed front lifter equipping the tractor;
- implement *positioned directly on the tractor's rear end* (i.e., on the plane above the rear axle).

The simulator can easily manage all the above-described situations and calculate the RSI value and the Type-I stability of the vehicle: every implement is described only in terms of mass M and CoG coordinates (x_G, y_G, z_G) in the tractor's frame of reference.

Therefore, we verified the possibility to safely use several different commercial implements on this tractor (**Table 8**); their dimensions, CoG positions and masses were taken from the respective catalogues. The hydraulic-driven implements were chosen by matching the minimum power requirements, indicated by the manufacturers, with the maximum available power of the tractor (26 kW at 3600 rpm).

Table 8. Different implements inquired in this study; observe that L is the distance implement's CoG from the front part of the tractor (positive: implement in front of the tractor) or from the rear axle (positive: the implement's CoG behind the rear axle), B is the distance CoG – tractor's longitudinal axis (positive if in the same direction of the *x* axis).

Implement		**Parameter**			
Type	*Front / rear*	*Implement mass (M)*	*Height of the implement CoG from the supporting plane (H)*	*Distance of the implement CoG from the front part of the tractor or from the rear axle (L)*	*Distance between the implement CoG and the tractor longitudinal axis (B)*
		kg	m	m	m
Sprayer equipment (*)	R	290	0.338	0.295 (from the rear axle)	0.00
Dumper carrying apples(*)	R	328	0.430	0.243 (from the rear axle)	0.00
Dumper carrying sand (*)	R	770	0.430	0.243 (from the rear axle)	0.00
Front shredder/fodder cutter	F	165	0.280	0.500 (from the front part)	0.00
	F	190	0.280	0.500 (from the front part)	0.00
	F	230	0.280	0.500 (from the front part)	0.00
Front vine-shoot shredder	F	250	0.280	0.500 (from the front part)	0.00
	F	275	0.280	0.500 (from the front part)	0.00

Implement		Parameter			
Type	*Front / rear*	*Implement mass (M)*	*Height of the implement CoG from the supporting plane (H)*	*Distance of the implement CoG from the front part of the tractor or from the rear axle (L)*	*Distance between the implement CoG and the tractor longitudinal axis (B)*
		kg	m	m	m
	F	300	0.280	0.500 (from the front part)	0.00
	F	320	0.280	0.500 (from the front part)	0.00
	F	335	0.280	0.500 (from the front part)	0.00
Lateral shredder/fodder cutter	F	245	0.280	1.050 (from the front part)	±1.05
	F	265	0.280	1.050 (from the front part)	±1.15
	F	285	0.280	1.050 (from the front part)	±1.25
Shoot remover	F	55	0.280	0.500 (from the front part)	±0.50
Bilateral shoot remover	F	110	0.280	0.500 (from the front part)	±1.00
Sickle bar	F	140	1.260	0.500 (from the front part)	±0.50
Double sickle bar	F	180	1.260	0.500 (from the front part)	±0.50

* This implement was considered at its maximum load capacity (i.e., the sprayer was supposed to be filled up with water, the dumper with apples or sand) and to be symmetrical with respect to the tractor’s longitudinal axis. Mass values are referred to the implement’s frame and the payload together.

Results

The effect of each of the listed implements on the global stability of the vehicle has been inquired in correspondence with two ground slopes (30°, 45°) and turning radii (2 m or infinite, i.e. when the tractor is travelling on a straight trajectory). Results are reported in Table 9.

Table 9. Assessment of the stability of the whole vehicle (tractor + implement); two numbers will be reported for lateral implements: the first/second one refers to an implement located at the external/internal side of the turn (i.e. with B negative or positive, respectively).

Implement	**Minimum RSI**				**Type-I st.**	
	α=30°		**α=45°**		**α=30°**	**α=45°**
	R=2	**R=INF**	**R=2**	**R=INF**	**R=2 or INF**	
Sprayer equipment	37	58	8	36	1.0	1.0
Dumper carrying apples	30	51	-6	21	1.0	1.0
Dumper carrying sand	16	45	-31	4	1.0	1.0
Front shredder/ fodder cutter	71	82	56	69	1.0	1.0
	70	83	56	70	1.0	1.0
	70	83	55	71	1.0	1.0
Front vine-shoot shredder	69	83	55	71	1.0	1.0
	69	83	55	72	1.0	1.0
	68	83	55	72	1.0	1.0
	67	83	55	73	1.0	1.0
	67	83	55	73	1.0	1.0
Lateral shredder/ fodder cutter	39/74	57/61	28/63	48/52	0.9/1.0	0.7/0.7
	34/71	53/57	23/61	44/48	0.8/1.0	0.6/0.7
	29/68	48/52	19/59	40/44	0.7/0.9	0.5/0.6
Shoot remover	73/78	81/83	53/59	63/65	1.0/1.0	1.0/1.0
Bilateral shoot remover	62/78	73/76	45/62	57/61	1.0/1.0	0.8/0.9

Implement	Minimum RSI				Type-I st.	
	α=30°		α=45°		α=30°	α=45°
	R=2	R=INF	R=2	R=INF	R=2 or INF	
Sickle bar	72/85	81/85	63/77	75/78	0.9/1.0	1.0/1.0
Double sickle bar	72/88	82/85	65/82	78/80	1.0/1.0	1.0/1.0

Observing the results in Table 9, it is possible to deduce some general trends; in particular, the minimum RSI value decreases:

- with the increase of the implement's mass M, which has the effect to move the global CoG of the vehicle towards the implement's CoG;
- with the increase of the distance L between the implement's CoG and the front part of the tractor (or the rear axle of the tractor), indicating a greater straddle of the implement with regards to the tractor chassis;
- with the increase of the distance B (between the implement's CoG and the tractor's longitudinal axis), shifting laterally the global CoG from the longitudinal axis;
- with the increase of the height H of the implement's CoG from the ground, having the effect to lift up the global CoG.

The implements to be mounted in the front part of the tractor result having a stabilizing effect on the vehicle, since they have very low centres of gravity; vice versa for the implements to be mounted on the tractor's rear end. In particular, if the tractor has the dumper full of sand or apples, Type-II rollover will surely occur when turning on a 45°-slope hillside (RSI<0). The same turning manoeuvre with the dumper full of sand is quite dangerous even at 30° (RSI very low and next to 0) so a particular care should be taken, especially on harsh terrains.

Looking at the Type-I stability, overturn can occur (e.g. the index is index different from 1.0) when turning on a 45°-slope ground with a 285-kg lateral shredder at the external side of the turn and when using a lateral shredder with a mass greater than 245 kg on a 45°-slope ground, whichever the position of the implement (external/internal side of the turn). Therefore, the driver must absolutely not use that implement in the described conditions.

Conclusions

This work shows a mixed experimental-numerical approach for evaluating the stability of agricultural vehicles equipped with different mounted implements and operating on a sloping ground. In particular, this approach has been applied to study the stability performance of a 4-wheel drive articulated tractor, very agile and having many points of innovation.

The described approach has proved to be able to raise effectively the safety of the tractor driver because it has allowed individuating preventively some possible dangerous situations. Thanks to it, we can suggest to avoid using two specific implements (e.g., the dumper and the lateral shredder on 45° hillsides) without having performed any experimental test on the complete vehicle (tractor+implement).

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Performance evaluation of a commercial tractor stability control system

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Abstract

The study takes origin from the increasing development of aftermarket devices to evaluate tractor rollover risk on the basis of dynamic parameters detected by sensors.
Aim of the research was a tractors rollover risk assessment in normal field operation, using a commercial device to evaluate the activities at higher rollover risk for the agricultural operators.
Five tractors used in the experimental farm of the Bologna University were monitored in the 2013 year. Each tractor was equipped with a stability control system based on a hardware multisensory device, a software risk index algorithm and an integrated position information system for tractor localizing. The detected parameters and tractors position were accessible via a dedicated web site. Fourteen transceivers were connected to implements for recognition when coupled to the tractor.
Preliminary tests demonstrated that the tilt sensors used in the device did not provide high performance when the tractors were subjected to sudden operative changes. The risk assessment, in fact, was based on a quasi-static evaluation of stability conditions.
On the other hand the device seemed suitable to monitor dangerous practices in the normal operation of the tractor; the system could represent a good tool to educate unskilled drivers, becoming an acceptable compromise between safety evaluation and farm management.
Among the monitored operations the liquid manure spreading and the round baling were the ones at highest risk, while plough and rotary harrow were considered as tractor stabilizers.

Keywords: Rollover, Safety, ROPS

Introduction

In the field of work safety in agriculture tractor rollover is matter of concern because it represents not only the most frequent injury (Mayrhofer et al., 2014), but also the leading cause of death (Abubakar et al., 2010; Arana et al., 2010; Reynolds and Groves, 2000). The great versatility of use, the environment changes and the long service life make the tractor a highly dangerous machinery. In the years a growing operator safety awareness led to promote stringent regulatory requirements, to define test procedures on the stability of tractors and machinery (Gravalos et al., 2011) and to assess rollover risk (Fargnoli et al., 2010).

Laboratory tests, under controlled conditions, allow using simplified models capable to predict tractor stability and non-continuous rolling behavior (OECD Code 6, 2015). Nonetheless, in field conditions a greater number of factors are involved. Tractor stability in fact is influenced not only by geometric parameters such as the position of the center of gravity, wheelbase and track, but also by dynamic characteristics, as forward speed, tractor-implement linkage, steering angle rate etc.

Moreover the contribution of factors related to the environment and land morphology, and those depending on the operator, such as skill, reaction time, experience and risk perception, affect the rollover of tractors and machinery.

Due to the complexity of overturning dynamics, the traditional approach has been to consider highly unseemly to avoid tractor rollover, orienting instead the efforts to minimise the effects of the accident on the operator through the adoption of Roll Over Protective Structure (ROPS) (Moerberg, 1973).

Such structures have greatly reduced the number of fatal accidents (Springfieldt, 1998; Röthemeier, 2013). However it has been proven that seat belts are a necessary complement to the protection provided by ROPS (Molari and Rondelli, 2007; Myers and Pana-Cryan, 2000).

A driver assistance device, alerting the operator in critical conditions for the stability of the tractor, may contribute to improve the driver perception of risk increasing the prevention of accidents by correcting inappropriate behaviors. These driver assistance devices, providing signals to alert the operator, have been developed by several researchers in the world (Murphy et al., 1985; Spencer and Owen, 1981).

Instrumentation for tractor pitch and roll angle measurement was tested at a constant speed on uniform gradient test tracks to evaluate the linearity of the acquisition system with good results (Freeland, 1990).

A system composed of uniaxial accelerometers, a gyroscope and a micro-controller was designed by Greene and Trent as a predictive tool of tipping (Greene and Trent, 2002).

Nichol et al. (2005) developed a device based on low-cost sensors and a microcomputer capable of providing a brief time history of roll angle to the operator. The mathematical model for the assessment of potential rollover situation was simplified and quasi-static and provides an evaluation of the stability in real time situations.

Recently, an interesting application for smartphones has been developed by Liu and Koc (2013) using integrated sensors with a calculation model derived by the model developed in 1999 by Liu and Ayers for the prediction of potential tractor tipping situations (Liu and Ayers, 1999).

These devices, although oriented to a possible industrial development, were mainly research tools; however nowadays commercial systems begin to be on the market. Therefore evaluating their performance could be of valuable importance. In fact a commercial product has properly to balance reliability and simplicity in use, being designed with components allowing a simple operation in field while providing an acceptable stability risk assessment.

The main aim of the study was to evaluate the performance of a commercial device designed for monitoring tractor stability in field conditions in order to characterize the reliability of the values of the dynamic parameters detected by the instrument and to verify the effectiveness in improving the risk perception of the operator. A monitoring activity was carried out on five tractors operating in the experimental farm of the University of Bologna to identify the most risky conditions for tractor rollover.

Materials and methods

A commercial stability control system for dynamic assessment of tractor stability conditions in real time was tested in normal field operation. Parameters influencing the risk of rollover were monitored.

The device was composed of hardware, software and an integrated information system (Rondelli et al., 2013). The localization of the tractor and the data detected by the sensors were stored in a dedicated database.

The hardware of the system consists of a main unit, installed on the tractor (Fig. 1a), a display, located into the tractor cabin to alert the operator with a risk signal when approaching the stability limit (Fig. 2a) and wireless transceivers placed on the implement linked to the tractor to allow for identification (Fig. 1b). The low cost and compact sensors integrated in the main unit were:

– Dual axis accelerometer as tilt sensor to measure the inclination angle.

– Tri-axial accelerometer to validate the signals from the bi-axial accelerometer, to confirm tractor overturn.
– Gyroscope to assess tractor steering angle rate.
– GPS for tractor geographical localization.
– GSM/GPSR for data transmission.

Data processed by the system, through a dedicated algorithm, provided a stability risk index based on a simplified quasi-static model. Geometric parameters of the tractor-implement system (mass and overall center of gravity of the system and wheelbase and track of the tractor) and the values detected by the sensors during the operation (speed, pitch and roll angles, steering angle rate) were computed in the model.

