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Tractor rollover fatalities, analyzing accident scenario

Valda Rondelli, * Camilla Casazza, Roberta Martelli

Department of Agricultural and Food Sciences, University of Bologna, Italy

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ROPS
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A B S T R A C T

Introduction: In many countries, traditional data sources for collecting injuries of workers covered by compulsory accident insurance have recently been integrated by new observatories whose results may differ. A comparative analysis of the Italian data collection systems related to fatal tractor accidents in agriculture was performed focusing on tractor rollover fatalities with the aim of analyzing the accident scenario. *Method:* Data from the Operational Archives of the Italian Workers Compensation Authority (INAIL), which collects injuries of workers covered by compulsory accident insurance and those of the National Surveillance System (INAIL_ASL), which provides narrative text reports of work-related fatal accidents have been analyzed and compared to the information collected by the INAIL Observatory. The INAL Observatory was recently set up to complement the collection of fatal accidents involving agricultural machinery. Italian data were then compared to data available at an international level. Fatal tractor accidents vary considerably with respect to fatal accidents in agriculture, being 10.6 and 43.7% for the Operational Archives and Surveillance System, respectively. National Surveillance System records, implemented with narrative texts allowed the accident scenario to be defined. *Results:* 71.7% of fatal tractor-related accidents refer to non-ROPS equipped vehicles and of these, 26.5% involved machines originally mounted with a ROPS that had been removed or was inoperative in the folded-down position during the rollover event. Just one fatal event from a collapsed ROPS on the overturned tractor was recorded. It is interesting that 16.6% of fatal accidents involved a clear environmental factor. *Practical application:* A campaign to train tractor drivers on the correct use of the combination ROPS and seatbelt can contribute to decreasing rollover events with fatal outcomes. Contemporarily a strict requirement to install ROPS and a seatbelt on tractors, combined to an official inspection at the farm level, can increase the chance of survival in a rollover accident.

1. Introduction

Tractors are considered the leading cause of agricultural work-related fatalities in many industrialized countries (Day, Rechnitzer, & Lough, 2004; Myers, 2010; Reynolds & Groves, 2000; Sanderson et al., 2006) and rollovers frequently account for more than 50% of tractor deaths (Jawa et al., 2013; Marshall, Clarke, Langley, & Cryer, 1996; Myers et al., 1998; Springfeldt, 1996; Springfeldt, Thorson, & Lee, 1998). Indeed tractors are particularly subject to rollover because of their high center of gravity, exposure to considerable external loads, large torque outputs, sloping or uneven ground (Guzzomi, Rondelli, Guarnieri, Molari, & Molari, 2009).

Over the years, research studies on tractor rollover have been well-documented (Arndt, 1971; Myers, 2000; Springfeldt et al., 1998; Tinc, Ayers, May, Purschwitz, & Sorensen, 2015). After the pioneer work of using safety education to preventing tractor rollover, the innovative tractor design approach in the 1950s was the mounting of a passive Rollover Protective Structure (ROPS), to provide the driver with a clearance zone during a rollover accident (Fig. 1). The ROPS solution has since been adopted worldwide and ROPS testing procedures have been issued (Harald & Moberg, 1973). The effectiveness of ROPS in preventing rollover fatalities has been widely demonstrated (Springfeldt, 1996; Reynolds & Groves, 2000) and since 1974 official rules have made ROPS compulsory for the type-approval of wheeled agricultural and forestry tractors in Europe (European Commission, EC Directive 1974/150).

A clear safety complement to ROPS in injury prevention during a tractor rollover event was demonstrated to be the fitment of a driver restraint system, such as a seatbelt (Reynolds & Groves, 2000; Myers & Pana-Cryan, 2000; Molari & Rondelli, 2007). In Europe, it has been compulsory to fit new tractors with seatbelts since 2005 (European Commission, EC Directive 1974/150, EC Directive 2005/67); while the requirement for the in use tractors in Italy has been in force since 2008 (Legislative Decree 81/2008). Nonetheless, even if the introduction of ROPS and driver seatbelts is now well consolidated all around the world, fatalities associated with farm tractors continue to be a serious occupational hazard (Reynolds & Groves, 2000; Bunn, Slavova, & Hall, 2008; Mayrhofer, Quendler, & Boxberger, 2014).

* Corresponding author at: Department of Agricultural and Food Sciences, University of Bologna, Viale Fanin, 50, 40127 Bologna, Italy.
E-mail address: valda.rondelli@unibo.it (V. Rondelli).

Fig. 1. Tractor ROPSs; (a) four post frame, (b) cab, (c) rear two post, (d) front foldable two post.

An analysis of the circumstances leading to tractor accidents could help in defining appropriate measures to prevent injuries and fatalities, and would provide information on the incidence of rollover and effectiveness of the ROPS protection. A statistical evaluation of tractor accident data is essential to develop prevention policies in agriculture. In many European countries, the reporting systems for work-related accidents insufficiently describe circumstances and causes of accidents, due mainly to the delay in acquiring information and lack of specific details. As a consequence, comparing data from different countries is rather difficult and often inappropriate because of the different approach in accident survey methods. In 1990, to harmonize countries data, the European Statistics on Accidents at Work (ESAW) was launched. However, tractor rollover accidents are not clearly specified in the ESAW approach; similarly, the additional circumstances that help in understanding the details of the accident, such as the presence of safety systems as ROPS and seatbelts, are not specified. To obtain more information on accident scenarios, Kogler, Quendler, and Boxberger (2015) suggested adopting the narrative text analysis approach as an accident reporting system.

In many countries, workers compensation archives include all types of injuries in agriculture if related to workers covered by compulsory accident insurance, but exclude the many self-employed workers, unpaid family members, or retirees who frequently work on farms. To overcome this limitation, national surveillance systems have been organized in many countries, together with report systems, based on information obtained from farm surveys, collection of news clippings, hospital and clinic-based surveillance, medical reports, or death certificate data (O'Connor, Gordon, & Barnett, 1993; Gross, Peek-Asa, Ramirez, & Gerr, 2012; Rissanen & Taattola, 2003). A modern approach for accident information is from news clippings by searching in national and local newspapers (Ozegovic & Voaklander, 2011; Pessina & Facchinetti, 2017).

In the current analysis, Italian agriculture has been considered an interesting case study for tractor accidents due to the widespread use of tractors, the presence of many hilly lands, and the large number of arable crops, orchards, and vineyards. Injury data are traditionally provided by the Operational Archives of the Italian Workers Compensation Authority (INAIL), which collect injury reports of workers covered by compulsory accident insurance. They also include less severe injuries, so these records represent the wider source of non-fatal accident data. However, in June 1993, with Italian law 243/1993, self-employed people were excluded from compulsory insurance. Thereafter, INAIL considered only professional workers and there was a sharp decline of recorded data in the historical series. Indeed, between 1992 and 1994, a 40% reduction of injuries was recorded in agriculture together with 53% fewer fatalities (INAIL, historical statistics). INAIL injury coding was then aligned to the ESAW approach. Nonetheless, given the variables describing causes and circumstances of accidents, obtaining detailed information about accident scenarios is rather difficult.

In 2002, an additional accident recording system was issued in Italy: the INAIL_ASL Surveillance System for fatal and severe work-related injuries. The database is managed by INAIL in cooperation with the Local Health Authorities (ASL), involving regions and autonomous provinces, with the coordination of the Ministry of Health. In archiving the accidents, a backward reconstruction process used in legal procedures is adopted. Factors leading to the accident and those influencing its severity are identified. Short narrative text reports describing fatalities and some severe injuries are available online by consulting the Infor.MO web tool. Even so, the main reconstructive descriptors of the accident are sometimes lacking (Lombardi & Rossi, 2013).

An INAIL Observatory project to add data and information on fatalities in agriculture covering workers, even those not INAIL insured, was then instituted in 2008. The Observatory collects accident data associated with the use of agricultural machinery; operational archives, INAIL_ASL Surveillance System, newspapers and websites are the information sources. Data from online newspapers and websites can reveal injuries not detected by the traditional data reporting systems; however, technical safety details are often omitted in news articles and, moreover, the correctness of the information is not always ascertainable.

The aim of the analysis in this article was to compare the tractor-related fatalities data provided by the three official Italian reporting systems. This was done to characterize the rollover accidents scenario by assessing the fitment on the tractor of the mandatory safety systems (ROPS and driver seatbelts) and their correct use, the age of the victims, and the contribution of environmental risk factors. The Italian data were then compared with data available at an international level.