The risk index was expressed as percent. Absence of risk conditions had a corresponding visual signal on the display consisting of concentric green circles, 70% rollover estimated risk was shown as yellow circles then, overcoming the 95% threshold of estimated risk, the color became red and an audio signal was added.

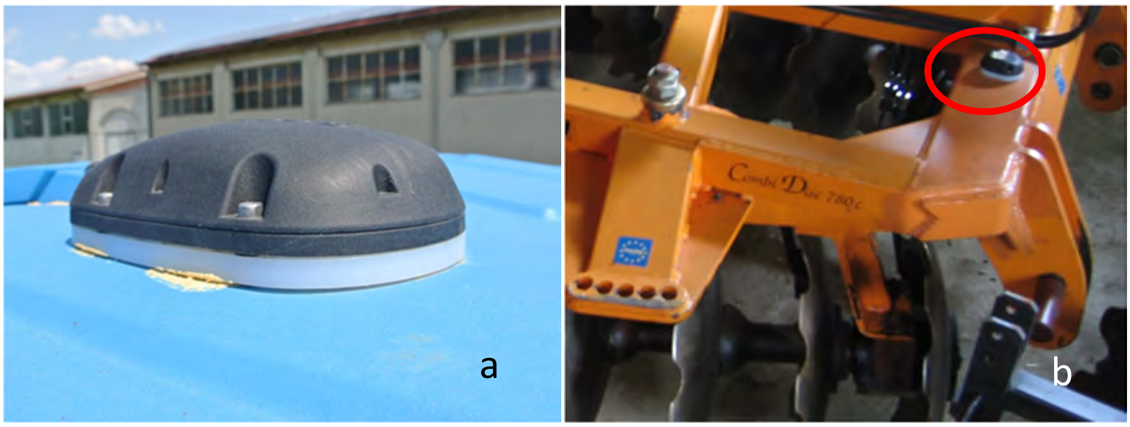

Figure 1. Main unit located on the tractor roof (a); transceiver on the implement (b)

Preliminary tests

Preliminary tests were carried out on an agricultural tractor to evaluate the performance of the stability control system in static and dynamic conditions.

Static tests were carried out on an inclined plane in concrete. The tractor equipped with the main unit was placed on the plane in different positions to evaluate pitch and roll angles. During the test a digital level was used to compare the angle measurements. In the tests the tractor reached values above the threshold limit for the alarm signal. Figure 2b shows pitch and roll angles simultaneously detected and the visual alarm represented by the concentric yellow circles.

The dynamic tests were carried out in controlled field conditions at the experimental farm of the University of Bologna. The real time values of pitch and roll angles were compared with those recorded by the digital level. Values of the forward speed detected on the display were compared to those simultaneously measured by a GPS speed sensor in use at the Test Station of the University of Bologna.

Figure 2. Tractor on the inclined plane during the static test (a); display of the system visualizing the alarm signal (b)

The tractor was driven forward a farm road at speed of 10.0 km h^{-1} on a hillside, with a longitudinal gradient of 8 degrees, to check the pitch angle.

Figure 3. Test in field to evaluate the roll angle (a) and the steering condition (b)

A 20 m track with a crosswise slope of 11 degrees and no longitudinal slope was used to verify the roll angle. The test was carried out at 2.3 km h^{-1} and 10.0 km h^{-1} forward speeds (Fig. 3a).

An additional test was carried out driving the tractor on a 10 m diameter circular track at a constant speed of 4.6 km h^{-1} (Fig. 3b). The track was marked on a grass area with a slope of 7 degrees.

Field tests

Five tractors operating in the experimental farm of the University of Bologna were monitored in 2013 during an entire growing season (Table 1). Tractors worked in flat and hilly areas. Transceivers were installed on fourteen implements coupled to the monitored tractors. The implements monitored were: rotary mower, tedder, liquid manure spreader, two round balers, two rotary harrows, harrow, subsoiler, mower conditioner, plough, grubber, liquid sprayer, flail mower.

Each tractor was fitted with the main monitoring unit; up to six implements equipped with transceivers were allowed per tractor. The most significant and frequent combinations were then selected providing a comprehensive evaluation of the activities performed in the farm.

To evaluate the effectiveness of the stability control system in improving the operator risk perception, each tractor driver had to complete per day a survey form explaining his perception about the operating conditions.

Table 1. Tractors monitored in seasonal stability evaluation

Tractor power (kW)	Working Area	Main field operations
107	hill	harrowing, baling, liquid manure spreading
74	hill	baling, liquid manure spreading, mowing
200	hill and plain	plowing
103	plain	harrowing, subsoiling, baling
63	plain	mowing, hay making

Results and discussion

In the preliminary static tests the real time values detected by the main unit and shown on the display showed a slight difference (±1 degree) with respect to those measured by the digital level. Data recorded on the dedicated database were perfectly coincident with the displayed values. High values of pitch and roll angles produced visual alarms on the display.

Table 2 shows the results of the preliminary dynamic tests comparing the values of the main unit with those obtained by the GPS speed sensor and the digital level.

Concerning the pitch angle, data detected by the stability control device had a difference of ± 1 degree with respect to those recorded by the digital level.

A significant difference of performance was evident in the assessment of the roll angle at the two speeds tested. The values of the speeds shown on the display, 2.3 and 10.0 km h^{-1}, were fairly consistent with those reported by the GPS speed sensor, respectively 2.8 and 10.6 km h^{-1}, but at the slow speed the measure of the roll angle was immediately displayed, about 9 degrees, while at the higher speed the roll angle was shown consistently only after the tractor travelled half of the test track, therefore with a noticeable delay.

In the test on the 10 m diameter circular track, with the tractor travelling at the speed of 4.6 km h^{1}, corresponding to 5 km h^{-1} for the GPS speed sensor, the main unit did not consistently detect the pitch and roll angles, probably due to the continuous and fast change of these parameters.

As a general consideration the device in the dynamic tests with steady conditions of stability showed an acceptable performance, while the fast variation in the conditions of stability evidenced the failure of the system. Since the device was a commercial system no in depth details were available on the hardware and overall architecture of software, therefore the main cause of the unsuitable performance was not identified.

Table 2. Parameters measured in the preliminary dynamic tests (mean values)

Track	Speed Main Unit (km h^{-1})	Speed GPS speed sensor (km h^{-1})	Pitch Angle Main Unit (degrees)	Roll Angle Main Unit (degrees)	Angle Digital Level (degrees)
Farm road	10.0	10.6	8	na	8
20 m track	2.3	2.8	-	9	11
20 m track	10.0	10.6	-	9*	11
Circular track	4.6	5.0	-	-	7

* Value provided by the stability control device with a delay of 3.6 s

A statistical analysis of the dynamic parameters recorded in the field operations during the growing season 2013 was carried out considering each tractor-implement system.

The operations carried out in the hilly area caused, as expected, a larger number of alarm signals. In figures 4 and 5, showing the most significant operations, the relative frequencies of the risk index were considered.

High frequencies at high values of risk index may not correspond to a high number of alarm signals if, for example, the implement was scarcely used. Indeed the analysis shows the level of risk of the implement with respect to the frequency of use.

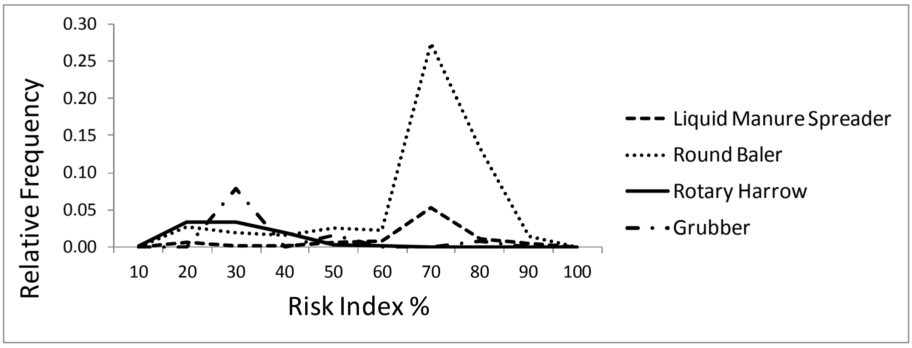

Figure 4. Frequency distribution of the risk values in the operations carried out in the hilly area (tractor 1)

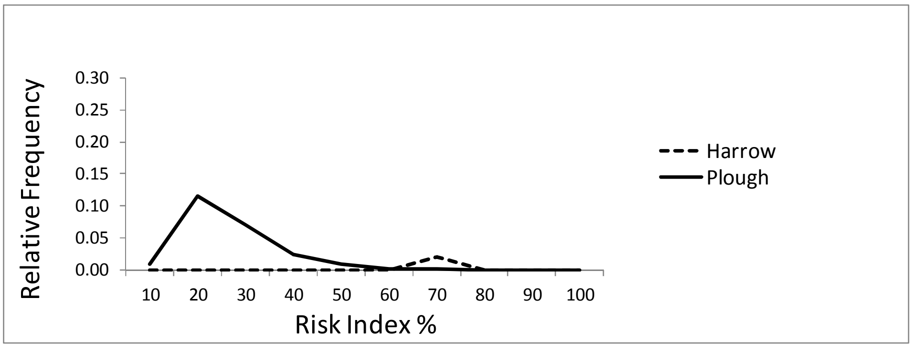

Figure 5. Frequency distribution of the risk values in the operations carried out in the hilly area (tractor 2)

Round baling and liquid manure spreading had frequency peaks at high levels of risk and, vice versa, plowing and rotary harrowing showed no alarm signals even if the system often detected high values of roll angle. The result probably has to be related to the risk index defined by the calculation algorithm for the different machinery. Plough and rotary harrow were probably associated to a stabilization action of the implement-tractor system.

In field operations the operator was alerted too frequently, as resulted by the survey forms filled in by tractor drivers. This result has to be considered with attention because it is important to adjust the frequency of the alarm events to the real field conditions in order to avoid boring the operators and therefore a consequent underestimation of the risk.

Conclusions

Tests carried out on a commercial tractor driver assistance system allowed to evaluate the reliability of the values of the parameters detected by the sensors and to verify whether the system increased the operator risk perception.

The results obtained showed an acceptable performance of the system in steady conditions of stability. On the contrary the values detected in operations characterized by a fast change in the stability conditions, likely the ones leading to a rollover event, evidenced the failure of the device. The results seem consistent with the risk assessment calculated by the system, based on a quasi-static evaluation of the tractor stability.

The stability control device could be considered a good tool to educate inexperienced operators to increase awareness and perception of risk but the algorithm adopted for risk index calculation needs improvement.

The stability parameters recorded on the dedicated website allowed to perform statistical analysis of the tractor-implement system in real field conditions. Data could be of interest to better define the basis assumptions of mathematical models aimed to define risk indexes.

The values recorded in the seasonal monitoring at the experimental farm of the University of Bologna helped to identify the operations with a higher frequency of risk.

The system provided acceptable results if considered as a compromise between a farm machinery management tool and a device to train unskilled operators to improve rollover risk perception.

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Non–continuous rolling in modern narrow-track tractors

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Abstract

Tractor rollover is one of the most hazardous event for the operator. Roll-Over Protective Structure (ROPS) was introduced to protect operator passively. In the specific case of protective structures in front of the drivers and fitted on wheeled narrow-track agricultural tractors, ROPS has to avoid the non–continuous rolling in the event of lateral rollover. Mathematical Model is included in the preliminary tests of the standardised testing procedures issued by the Organisation for Economic Co-operation and Development in order to check non-continuous rolling behaviour in narrow-track wheeled agricultural tractors. Modern narrow-track tractors fitted with rubber-tracks are currently designed but the standardised calculation does not cover the rubber-track tractors. The aim of the evaluation was to analyse the lateral tractor rollover behaviour as affected by the replacement of the tyres with the rubber-tracks. In the tested tractor the fitment of rubber-tracks replacing the rear wheels showed to increase the tractor mass and to affect the position of Centre of Gravity causing a downward and rearward shift with respect to the equivalent wheeled tractor. The track-ground interaction was different compared to the tyre-ground one. Mainly, the behaviour of the rubber-track with respect to the tyre at the state of unstable equilibrium under full load caused the rotation of the tractor around the outer edge of the track.

Keywords: ROPS, Rollover, Stability, Rubber-Track.

Nomenclature	
M	reference mass (kg)
B	minimum overall width of the tractor (m)
B_6	width of protective structure between the right and left points of impact (m)
m	weight of the pendulum block (2000 kg)
g	gravitational acceleration (9.81 m s^{-2})
F	crushing force (N)
H	height of fall of the pendulum block (mm)
E	energy input (J)
$A0$	non-continuous rolling model ground slope (34 deg)
ρ	non-continuous rolling model angle between the CoG and the point of unstable equilibrium (deg)
h	difference of CoG height (from initial position at the unstable equilibrium to first impact) (m)
d	distance between the rotation point and CoG (m)
ω	angular velocity (rad s^{-1})
PE	potential energy (J)
Abbreviations	
CoG	Centre of Gravity
ROPS	Roll-Over Protective Structure
OECD	Organisation for Economic Co-operation and Development

Introduction

Intense competition among manufacturers of agricultural narrow-track tractors caused innovative design solutions (Figure 1). The new design approach allowed the development of an agricultural machine suitable to many operations in the farm. The small size of these narrow-track tractors is suitable to modern orchards and vineyards with narrow inter-rows. On steep slop track-laying tractors (Figure 1b-1d), with a greater contact surface to the ground, allow a higher stability and adherence and are often preferred to the wheeled tractors (Figure 1a). However, the steel track does not allow speeds comparable to the tyre. The development in the design led to new narrow-track tractors to combine the advantages of tyre and track. These tractors are derived from the wheeled ones replacing tyres with tracks (Figure 1c).