2. Materials and methods

Data of INAIL Operational Archives were provided by the statistical service of INAIL (personal communication) and include 213 fatalities in agriculture from 2002 to 2014. The Infor.MO web tool of the INAIL_ASL Surveillance System was the second database analyzed for data on fatal and severe work-related injuries. The website provides short narrative text data for each recorded accident. Eight hundred and seventeen fatalities were reported in agriculture from 2002 to 2012. These reports were analyzed to define the tractor rollover accident scenario. To identify the main cause of tractor-related accidents, a text search method based on specific keywords (tractor, rollover, overturn, ROPS, vehicle) was adopted. Fatalities due to tractor rollovers were identified. The second step was studying additional elements influencing the accident severity and its dynamics to identify the presence of ROPS and seatbelts, and specifying if these were mounted on the tractor at the time of the accident, had been removed or were in the folded-down position (Fig. 2).

However, given that the ROPS fitment was not always clearly stated, in the current analysis the not specified ROPS rollover events were identified as "undefined." Therefore, a separate group of rollover accidents related to the accident narrative texts lacking information regarding the ROPS was considered. Concerning the driver restraint system as a complement of the ROPS safety provision, most of the narrative reports were absolutely vague on the fitment of a seatbelt system on the tractor. Taking into consideration that, unfortunately, the requirement of the seatbelt anchorage on the tractor is quite recent with respect to the time period evaluated in the analysis, to show clear safety evidence it was considered advisable to check if the driver was restrained by the seatbelt.

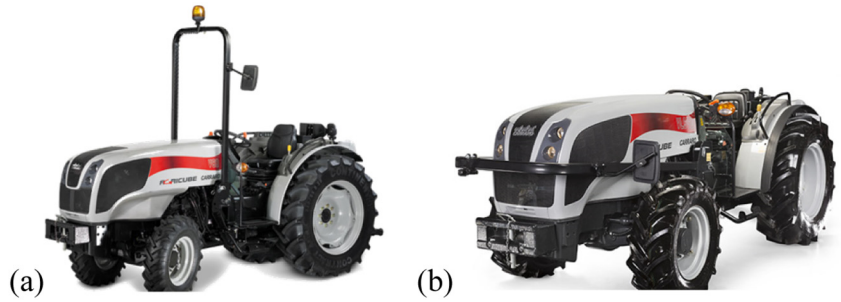

Fig. 2. Tractor fitted with a front foldable two post ROPS: (a) upright position of the ROPS providing for driver clearance zone, (b) inoperative ROPS in the folded-down position.

Since driver age is considered an important risk factor (Arana et al., 2010; Gross et al., 2012; O'Connor et al., 1993) tractor rollover fatalities were also divided between tractor drivers over 65 years old and those under 65 based on the driver age recorded by Surveillance System.

Lastly, environmental factors considered as relevant to the accident and reported by the Surveillance System were evaluated to better analyze the accident scenario. Main environmental factors in the database were: slippery soil (even for heavy rain or ice), steep embankment, steep slope, collapsed embankment, and deep ditches covered by thick vegetation.

The third accident database evaluated in the comparison was the INAIL Observatory from the period 2009–2014. Data were obtained by personal communications and official publications (INAIL, 2014, 2015) and were analyzed to distinguish tractor-related fatalities. However, the records did not allow details to be added on the definition of accident scenario.

3. Results

3.1. Tractor-related fatalities overview

INAIL Operational Archives for the period 2002–2014 reported 2007 fatalities in agriculture (on average, 154 per year), 213 were tractor-related (10.6%, 16 per year); however rollover events were not identifiable.

According to the data of the INAIL_ASL Surveillance System, in 2002–2012 there were 817 fatalities in agriculture (on average 74 per year) with 357 tractor-related (32 per year) and 205 tractor rollover fatalities (18 per year). Therefore, in this database tractor-related fatalities were 43.7% of total fatalities in agriculture, while rollover fatalities were 57.4% of tractor-related fatalities.