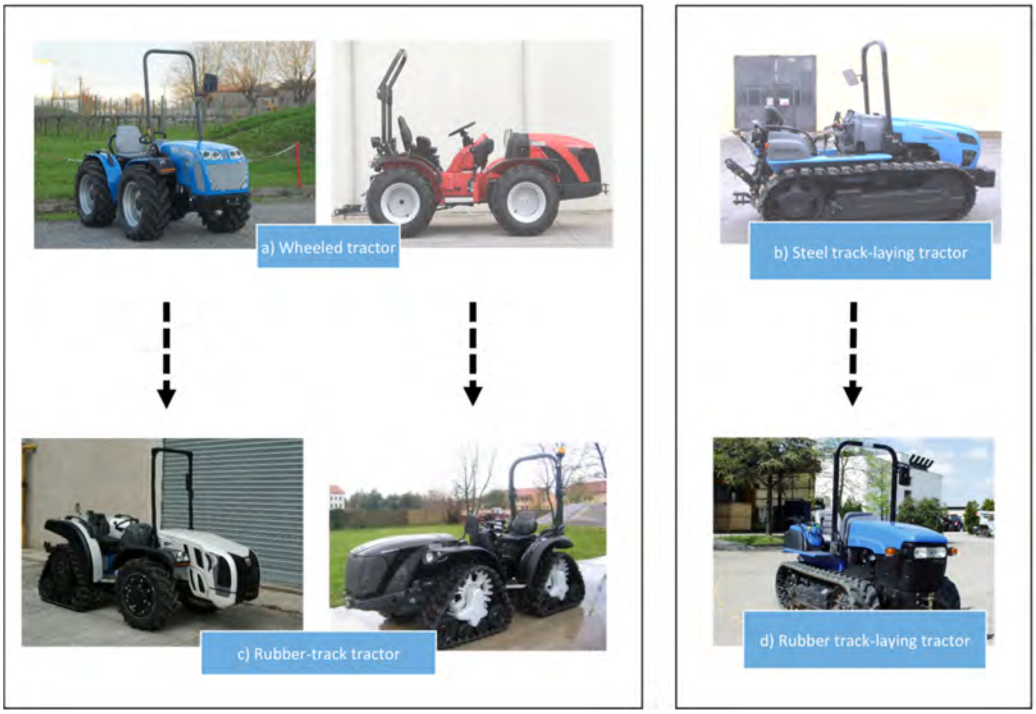

Figure 1. Narrow-track tractor types

The design approach has been to replace tyres with rubber-tracks on the rear axle or even in both axles (Figure 2). The rubber-track allows the tractor to have higher travelling speed with respect to the steel track-laying tractor and at the same time provides a traction performance higher than the wheeled tractor. Rubber-tracks are more comfortable than steel-tracks because of the lower noise and vibration levels. A negative aspect of the rubber-tracks is related to the tractor steering. To overcome the problem, the rubber-tracks on the front axle are fitted on articulated tractors in which the steering of the front part of the tractor is obtained through its central joint (Guzzomi & Rondelli, 2013). The variable conditions in tractor field operation (such as slopes, slippery surfaces, drainage ditches, etc.) introduce the risk of instability, potentially leading to tractor rollover. ROPS is the structure fitted on the tractor to minimize the risks to the driver in a rollover event during the normal tractor operation. The ROPS is characterized by the provision of a clearance zone large enough to protect the driver (OECD Codes, 2015).

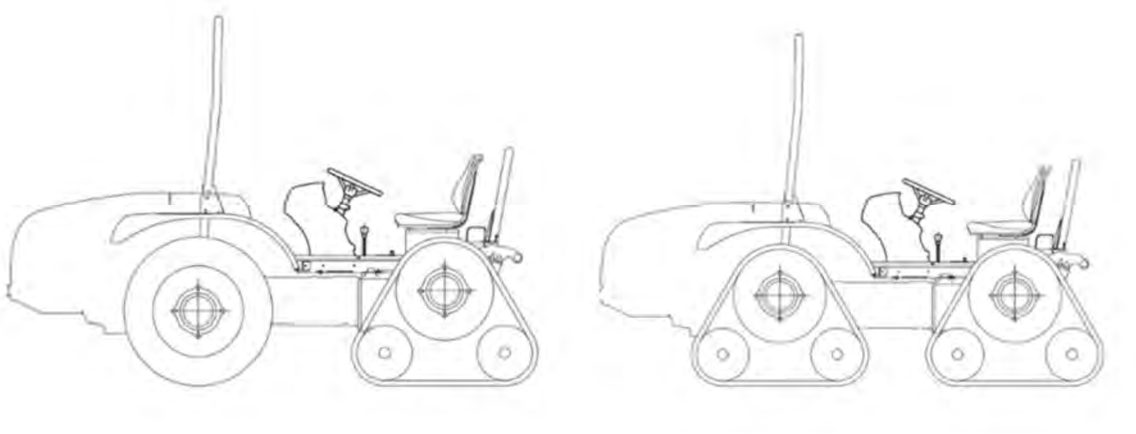

Figure 2. Design solutions of rubber-tracks fitted on narrow-track tractors

Before the widespread introduction of ROPS, tractor rollover caused severe injuries and fatalities (Chisholm, 1972; Moberg, 1964). Fortunately ROPS has long been recognised as an effective mean to greatly reducing the likelihood of operator injury in tractor overturning (Springfeldt, 1996). Over the last forty years, ROPS gave a major contribution to agricultural vehicle safety, even if it is worldwide accepted that it is impossible to protect the operator in all rollover instances. Consequently ROPS test criteria were issued to ensure tested ROPS providing an acceptable driver protection in tractor rollover occurring in normal operation. However, the testing criteria for front ROPS fitted on narrow-track tractors have been defined only for wheeled tractor (Chisholm, 1979a, 1979b, 1979c; OECD Code 6, 1990).

The effect on the safety provisions to replace tyres with tracks has to be evaluated.

ROPS testing procedure

Test procedures for narrow-track wheeled agricultural tractors defined by international standardisation organisations to evaluate the strength requirements of ROPS fitted in front of the driver are already available (87/402/EEC, 1987; ISO 12003-1, 2008; OECD Code 6, 1990). Unfortunately modern narrow-track agricultural tractors with rubber-tracks are not included in the field of application. A reduced clearance zone is provided for the front foldable ROPS (Figure 3) allowing the tractor to operate in narrow conditions such as orchards and vineyards. In reason of this reduced survival volume, the ROPS strength procedures are completed by two preliminary tests to verify the tractor behavior in case of a lateral rollover. The protective structure may only be subjected to the strength tests if both the Lateral Stability Test and the Non-Continuous Rolling Test have been satisfactorily completed. ROPS tests are performed with dynamic or static procedures. The sequence of strength tests for OECD Code 6 (Table 1) is as follows:

1. Impact (Dynamic test) or loading (Static test) at the rear of the structure;
2. Crushing at the rear of the structure (Dynamic or Static test);
3. Impact (Dynamic test) or loading (Static test) at the front of the structure;
4. Impact (Dynamic test) or loading (Static test) at the side of the structure;
5. Crushing at the front of the structure (Dynamic or Static test).

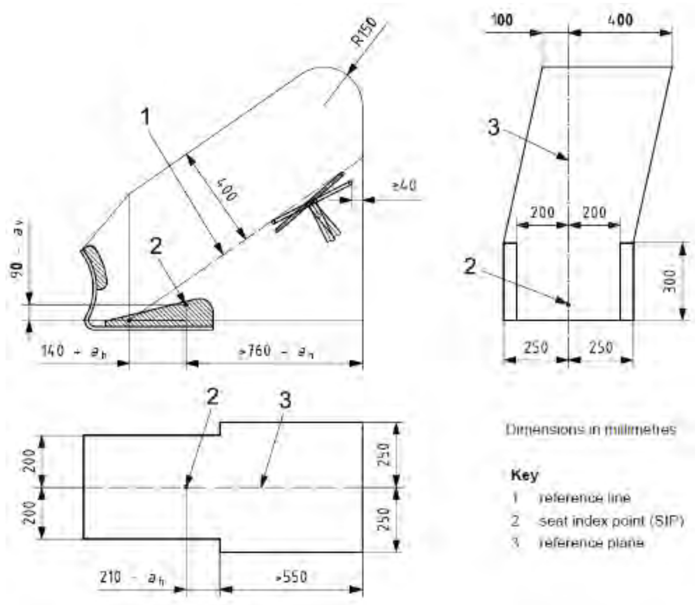

Figure 3. Reduced clearance zone according to the normalised testing procedures

Table 1. Sequence of codified tests

Sequence of strength tests	Dynamic procedure	Static procedure
Impact (Dynamic test) or loading (Static test) at the rear of the structure	$H = 25 + 0.07M \quad if\ M < 2000$ kg $H = 125 + 0.02M \quad if\ M > 2000$ kg	$E = 500 + 0.5M$
Crushing at the rear of the structure	$F = 20M$	
Impact (Dynamic test) or loading (Static test) at the front of the structure	$H = 25 + 0.07M \quad if\ M < 2000$ kg $H = 125 + 0.02M \quad if\ M > 2000$ kg	$E = 500 + 0.5M$
Impact (Dynamic test) or loading (Static test) at the side of the structure	$H = (25 + 0.2M)\left(\frac{B_6 + B}{2B}\right) \quad if\ M < 2000$ kg $H = (125 + 0.15M)\left(\frac{B_6 + B}{2B}\right) \quad if\ M > 2000$ kg	$E = 1.75M\left(\frac{B_6 + B}{2B}\right)$
Crushing at the front of the structure	$F = 20M$	

The tractor reference mass (*M*) is the mass, selected by the manufacturer to determine the energy and force to be reached during the strength tests. With respect to the dynamic test, M defines the fall height of the pendulum block (*H*); instead, in the static test it defines the energy that an actuator has to input to the structure (*E*). In both procedures, M defines also the value of the crushing force (*F*). The static procedure is satisfied when the required energy (*E*) is absorbed by the ROPS; while the impact dynamic procedure when the pendulum mass is pulled back so that the height of its center of gravity corresponds to the required height (*H*) and it is dropped to impact the ROPS. The preliminary lateral stability test has to verify the static stability of narrow-track tractors on a slope of 38 degrees. The non-continuous rolling test is intended to check whether a ROPS fitted to the tractor can satisfactorily prevent continuous rollover in the event of a lateral overturning on a slope with a gradient of 1 in 1.5

(34 degrees). The non-continuous rolling behaviour evaluation in Code 6 refers to a virtual method. Many theoretical and experimental studies were carried out in the seventies and eighties and the Mathematical Model able to simulate the behaviour of a wheeled tractor during a lateral overturning was developed (Schwanghart, 1984). This model takes into consideration specific critical boundary conditions and in 1990 was included into the OECD Code 6 (OECD Code 6, 1990). The replacement of tyres with tracks, however, introduces an additional parameter not considered in the original development of the model and affects the energy repartition at the ROPS-ground impact time, as studied by Chisholm (1979d).

The aim of the study was to analyse a narrow-track tractor fitted with front tyres and rear rubber-tracks in lateral stability test and non-continuous rolling behaviour calculation, as required by the standardised ROPS testing procedures.

Materials and methods

The behaviour of narrow-track tractors fitted with tyres (Figure 4, Tractor A) and rubber-tracks (Figure 4, Tractor B) was studied in terms of lateral stability and non-continuous rolling.

Tractor A

Tractor B

Figure 4. Tested tractors

The assessment refers to two narrow-track agricultural tractors fitted with a front foldable ROPS (Figure 4). The first tractor was fitted with tyres (Tractor A) and the second one with tyres on the front axle and rubber-tracks on the rear axle (Tractor B). The wheeled tractor was a tractor already on the market and typically tested according to the OECD Code 6. The Tractor B was a prototype derived from the wheeled tractor by substituting the rear tyres with rubber-tracks. The evaluation was carried out at the OECD Test Station of Bologna, Department of Agricultural and Food Sciences, University of Bologna. OECD Code 6 preliminary tests were carried out on both tractors.

Lateral stability test

The tractors were placed on a horizontal plane with the front tyres turned to full right lock and the heaviest axle tilted while measuring constantly the angle of inclination. The test was stopped at the unstable equilibrium time of the tractor. The test was repeated with the front tyres turned to full left lock. The requirement for lateral stability is the tractor resting in a condition of unstable equilibrium at an angle of inclination of at least 38 degrees on the wheels touching the ground. During the lateral stability test, the rubber-track behaviour was video recorded to analyse the track-ground interaction.