According to the INAIL Observatory, tractor-related fatalities for the period 2009–2014 were 766 (on average 128 per year), with 594 rollover fatalities (99 per year) representing 77.5% of tractor-related fatalities. Clearly the time considered for the three reporting systems differed. Nonetheless, a comparison of the yearly average of fatal injuries as recorded by the three reporting systems in the same observation time period (2009–2012) is shown in Fig. 3. There is an obvious difference in the data. The Surveillance System recorded a much lower number of fatalities in agriculture with respect to the Operational Archives (74 and 171, respectively). A possible explanation could be that the Operational Archives are compulsory and the notification of the accident is to obtain the insurance payment for the insured worker while the Surveillance System is based on data collected at regional level and the database could be affected by local procedures in providing accident details.

Considering the tractor effect on fatalities, according to the Surveillance System 43.7% of fatalities in agriculture were tractor-related (2002–2012), while the Operational Archives recorded only 10.6% (2002–2014). The Observatory gave many more tractor-related fatalities than the other two data sources; moreover, 43% of the victims were over 65 years old, a category of workers neglected by the Operational Archives statistics. The crucial contribution of news clippings for a more reliable evaluation of tractor fatalities is thus evident.

Data analyzed showed how the actual number of accidents in the different reporting systems is clearly influenced by the database origin. Without case matching, it could be totally inappropriate to mix data from different sources to overcome the incompleteness of each data set. Nevertheless, a thorough analysis of the different systems could allow information from the various databases to be used as a stand-alone source. The Operational Archives approach could be suitable for comparing injuries and fatalities of professional workers to obtain indexes representing farm workers, whereas poor information is provided on accident dynamics and the vehicle involved. The Surveillance System would be appropriate for investigating the causes and aggravating factors of fatalities because the short narrative text recording the accident scenario allows the circumstances of the event to be defined, which may allow appropriate measures to prevent accidents and/or their severity to be identified. Indeed the added value of the database approach is related to the ASL staff inspecting the accidents, who are properly trained to draft the accident text reports detailing the surrounding conditions, aggravating factors, and incorrect behavior. However, a clear limitation in the INAIL_ASL Surveillance System is the fewer accidents recorded with respect to the INAIL Operational Archives. To improve the efficiency of the system, a higher number of assigned operators would be advisable. The INAIL Observatory system appears to be the most effective data source due to its ability to collect the largest number of tractor fatalities, but the approach adopted made it difficult to compare their data with the other sources and did not allow the event and surrounding conditions to be described in detail.

3.2. Accident scenario evaluation

Analysis of the narrative text recorded for tractor rollovers by the INAIL_ASL Surveillance System allowed the dynamics of the accident

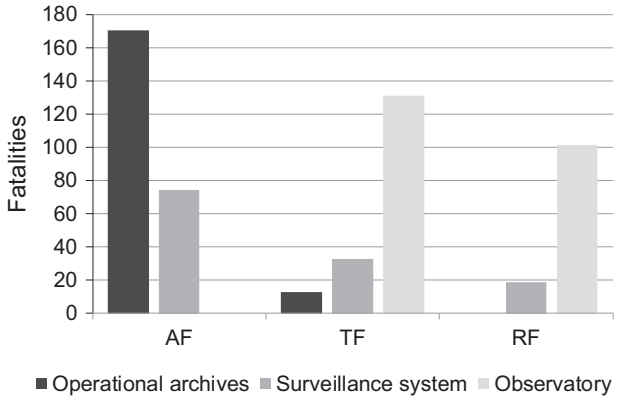

Fig. 3. Work-related fatalities in agriculture, yearly average (2009–2012), in the three Italian reporting systems. Total fatalities in agriculture (AF), tractor-related fatalities (TF), tractor rollover fatalities (RF).

Table 1
Fatalities in Italian agriculture between 2002 and 2012, source Infor.MO web tool.

Fatalities	Frequency	%
Tractor rollover	205	25.1
Fall from height	124	15.2
Hit by falling object	88	10.8
Change in the vehicle direction (rollover excluded)	79	9.7
Contact with objects, equipment or vehicles in motion	78	9.5
Accidental starting of the vehicle	63	7.7
Contact with moving parts	69	8.4
Projections of solids	21	2.6
Direct electrical contact	19	2.3
Other fatalities	71	8.7
Total	817	100

to be characterized, even though it should be noted that the information in the short reports was not homogeneous. Indeed, reports with a very detailed description of the accident scenario were available and narrative texts with very few details on the accident circumstances also existed.