Non-continuous rolling test

Evidence of non-continuous rolling was carried out by calculation. 17 input parameters were measured for each tractor to be tested and inserted in the mathematical model. Figure 5 refers to a wheeled narrow-track tractor with a front ROPS, as it is considered in the mathematical model with the dimensions and positions of the geometric parameters. Tractor's inertia and CoG height were calculated from the period of oscillation when the tractor was secured on an oscillating platform for two different pivot heights, according to the parallel axis theorem (Casini-Ropa, 1976). The other parameters were directly measured on the tractor (Table 2).

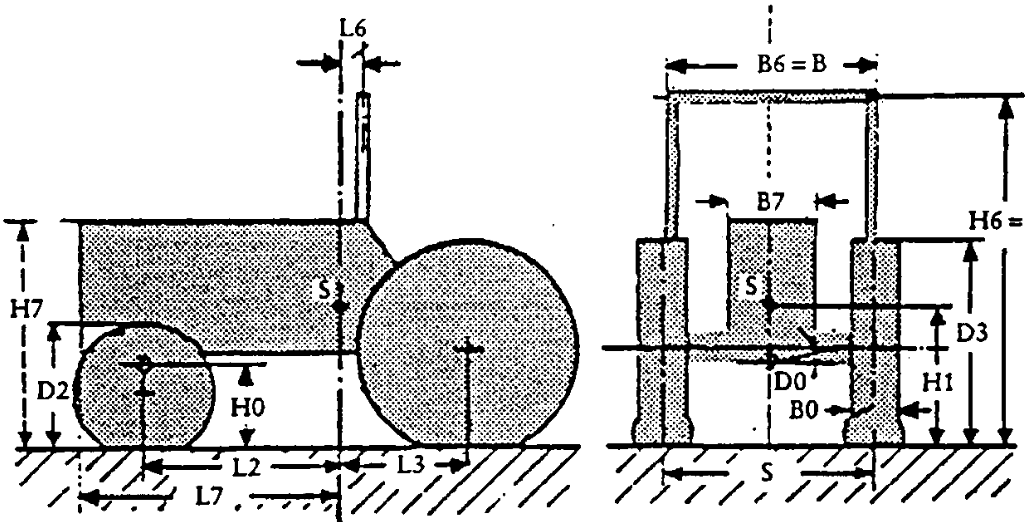

Figure 5. Narrow-track tractor data according to OECD Code 6

Table 2. The 17 characteristic tractor data

B0	Rear tyre width (m)
B6	Width of protective structure between the right and left points of impact (m)
B7	Width of engine bonnet (m)
D0	Front-axle swing angle from zero position to end of travel (rad)
D2	Height of front tyres under full axle load (m)
D3	Height of rear tyres under full axle load (m)
H0	Height of the front-axle pivot point (m)
H6	Height at the point of impact (m)
H7	Height of engine bonnet (m)
S	Rear track width (m)
L2	Horizontal distance between the centre of gravity and front axle (m)
L3	Horizontal distance between the centre of gravity and rear axle (m)
L6	Horizontal distance between the centre of gravity and the leading point of intersection of the protective structure (m)
L7	Horizontal distance between the centre of gravity and the front corner of the engine bonnet (m)
Mc	Tractor mass used for calculation (kg)
Q	Moment of inertia about the longitudinal axis through the centre of gravity (kg m^2)
H1	Height of centre of gravity (m)

Concerning the rubber tracks, among the 17 data of the non-continuous rolling behaviour model, *D3,* height of rear tyres under full axle load, and *B0,* rear tyre width, were defined taking into consideration the track design so as to produce the model output. The height and the width of the rear tyres were replaced by the height and the width of the rubber-track. The mathematical model calculated the unstable angle and the angular velocity during the rollover event. It was then verified if the tractor stopped the rolling by evaluating if the angular velocity decreased to zero when the protective structure touched the ground. The non-continuous rolling behaviour test defines some assumptions in order to simplify the determination of the tractor behaviour during the rollover. In the study the assumption referred to the unstable equilibrium time (Figure 6) was considered. The position of CoG and the mass of the tractor determining the level of potential energy (*PE*) stored in the tractor system were evaluated for both tractors.

$$PE = M_c\ g\ h$$

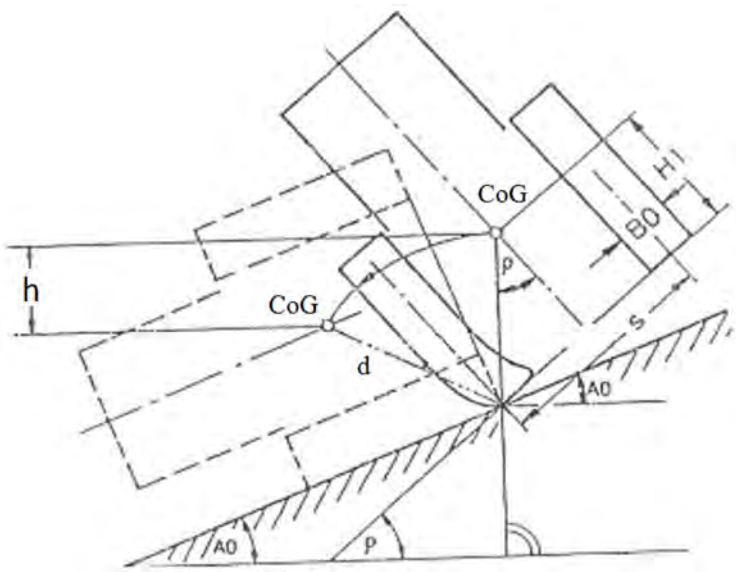

Figure 6. Tyre deflection at the unstable equilibrium time in Code 6 model

Results

Lateral stability test

The lateral stability test had positive results and the tractors were tilted until the state of unstable equilibrium (Figure 7). At the state of unstable equilibrium of the Tractor A, the rotation was around the mid-point of the tyre width because of the tyres deflection. The behaviour of the rubber-track at the state of unstable equilibrium under full load caused the rotation of the tractor around the outer edge of the track. This was mainly due to the non-deflected track under full load and the wider contact surface to the ground. The rubber-track increased the lateral stability angle with respect the tyre because the outer edge of the rubber-track was not subject to deflection. The tractor lost stability when the vertical projection of CoG overcame the rubber-track outer edge (Figure 8).

Figure 7. Tyre and rubber-track behaviour at the unstable equilibrium time

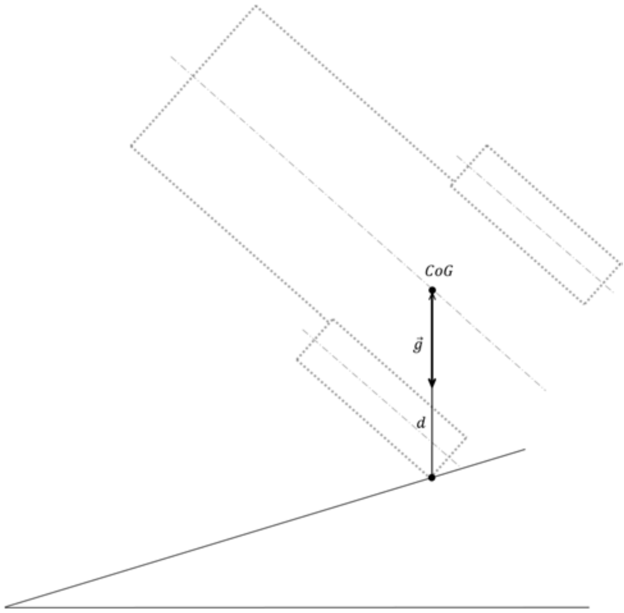

Figure 8. Unstable equilibrium time

<u>Non-continuous rolling test</u>
Non-continuous rolling behaviour was evaluated by calculation on the basis of the 17 characteristic tractor data measured. The measures carried out by the oscillating platform showed the modification of CoG position and moment of inertia about the longitudinal axis through the Centre of Gravity. The CoG of the Tractor B was located downward and rearward with respect to the equivalent Tractor A. The fitment of rubber-tracks replacing the rear tyres increased the tractor mass and the moment of inertia. At the unstable equilibrium time, it was verified the potential energy stored in the tractor system by means of the position of CoG and the mass of the tractor. The potential energy of the Tractor B was higher than that of the Tractor A. The non-continuous rolling behavior results were different for the examined tractors. In case of Tractor A, the calculation gave a positive result and the rolling stopped. On the contrary, Tractor B had a negative result and the rolling continued. The greater mass and the lower and rearward CoG position of the tractor B (fitted with rubber-tracks) increased the tractor angular velocity in the lateral rollover. Consequently, the angular velocity did not

decrease to zero during the lateral rollover calculation (Figure 9) and the non-continuous rolling behaviour was not assessed.

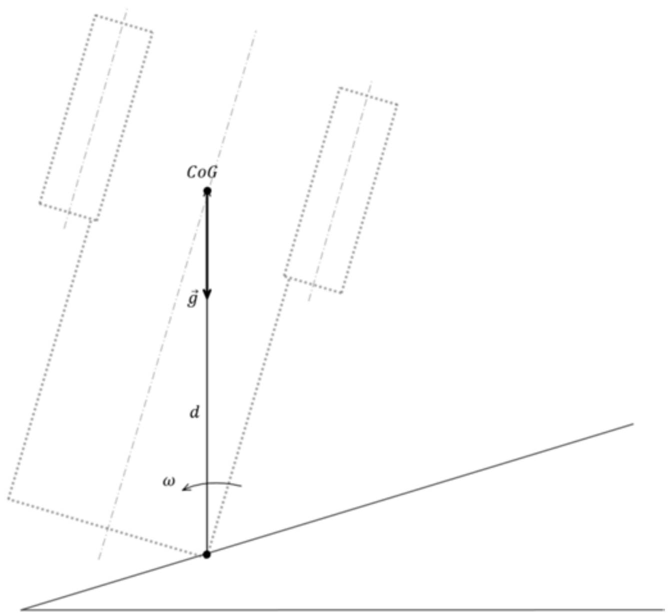

Figure 9. Continuous rolling behaviour

Conclusions

The focus of the study was on the tractor-ground impacts as affected by the introduction of rubber-tracks in replacing the tyres during tractor rollover. The experimental analysis and the observation of the tractor with rubber-tracks during the lateral rollover allowed to understand the differences between the two tractors tested in the phase of lateral rollover. The tractor mass and CoG position measured for the rubber-track tractor affected the stability and the dynamics behaviour in the preliminary test. The analysis of the rollover dynamics seems to confirm that the replacement of the wheels with tracks increases the behaviour to continuously rolling of the tractor. The preliminary test results showed that the non-continuous rolling calculation has to be updated. The rolling behaviour in case of tractor fitted with rubber-track did not correspond to the current assumptions of the Code 6 model for non-continuous rolling behaviour, mainly with respect to the tyre deflection and the tractor pivot point.

The narrow-track tractor fitted with rubber-tracks had a design really close to a wheeled tractor making the comparison between the two tractor types an acceptable approach. This means that potentially Code 6 provisions could cover the ROPS needs of rubber-track tractors. It would be advisable to update the existing mathematical model in order to have for wheeled and rubber-track tractors equivalent levels of safety in the event of tractor rollover.

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Experimental determination of operator perception of tractor instability

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Abstract
Tractor instability is a major cause of serious injuries and fatalities in the agricultural industry. Thus, preventing tractor rollover can have a vital impact in reducing injury risk and saving lives of operators. This study presents preliminary experimental results on the perception of tilt angles. Using a novel tractor driving simulator developed at Penn State, a testing protocol was implemented in order to evaluate the ability of subjects to remember poses at various roll-pitch combinations. Results suggest that roll and pitch are both systematically underestimated, the former more severely than the latter. They also show no statistically significant correlation between the effect of pitch angles on the perception of roll, but do provide an upper bound on typical perceptual errors. These pilot-test results will serve as the basis of a comprehensive study with a wider subject pool. The bigger goal in this effort is to develop rollover alert systems that can prevent these accidents from happening. In that regard, the data obtained from this experiment can be useful in the design and tuning of predictive rollover alerts that promote safe operation of farm tractors, using human perception errors of roll and pitch to guide the thresholds at which warnings should be initiated in each of these directions.

Keywords: Rollover Protective Structure, Tractor Stability, Risk Perception, Stability Research

Introduction
Occupational safety statistics have shown for decades that tractor rollover remains one of the leading causes of fatalities and serious injuries in the agricultural industry. Data from the US Department of Labor's Census of Fatal Occupational Injuries (CFOI) indicate that, out of the 2,320 work deaths that occurred between 2003 and 2007 in the production agriculture sector, nearly 900 of them involved tractors, 43% of which were overturn incidents. While these fatalities have shown a decreasing trend over the last 20 years, the decline is not uniform across all demographic and geographical groups, many of which retain high risk indicators (Myers 2009).

The introduction of Roll Over Protection Structure (ROPS) devices, via legislature or promotion and education programs, has sought to address rollover accidents but various characteristics of the agricultural sector can limit their impact across the industry (Pessina 2010). The fleet of tractors currently in operation is heterogeneous; machines over 20 years old remain popular, and changing technologies in newer models impose challenges on current safety standards (Jarén et al. 2009). Foldable ROPS systems offer favorable solutions for retrofit installation and flexibility, but human factors also interfere with their practical use: "the time, effort, and safety risks associated with operating foldable ROPS limits their effectiveness" (Ayers et al. 2012). In this context, there's a justifiable need to prevent rollover incidents from happening, as a complimentary measure to the use of ROPS (Murphy et al. 2010).

While training and education programs have succeeded, another avenue is to provide in-vehicle technological assistance to operators. As an example, in the automobile industry Electronic Stability Control has been shown to reduce the odds of a single-vehicle crash by 30% in general, and by 49% for sport utility vehicles in particular (Green 2006).

Similarly, intelligent vehicle systems can be brought into the agricultural sector for added safety and accident prevention. Tractor operators determine safe operational limits based on past experience, which is nearly always comprised of situations that did not involve rollover. Thus, warning systems can be used to indicate imminent rollover, but these may be ignored if the driver's perception of the situation does not agree with sensor data.

In this regard, (Nichol et al. 2005) developed a compact, low-cost sensor unit, which employs a microcomputer and a simplified mathematical model to inform the operator of potentially hazardous driving conditions through an LCD display. Furthermore (Tillapaugh et al. 2010) showed that adding a visual slope indicator in the tractor cabin could help operators improve their accuracy in ranking the risk of simulated driving conditions. This experiment was conducted on a tractor simulator with a single degree-of-freedom motion base, setting a precedent for the work presented here.

The goal of this study is to evaluate a tractor operator's nescient perception of vehicle stability, and whether confounding factors such as pitch-roll coupling affect this perception. This paper in particular examines the operator's "memory" of pose, whether this memory is affected by pitch and roll, and how to use this information in the design of rollover alert systems.

The remainder of this paper is organized as follows: first, the Materials and Methods section describes the driving simulator that was used and the test protocol. The Results section summarizes the regression analysis on the data, analysis of regression error, and analysis of absolute error. The primary findings of this work are then summarized in a Conclusions section.

Materials and Methods

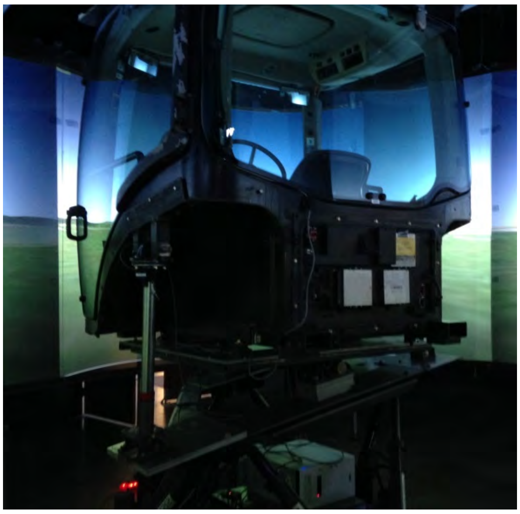
Tractor Driving Simulator

This study utilizes a novel tractor simulator shown in Figure 1 wherein a tractor cab is mounted on top of a custom-modified motion base that enables +/- 28 degrees of roll motion and +/- 18 degrees of pitch motion. The motion base is comprised of two parts. First, a commercial off-the-shelf industrial parallel robot manufactured by Moog, with 6 degrees-of-freedom for full 3D motion, which provides up to +/- 18º of pitch and roll for a 2,000 lb. payload. Additionally, an inverted slider-crank (IS-C) mechanism (detailed on the right in Figure 1) was designed and installed between the Moog robot and the tractor cabin, providing an additional 10º of roll in each direction, relative to the Moog's motion base position.

The simulator also includes an 8 ft. tall, 360º surround screen with 12 High-Definition projectors for an immersive simulation environment. The whole system (Moog robot, IS-C mechanism, projectors and cabin sensors) is operated through a cluster of 9 Linux-based computers, networked with the Robot Operating System (ROS) and running the Gazebo simulation software, which are both open source.

Prior to conducting any tests, the motion system was calibrated to verify the precision of its tilting motion. Total roll angles were measured using a digital slope-meter, with resolution of 0.01% slope (equivalent to 0.06º) (Figure 1, right image). This was used to calibrate both the commands that are sent to the Moog robot, as well as the custom-built roll-tilt mechanism.

The mechanism employs a linear actuator instrumented with a string potentiometer to control the cabin's roll angle relative to the Moog, as well as an encoder with 40,000 counts-per-revolution installed on the shaft around which the cab rotates. Both give precise relative control of the cab's motion, and additionally allow control if there is an intermittent power failure in the system. During subject testing, the positioning errors of the custom motion base were recorded and found to be negligible: 0.07º +/- 0.28º (95% confidence).



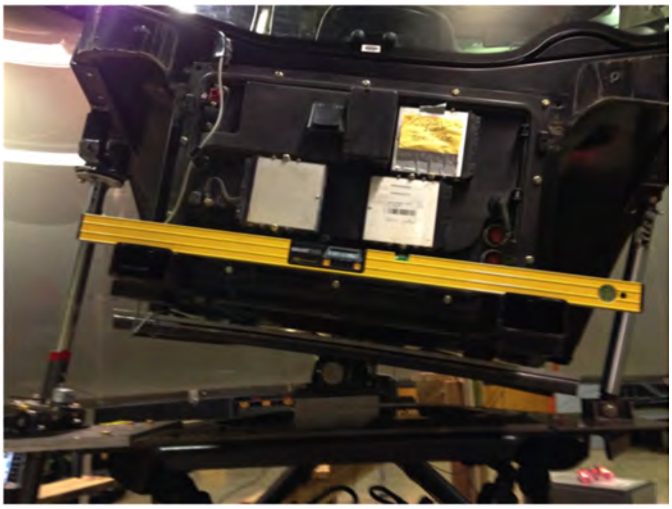


Figure 1. On the left, the tractor driving simulator; on the right, the IS-C mechanism fully extended for 10º of additional roll relative to the Moog robot.

<u>*Test Protocol*</u>
Once the system was calibrated, operators were tested on their ability to remember various roll-pitch combinations. The test protocol consisted of the following steps:

1. The test subject boards the simulator and the system is initialized.
2. The motion base moves the cabin to a set roll-pitch combination, and remains stationary for 5 seconds, after which it returns to level.
3. The subject is then instructed to operate the motion base (using a videogame controller) until they reach what they believe is the same angle at which the motion base paused earlier.
4. Once the subject is satisfied with their position, a data point is recorded, registering the original roll-pitch angles and the subject's perceived roll-pitch.
5. The platform is returned to level, and steps 2-4 are repeated for the 28 tilt angles across a randomized pattern.

The set of tilt angles is shown in Figure 2. The reader may note that the set is not symmetric; two angles on the top left corner are missing. They were removed from the sequence because the Moog motion base can be overloaded in force when tilting the cabin to these large angles. This happens because the mass of the cabin in this severe roll-pitch combination is close to the maximum payload, and additional motion past this point has the potential of overloading the motion base's actuators.

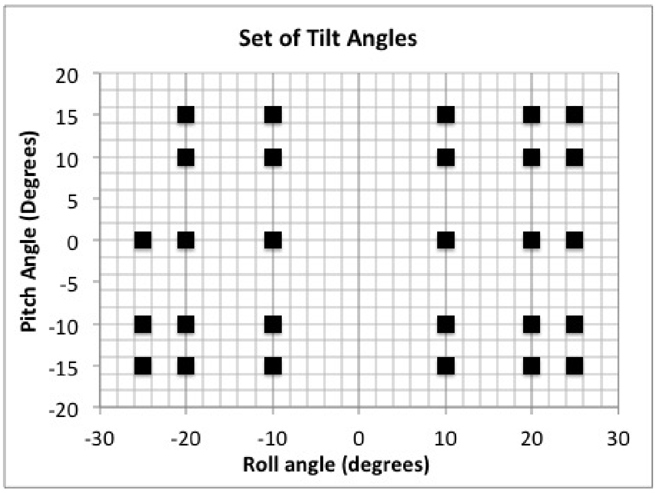


Figure 2. Subjects were exposed to 28 tilt angles of various roll-pitch combinations.

The sequence was presented in randomized order, so that every subject goes through the same angles, but in a different order. This was done to prevent skewing the results with fatigue during the test, as measurement of all angles for a test subject takes around 50 minutes to complete.

During the test, a fixed image with a virtual rural scene is projected on the screen. The subjects are instructed to look at the screen during the whole procedure. The intention here is twofold: first, observance of the horizon line is considered an important visual cue for tilt estimation in the open field; second, in order have the subjects refrain from using external visual cues –ones which would be unavailable in the natural driving environment, such as the top/bottom edges of the screen, or the screen structure– to aid in their tilt estimation task.

Preliminary testing was done with pilot test subjects in order to evaluate the system's performance and polish the software that controls the experimental protocol. During this process, full and consistent data was collected for four subjects, and its results and analysis are presented in the following section. Testing is ongoing at present using an identical protocol but with a deeper subject pool including up to 60 tractor operators, of varying degrees of experience, age and other demographic factors. These results will appear in a follow-up publication.

Results

The graphs in Figure 3 plot the pilot-testing subject pool's perceived tilt angles versus the angles they were exposed to. The figure on the left does so for roll, and the one on the right for pitch. The graphs show three types of information: first, the individual data points for all subjects (28 per subject); second, a linear regression of these points (in thick blue line) with its corresponding equation; and third, the ideal result for the regression if the subjects were to have perfect tilt angle estimation i.e., slope equal to one, and intercept equal to zero.

The first notable result is that the roll angle is systematically underestimated, having a slope of 0.88 with 95% confidence interval (0.85, 0.92), compared to the ideal value of 1.00. Meanwhile, the intercept is 0.23º –with 95% confidence interval (-0.85º, 0.40º), meaning that the estimation can be assumed to be unbiased:

$$roll_{perceived} = 0.88 \cdot roll_{actual} + 0.23°. \quad (1)$$

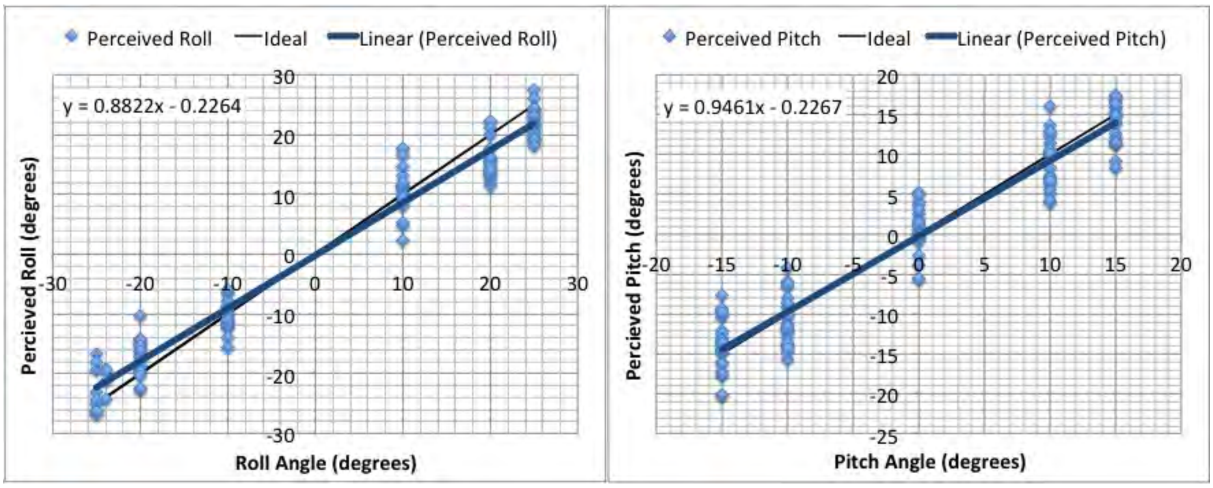


Figure 3. Tilt perception plots show that roll and pitch are systematically underestimated and unbiased. Roll on the left; pitch on the right.

Similarly, pitch is also underestimated, with slope of 0.95 with 95% confidence interval of (0.89, 1.00), and can be considered to be unbiased, with intercept of -0.23º with 95% confidence interval (-0.81º, 0.35º):

$$pitch_{perceived} = 0.95 \cdot pitch_{actual} + 0.23°. \quad (2)$$

Interestingly, roll perception has a bigger issue with underestimation than pitch, meaning that roll perception errors have a dominant effect over pitch perception errors, and thus would pose a larger threat during risky driving tasks at high tilt angles.

While these two regression models had good fit (R^2 values of 0.962 for roll and 0.923 for pitch), other regressions that were attempted showed poor goodness of fit values, which can be indicative of the independence of certain variables in the experiment. For example: from current results, pitch angle does not appear to have an appreciable influence on roll estimation. For the model

$$roll_{perceived} = m_p \cdot pitch_{actual} + b_p, \quad (3)$$

the regression results in a slope of 0.1503 (-0.1314, 0.432) which can be considered statistically insignificant, as it contains zero well within its 95% confidence interval, as well as a negligible goodness of fit metric: $R^2 = 0.010$. For further confirmation, a two-factor model on roll estimation,

$$roll_{perceived} = m_1 \cdot roll_{actual} + m_2 \cdot pitch_{actual} + b_t, \quad (4)$$

produced a good fit ($R^2 = 0.962$), with slope $m_1 = 0.88$ (0.85, 0.92) which is statistically significant and consistent with the regression model from Figure 3, while a slope $m_2 = 0.004$ (-0.05, 0.06) which, like the earlier pitch-only regression model, is not statistically significant. Similar results were obtained for the influence of roll angle on pitch estimation. The current data set does not show a significant effect of pitch affecting the subject's roll perception, or vice versa.

Average Errors
Another issue that was examined was the possible influence of tilt angle magnitudes on the subjects' estimation errors. Figure 4 shows the mean estimation error, with corresponding 2-σ error bars (for 95% confidence), at different roll and pitch magnitudes.

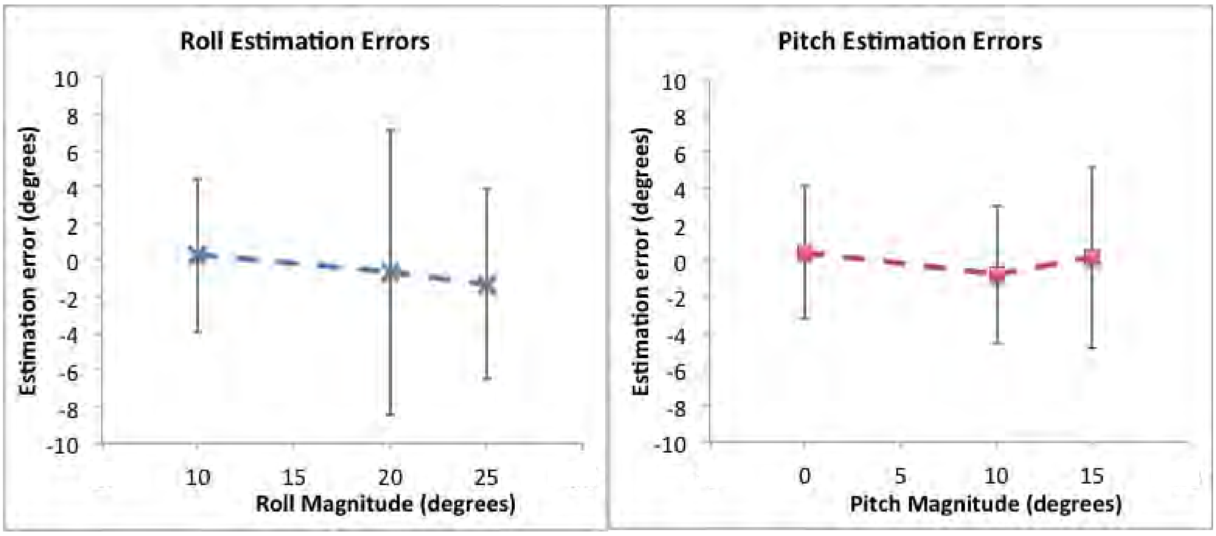


Figure 4. Estimation errors are not strongly influenced by angle magnitude. Roll is shown on the left; pitch on the right.

The mean of the roll estimation errors show a slight tendency to slope downwards as roll magnitude increases. However, the averages for all three cases are below 1.4º in magnitude, while the confidence intervals range between +/- 4.2º and +/- 7.8º. In that regard, any apparent pattern cannot be considered statistically significant. A larger sample would be required to draw a conclusion on this relationship, and tests on larger subject pools are ongoing. In similar fashion, the mean pitch errors have slightly smaller variability compared to roll (ranging between +/- 5.1º and +/- 6.9º) but again show small magnitudes (below 1.4º) and no statistically significant impact from pitch magnitude.

What these plots do show, however, is that errors for both roll and pitch are centered close to zero, meaning there's no clear bias towards positive or negative estimation errors. The two-variable relationships (roll error vs. pitch magnitude, and pitch error vs. roll magnitude) were also not statistically significant, and are thus are omitted for brevity.

Absolute Errors
One final indicator that was analyzed was the absolute value of the estimation errors, or the distance-to-truth. This is a measure of how far off the subject's perception is from the true tilt angle, irrespective of whether they incurred in over-estimation or under-estimation. Figure 5 shows the average distance-to-truth for different angle magnitudes.

As was the case for the error averages, the distance-to-mean metric does not show a clear pattern or influence from tilt angle magnitude. However, it does reveal three key trends:

- Pitch estimation has lower mean absolute errors than roll (below 2.7º vs. up to 4.0º in roll), and can thus be said to have higher estimation accuracy. Test subjects can apparently perceive pitch with more accuracy than roll.
- The variability of distance-to-truth for pitch does increase with pitch magnitude, as seen from the error bars. At zero pitch the 95% confidence interval is very small

+/- 0.6º, and it increases at 10º to +/- 1.6º, and further increases at 15º to +/- 2.13 º. Thus, test subjects appear to become worse at perceiving pitch with larger pitch angles.

- For the pitch and roll angles of interest in this study – namely those that are near the rollover or skidding threshold of an agricultural tractor, absolute roll errors of up to 4º-5º would be expected to be commonplace; for pitch, absolute errors up to 3º-4º would be widely expected.

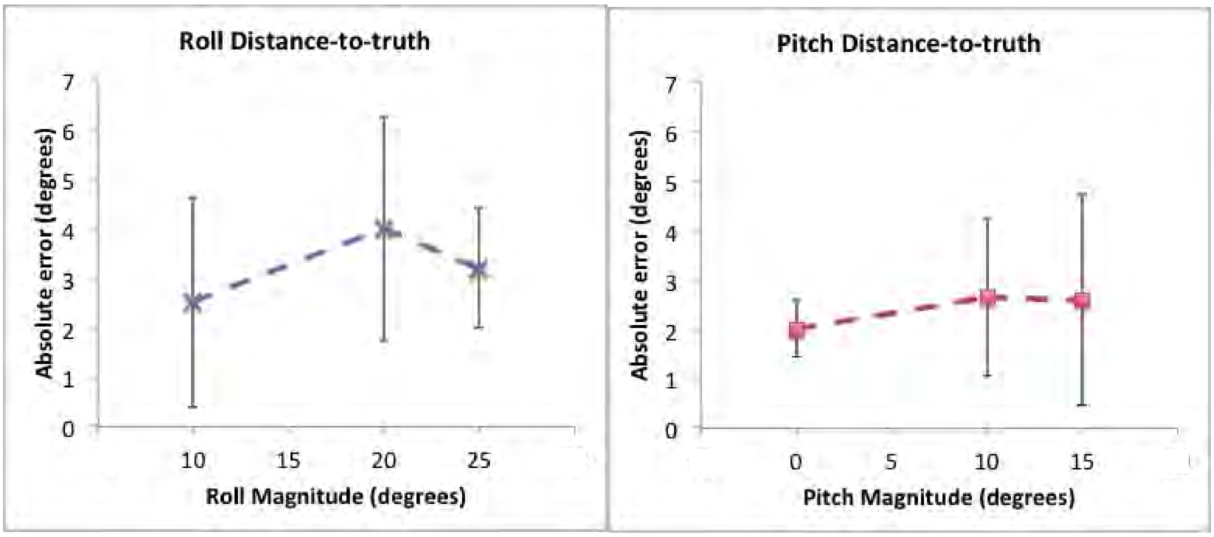


Figure 5. Distance-to-truth averages show the magnitude of typical perception errors.

This last observation can be a useful indicator in tuning a rollover alert system, knowing that a tractor operator driving on a 20º roll slope can commonly perceive this to be in the 15º-16º roll range, therefore underestimating the risk of a rollover accident. Any warning system for roll should therefore give a severe warning within 4 degrees of a tractor's actual rollover threshold.

Conclusions

This study on a pilot-test pool provides insights that are useful for tractor warning systems. In particular, subjects systematically underestimated roll, but produced unbiased errors. Pitch was also systematically underestimated, but to a lesser degree, and was also unbiased.

The current data set showed no two-variable relationships between roll estimation and pitch angle, nor one for pitch estimation and roll angle. While the expectation was that combined roll-pitch angles would prove to be more difficult to estimate correctly, the results suggest that roll and pitch estimation operate independently in terms of human perception.

Estimation errors for both roll and pitch are centered close to zero, further evidence of the absence of bias, and do not exhibit a relevant relationship with tilt angle magnitudes.

In similar fashion the mean absolute errors, or distance-to-truth, showed no influence from tilt angle magnitude, but do provide upper bounds on typical roll and pitch estimation errors. Such bounds can be useful in determining the threshold for a rollover alert system, as they offer a statistically-supported worst-case scenario for roll underestimation, which can lead to dangerous tractor operation on steep hills.

These conclusions based on this preliminary data set have provided guidance on testing with a wider subject pool (close to 60 subjects), which will include experienced and novice tractor operators of different ages. Additionally, these results are useful to develop prototype tractor rollover and pitch-based warning systems to be tested with that same test pool.

Acknowledgements
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Narrow-track agricultural tractors: a survey on the load of hand-operated foldable roll-bar

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Abstract
To protect the operator in case of overturning, the narrow-track tractors (used in vineyards and orchards) can be equipped with a ROPS consisting of a 2-pillars front mounted foldable roll-bar.
The handling of this type of ROPS, in particular the transition from the horizontal (rest) to the vertical (protection) positions, is generally operated through two removable pins managed manually by the driver of the tractor. Apart the time necessary to perform some times a day this operations sequence, a moderate/medium physical load should be also required, given that often these roll-bars have a mass of some tens of kilograms.
The reality is indeed quite different, since neglect and a poor attention to safety lead to the condition in which the foldable roll-bar remains continuously in the rest condition and is no longer moved back in the vertical (protection) position. Several roll-over accidents were fatal for the operator because the tractor, although equipped with a 2-pillars front mounted ROPS, at the time of the event had the roll-bar in the horizontal (rest) position, so assuring no protection to the driver.
This issue is quite serious. To remove at least one of the problems for the proper managing of this type of ROPS, the OECD have recently updated its Code 6, by introducing an optional test dealing with the manual handling of the front mounted roll-bar, providing a maximum load of 100 N.
Several tests on new roll-bars were carried out to ascertain the respect of this limit. The 100 N value is generally exceeded, so showing its criticism. Indeed, a more appropriate reference for the manual handling should be in this case higher load values (up to 250 N) already provided by several Standards for non-continuous tasks.

Keywords: Tractor Overturning, Front Mounted ROPS, Raising Force

Introduction

Since the '50s of the last century, the most frequent type of accident occurring with agricultural tractors is the overturning. The relevant injuries can be prevented with some success by fitting Roll Over Protective Structures (ROPS), combined with the fastening of a driver's seat belt. In many countries, authorities have imposed this type of protection on tractors for many years (*Springfeldt, 1996*). The Scandinavian countries were the first group of countries to issue mandatory regulations and obtain encouraging results: in Sweden, the frequency of fatal rollovers per 100 000 tractors per year decreased from 17 to 0.3. In Norway, the frequency of fatal rollovers decreased from 24 to 4 from 1961–1969 to 1979–1986 periods. In Finland, the frequency of fatal rollovers decreased from 16 to 9 from 1980 to 1987. Moreover, from 1961 to 1986 the frequency of fatal rollovers in West Germany decreased from 6.7 to 1.3.

A widely recognized criterion considers the amplitude to classify the tractor roll-over, in particular if the tractor at the end of its overturn has rolled no more than 90° or was subjected to continuous rolling. In any case, many of the accidents occurring during agricultural activities are not officially recorded for many reasons. A comparative study of 388 fatal accidents related to agricultural machinery occurred in Spain from 2005-2010 concluded that only 61.9% of the deaths were regularly reported. In any case, based on 272 reported fatal overturning accidents, the main cause of death was the lack of a ROPS on the tractor; only one accident involved a tractor that was equipped with a homologated ROPS (*Arana et al., 2010*).

In Italy, the fitting of a ROPS on new conventional tractors has been compulsory since 1974. In the following decades, this requirement has been gradually extended to other tractor categories. In particular, the so called "narrow-track" tractors (frequently used in vineyards and orchards) must be equipped with a ROPS since mid '80s of the last century. The strength of the ROPS is verified using a series of loading tests, which are specified in dedicated standards issued by international organisations (EU, OECD, ISO and SAE) (*OECD Standard Codes , 2014*).

Starting from an official figure of 200 fatalities in the early 1970s, INAIL currently reports that an average of 25-30 deaths per year are caused by the overturning of agricultural tractors. Surveys from different sources reveal a considerably higher number of fatalities (*Pessina and Facchinetti, 2011*).

This large discrepancy is attributed to the notion that the compensation for injuries (fatal or nonfatal) is typically related to the so called "professionals". However, in agriculture, the operation of tractors on a secondary basis by an extensive variety of non-professional workers is common.

The official mode of the recording, classification and management of these events produces dynamics that do not facilitate prompt and updated monitoring on a national scale. The consensus is that a real situation is different and the consideration of alternate solutions may enable a real overview of these situations.

The Web has recently changed with regards to the approaches used to communicate information. Many international, national, and local portals were established to systematically report news that has relevant significance (*blogspot "Caduti sul lavoro"*). Thus, a fatal accident at work, such as a tractor overturning with one (or more) victim(s) will not go unnoticed even if is not mentioned by the press at a national level, as it will be reported on local web portals (of regions, municipalities, local TV, newspapers and news sites) and on numerous blogs.

Since 2008 fatalities due to agricultural tractor overturning were systematically recorded by examining many web portals of news and information. The maximum detail level was extracted from each portal and subsequently used to construct a truthful, effective and timely scenario of the situation. Indeed, the adopted method has some limitations: the obtained values do not completely reflect the real situation and the details of the reported events are not completely congruent and may be subjected to the inaccuracies of the press. Notwithstanding these problems, the survey highlighted that in approximately 55% of these cases the tractors were not equipped with ROPS (fig. 1). In 30% of the cases, the type of ROPS fitted was the 2-post front-mounted foldable roll-bar. Considering only the overturning accidents that involved tractors equipped with a 2-post front mounted foldable roll-bar, the roll-bar was determined to be in a horizontal position, which assures no protection, prior to the fatal event in 80% of the cases.

This finding represents a quite critical condition that requires urgent countermeasures.

On narrow track tractors, the roll-bar is foldable to allow travelling inside of the vineyards and orchards rows without damaging the branches for the possible entrapment with the pillars and/or entering of the tractor into low height garage doorways.

In all the other working tasks, the roll-bar must be maintained in a vertical (protection) position.

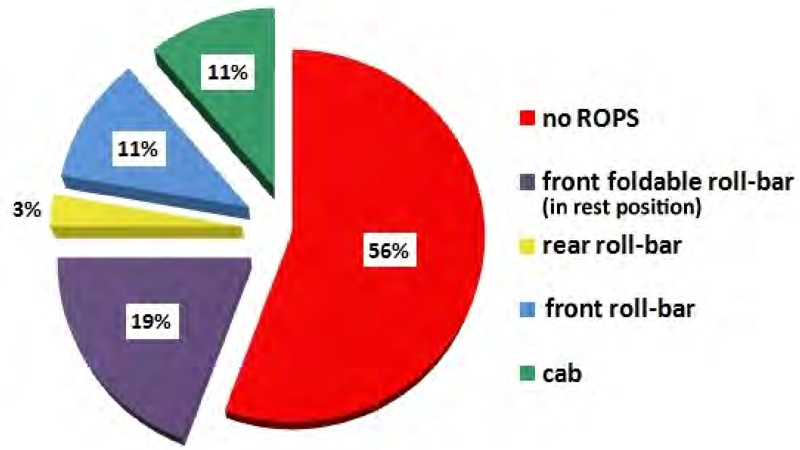

Figure 1. Type of ROPS fitted on agricultural tractors involved in fatal overturning accidents occurred in Italy in the period 2008-2014.

The transition between the horizontal (rest) to the vertical (protection) positions (and viceversa), is generally operated through two removable pins managed manually by the driver of the tractor. Apart the time necessary to perform some times a day this operations sequence, a moderate/medium physical load should be also required, given that often these roll-bars have a mass of some tens of kilograms.

Thus, several of the reported roll-over accidents involving tractors equipped with a 2-post front-mounted foldable rollbar were fatal for the operator because the tractor at the time of the event had the roll-bar in the horizontal (rest) position, so assuring no protection to the driver. The main complaint facing this problem is the excessive manual load to be exerted to manage the roll-bar.

The present survey is devoted to ascertain the real handling loads of the front foldable roll-bars, to be compared to the values provided by the relevant general standards and a new measure recently introduced in the OECD Code 6, dealing with the strength test of the front foldable ROPS to be fitted on the narrow-track tractors.

Materials and method

The roll-bar handling loads were ascertained on new narrow-track tractors, at different inclination angle values, when raising the ROPS. The recently introduced new optional test into the OECD Code 6 provides the clear and indelible identification of a so called "grasping area", defined by the manufacturer on the roll-bar pillar(s) and designed to handle manually the roll-bar by a standing operator (fig. 2).

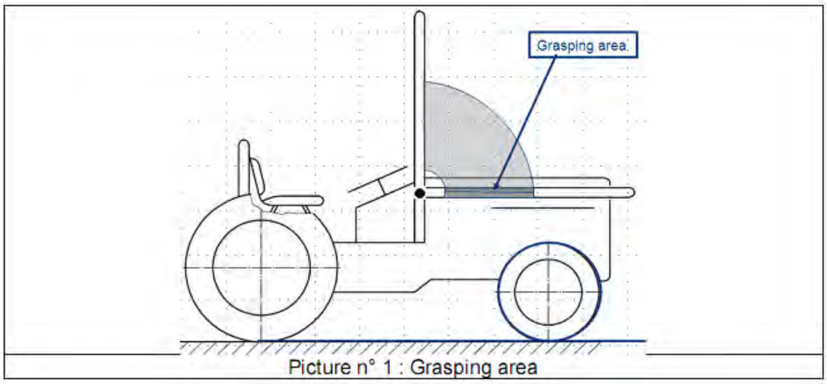

Figure 2. Detail of the so called "grasping area", a zone designed to handle manually a 2-pillars foldable front mounted roll-bar by a standing operator.

Three accessible zones with different amounts of allowed force are defined with respect to horizontal plane of the ground and the vertical planes tangent to the outer parts of the tractor that limit the position or the displacement of the operator, as follows (fig. 3).

- zone I : comfort zone;
- zone II : accessible zone without forward leaning of the body;
- zone III : accessible zone with forward leaning of the body;

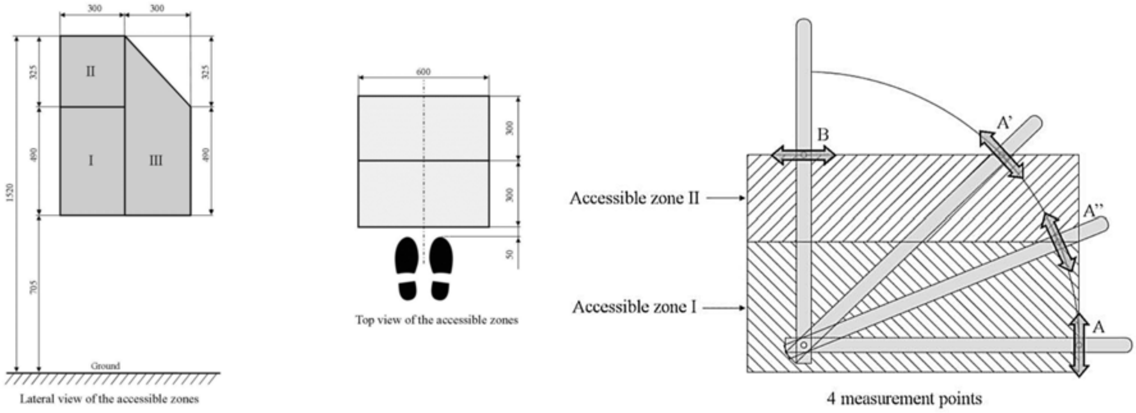

Figure 3. Dimensions of the 3 accessible zones for the handling of the foldable front roll-bar (left) and sketch of the procedure to be followed for measuring the forces for the foldable front roll-bar handling (right).

Each force measurement necessary to raise or lower the roll-bar shall be made in a direction tangent to the trajectory of the roll-bar and passing through the geometric centre of cross sections of the grasping area, in a static condition. It is provided that the force shall be measured in different points that are within the accessible part of the grasping area.

The first measure is carried out at the extremity of the accessible part of the grasping area when the roll-bar is fully lowered (point A). The second is defined according to the position of point A after rotation of the roll-bar up to the top of the accessible part of the grasping area (point A'). If in the second measure the roll-bar is not fully raised, an additional point shall be measured at the extremity of the accessible part of the grasping area when the roll-bar is fully raised (point B). Moreover, if between the first two measures the trajectory of the first point crosses the limit between zone I and zone II a measurement shall be made at this crossing point (point A"). In order to measure the force in the required points, it is possible either to measure directly the value or to measure the torque needed to raise or lower the roll-bar so as to calculate the force. The force acceptable for the actuation of the ROPS depends on the accessible zone, as shown in tab. 1.

Table 1. Maximum actuation force values provided by OECD Code 6, depending on the accessible different zones.

Zone	I	II	III
Acceptable force (N)	100	75	50

Starting from the described procedure, some tests preliminarly carried out ascertained that, as expected, very often the operators start to raise the roll-bar lying in the horizontal position grasping it at its absolute top, and not at the top of the defined grasping area (i.e. at 1520 mm from the ground). For this reason, the static raising force values were measured at the top of the foldable part of the roll-bar, when lying in the rest (approx. horizontal) position and for 8 of the 17 tractors investigated, in other 5 significant conditions (always in a perpendicular direction to the tangent of the trajectory), i.e. at angles of 0°, 30°, 45°, 60° and 90° in respect to the horizontal plane, always at a distance of 1520 mm from the ground when the roll-bar is in the vertical (protection) position (fig. 4).

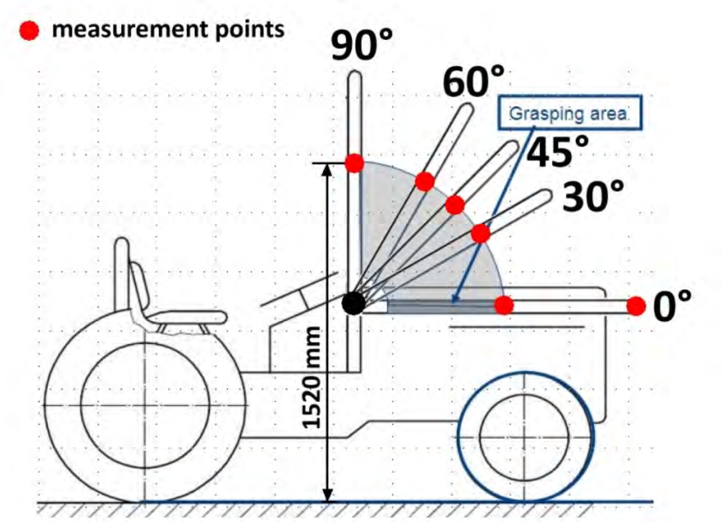

Figure 4. Measurement point locations and angles of inclination of the roll-bar at which the raising force was measured.

17 new narrow-track agricultural tractors were examined; they all were equipped with a 2 front-post foldable roll-bar, having a mass of the foldable part varying from 8 to 34 kg. Inside of the machines group investigated, traditional wheeled (10), articulated wheeled (6) and tracked (1) models were included.

To measure the force values, an integrated load cell with a digital display was used, make Macmesin model AFG 500 N, having a full scale of 500 N (plus an overload capacity of 50%) and a reading sensitivity of 0.01 N, while the inclination was measured thanks to a digital inclinometer make Lucas model Anglestar, with a minimum reading sensitivity of 0.1° (fig. 5).

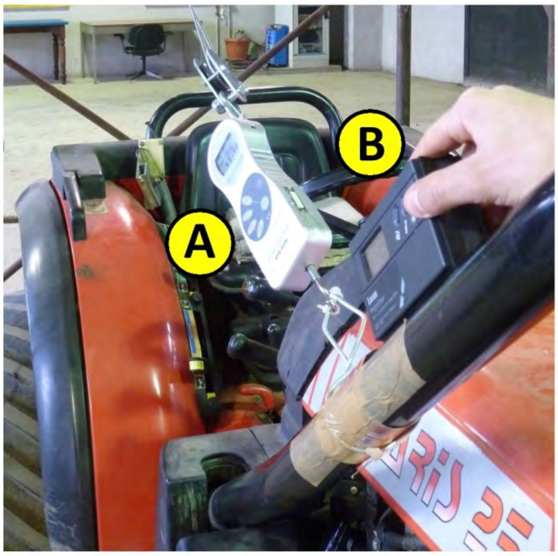

Figure 5. Execution of a static raising force measurement. A - integrated load cell with digital display; B - digital inclinometer.

Moreover, apart the recently introduced new optional test into the OECD Code 6, also the ISO 11228-1:2003 standard "Ergonomics – Manual handling – Part 1: Lifting and carrying" (*ISO, 2003*) was considered. This Standard takes into account the intensity, the frequency and the duration of the manual lifting and carrying of the loads.

For the lifting condition (appearing the most similar to be applied for the roll-bar raising) in the Annex C of the ISO 11228-1 is considered a limit of 25 kgf (approx 250 N) for a non repetitive task (frequency less than 1 time/minute), for adult working population and professional use. If these parameters seems to be correctly applicable to the action considered in this case, it is stated that the amount of population protected is 85% as an average (95% of the males and 70% of the females). Moreover, taking into account that the operators working in agriculture (and above all those driving and managing agricultural machinery) are for the 99% males, it should be concluded that the figure of 250 N may be appropriated to be considered a suitable limit. For this reason, both the limits (100 N, OECD Code 6; 250 N, ISO 11228-1) were compared to the obtained results.

Results and discussion

For all the 17 tractors examined, in fig. 6 the raising force values recorded at the top and at a height of 1520 mm from the ground are shown, when the roll-bar was in the rest (horizontal) position, i.e. at a conventional 0° angle. Indeed, in some cases the rest position was varying up to 8-10° above or below the horizontal line, due to different design solutions, devoted to minimize the view obstruction of the roll- bar to the driver, of course taking into account the bonnet contour. This parameter could have affected the initial raising force value, but in any case a good simulation level was assured in measuring the real operator's load.

All the force values obtained exceeded the 100 N limit, apart those of the roll-bar fitted on tractor no. 16 and that of tractor no. 1, being in this last case equipped with a couple of gas springs. In other words, *in 88% of the examined cases the limit was overcame*. On the contrary, considering the data obtained at the top of the roll-bar, the limit was exceeded only in 11 of the 17 cases (65%), but in many other tests the recorded value was a little bit higher than 100 N. Comparing the data to the limit of 250 N provided by the ISO 11228-1 standard, the force was exceeded only in 8 of the 17 tests (47%) at a height of 1520 mm from the ground, while all the values at the top of the roll-bars were lower.

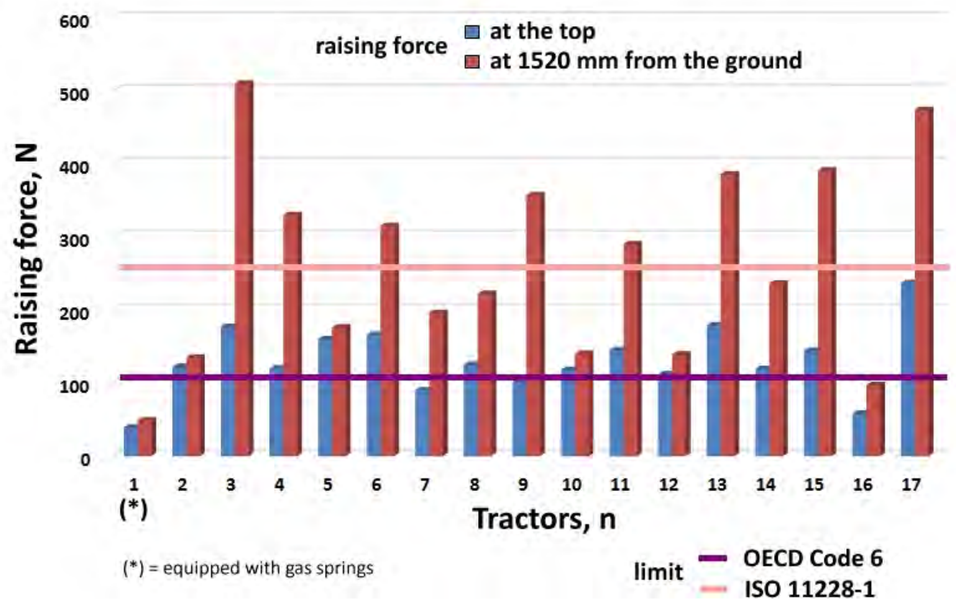

Figure 6. Raising force values of the investigated roll-bars at conventional 0° angle, at the top of the ROPS and at a height of 1520 mm from the ground, as provided in OECD Code 6 optional test.

This is a first evidence on how the limit taken into account may affect remarkably the need to improve the roll-bar handling (i.e. by fitting an aiding device).

Considering the typical handling of the roll-bar taken into account, i.e. its rotation for an overall angle of approx. 90° referred to a hinging point, a strong link from the roll-bar mass and the raising force should be found. Unexpectedly, the relevant results show a poor correlation between the two parameters (fig. 7).

Indeed, the raising force is affected not only by the roll-bar mass (and of course by the height of the foldable part), but also by the friction of the pins on which the foldable part of the roll-bar is rotating.

Sometime, the friction force reaches a remarkable figure, due to the limited tolerance between the diameters of the pins and that of the holes in which they are fitted. In fig. 8 the raising force trends for inclination angles from conventional 0° to 90° for 8 of the 17 tractors examined are shown.

Notwithstanding the force values quite different, as expected the maximum raising force was recorded at the horizontal position, apart one case, where at 30° a remarkable value was recorded, due probably to a high pin friction. Moreover, in many cases till to 30° of the roll-bar inclination (starting from the horizontal) the force tends to remain high, decreasing more or less suddenly for angle values over than 30°.

The opposite trend was recorded when gas springs are fitted, probably due to the typical behavior of these aiding devices. In any case, the gas springs allow to decrease remarkably the raising forces over all the roll-bar excursion.

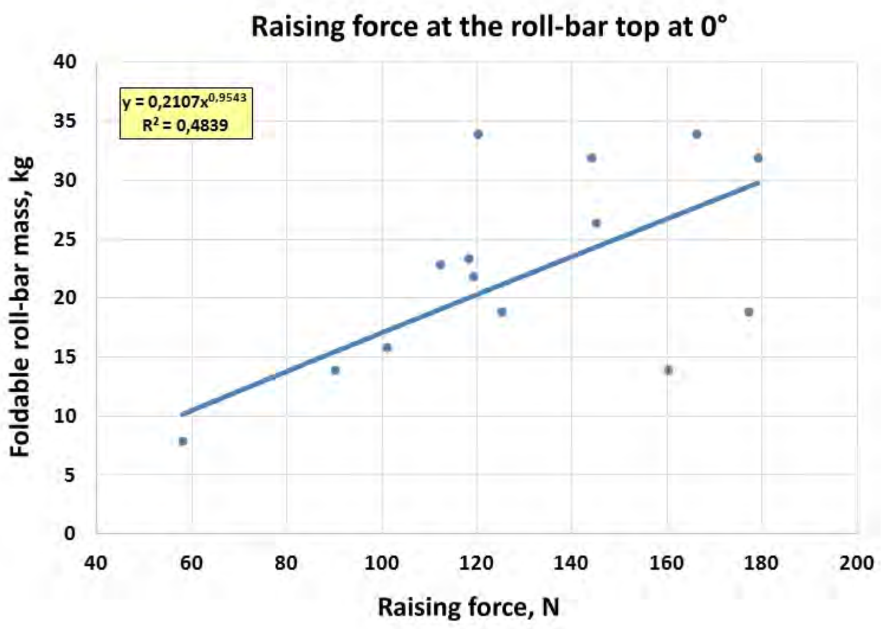

Figure 7. Comparison between the roll-bar mass values and the correspondent raising forces recorded at the top of the roll-bar.

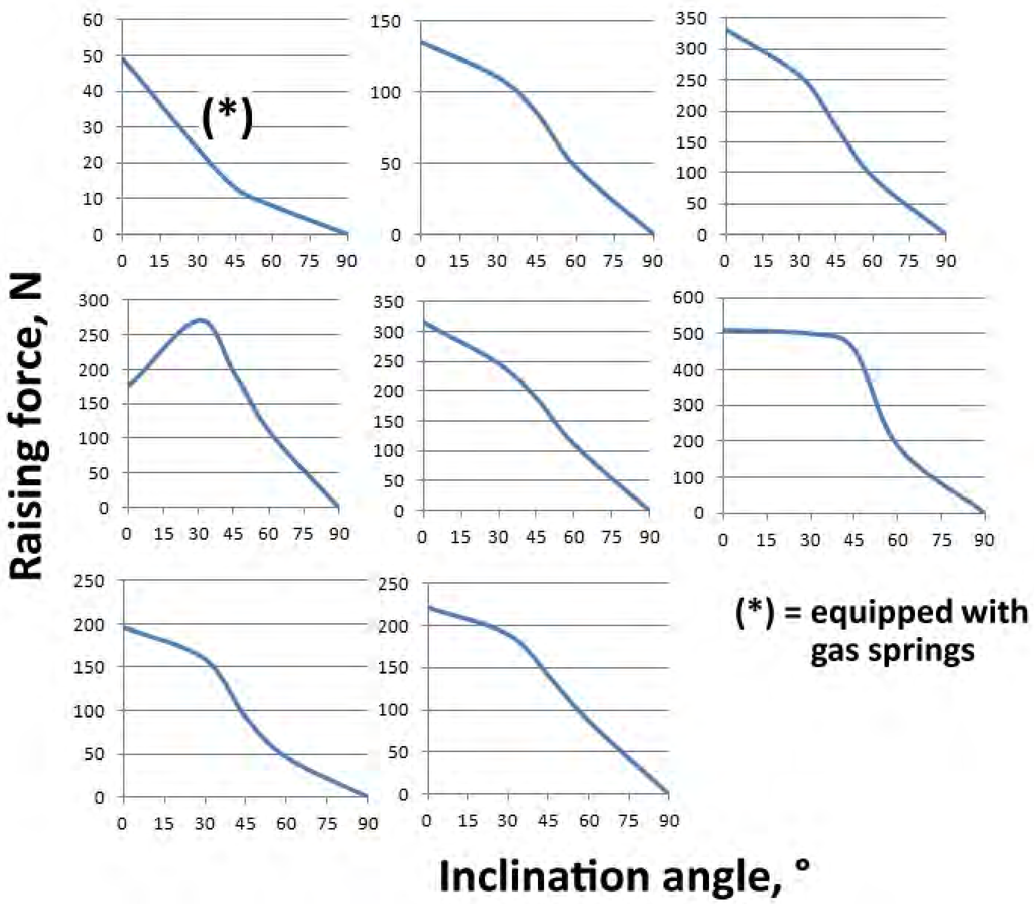

Figure 8. Raising force trends for inclination angles from conventional 0° to 90°, for 8 of the 17 tractors examined.

Conclusions

In Authors' opinion, the force limit of 250 N seems to be more appropriate in respect to 100 N value; in fact, it is a figure established in an ISO International Standard, diffused at a worldwide level, for non-continuous tasks of workers (like the roll-bar handling is) and statistically validated for a quite high percentile (95%) of male operators, thus representing well the manpower employed in agriculture. Although the data obtained in this survey are not completely exhaustive, the relevant trend is sufficiently clear, i.e. the 100 N limit is exceeded on practically all the roll-bars. As a consequence it should be respected only by fitting an aiding device (gas springs or hydraulic cylinder(s)). Viceversa, the 250 N limit appears fully justified under the ergonomic point of view and allows the handling of several roll-bars without any supplementary mechanism. On the other hand, some roll-bars show a very remarkable weight and are exceeding also the higher limit, so that an aiding device should be necessarily provided. Again, in the Authors' opinion, this could be a quite well-balanced approach to the problem, finalized to reduce effectively the handling load to be developed by the narrow-track tractor driver, but at the same time able to avoid difficulties in adapting many roll-bars to an unjustified low force limit. The next step (already made by some manufacturers) is to avoid at all the manual handling of the roll-bar, by introducing different levels of automation. Firstly, one (or two) raising hydraulic cylinder(s) could be fitted and operated manually, by means of a leverage or a button; a further level could be represented by the fully automation of the roll-bar position depending on the dangerous conditions occurring (i.e. lack of lateral and/or longitudinal stability). In any case, the safety belt should be fitted and above all should be correctly fastened; in fact, if the operator is not safely fixed to the seat, it is quite probable that, especially in case of lateral overturning, he/she is thrown out and is fatally hit by the ROPS, the device that on the contrary should have assured a proper protection.

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Design Considerations in fixture development to Retrofit ROPS on Agricultural Tractors

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Abstract

Tractor population has reached about 5 million in India. Though being the largest tractor market, rollover kind of accidents have not got attention so far. Recent tractors are being equipped with safety devices such as SMVE, NSS and safety guards on moving parts. Stability sensors are also being thought-off to inform overturning situation. In fact, ROPS retrofitting is one of the best engineering controls for passive safety of rollover accidents through ROPS is not compulsory accessories of tractors. Therefore, operators' safety is at stack. Regulations coupled with design variation of various tractor models are hindering the use of market/common ROPS for retrofitting on tractors. Therefore, investigation has been planned to develop a fixture to retrofit ROPS to insure operators' safety.

To develop mounting fixture, medium range horse power tractors has been targeted. Two way approaches have been adapted to design fixture. First, in view of design of structural mount point and second, ROPS cross sectional view point. Structural mounting location is nothing but axle housing of various tractor models. These all have been clustered based on geometrical similarity of axle housing followed by strength predication of selected pre-ROPS axle housing. Alike to axle housings design parameter of ROPS were also considered.

It was found that most of the axle housing were circular in shape so as structural mount point. The critical diameter and thickness were varying about 90-250 mm and 14-18 mm respectively. Developed fixture could accommodate maximum of 70 mm × 90 mm prismatic cross section and up to 90 mm diameter of circular. Fixture was found capable of satisfying requirements of IS: 11821(Part 2) identical to OECD test code. Proper implementation of fixture along with regulation expected to reduce fatalities of tractor operator.

Keywords: ROPS Retrofitting, Axle housing, Design.