Table 1 shows the main causes of fatalities in agriculture recorded for the period 2002–2012. Two hundred and five tractor rollovers fatalities were recorded. An evaluation of the accident text reports was done concerning the safety systems mounted on the tractors at the time of the accident.

Concerning the driver seatbelts, few narrative texts highlighted the fitment of the seatbelt anchorage on the driver seat. Very few reports did note that the driver was not restrained during the rollover event but there were no reports that referred to the driver being restrained at the time of the accident. Consequently, it was assumed that in the 205 rollover fatalities, the drivers were not fastened in during the event, and therefore the information on seatbelt was not included in tables and figures. This approach was also supported by the fact that it is estimated that only 23% of the 1.5 million tractors in use in Italy are mounted with a driver restraint system (Italian Senato Resolution, 2015).

ROPS fitment on the tractors involved in fatal rollover accidents with respect to the activity performed, for example, in field operations or in transport on farm or public roads, for workers under and over 65 years old is depicted in Table 2. The results showed that ROPS fitment is a discriminant factor on the outcome of the overturning: 71.7% ($n = 147$) of the fatal accidents were related to tractors without ROPS, 18% ($n = 37$) to ROPS equipped tractors and 10.2% ($n = 21$) to the not-specified category. Nevertheless, by assuming this category as part of the ROPS equipped tractors the percentage would increase to 28.2% of fatalities.

Analyzing data for both driver age and ROPS fitment, 42.4% of fatal accidents involved workers over 65, and these were driving tractors without ROPS in 78.2% of the rollover events. Only 12.6% of the accidents pertained to ROPS equipped tractors (Fig. 4). The percentage of over 65 driving non-ROPS equipped tractors (78.2%) was, as expected, higher than the percentage of other workers (66.9%).

52.2% of fatalities occurred in normal field operations while 42.9% referred to the tractor in operation or while being driven on the farm or on a public road. The ROPS fitment in field and road accidents were substantially equivalent, 71.9% of tractors were non-ROPS equipped in field operations with respect to the 71.6% on the road

The fatalities attributed to no ROPS tractors ($n = 147$) were evaluated to verify if the tractors were manufactured without ROPS or if the ROPS was originally installed but had been removed or was in the folded-down position (Fig. 2) at the time of the accident, as frequently observed when narrow track tractors are used in the field (Khorsandi, Ayers, Jackson, & Wilkerson, 2016). The data were recorded according to the activity performed for both worker groups (Table 3).

73.5% of fatalities involved tractors without a ROPS protection originally installed by the manufacturer, 21.8% of fatalities were related to tractors with foldable ROPS with the ROPS in the folded-down position (equivalent to no ROPS protection for the driver), and lastly, 4.8% of fatal accidents concerned tractors with foldable ROPS but the ROPS had been removed at the time of the event (Fig. 5)

Considering the fatalities related to worker age, the percentage of tractors without ROPS involved in fatal rollovers was 25.2% higher for the over 65 age group (82.4 and 65.8% for the over and under 65 years old workers, respectively). Taking into consideration the tractors equipped with foldable ROPS in the folded-down position at the time of rollover, the percentage of fatalities for drivers under 65 years old is almost double that involving drivers over 65 (27.8% and 14.7%, respectively).

Considering activities, for the tractor in field operations the fatalities involving no ROPS tractors were 66.2% while they were 82.5% for the tractor in operation or while being driven on the farm or on a public road. The ROPS was in the folded-down position in 28.6% of field events and in 12.7% of those on the road. This is consistent with the fact that when working in the field, the upright position of the ROPS could affect performing the operation correctly; that is why narrow track tractors are mounted with front foldable, two post ROPS allowing a folded-down position when the space for the tractor is restricted by the crop, as in orchard or vineyard inter-rows. Nevertheless, the fatalities recorded during road operation clearly do not involve this need and denote an incorrect use of the tractor.

Analyzing the fatal rollovers to ROPS equipped tractors ($n = 37$), for which an acceptable level of protection for the driver could be expected, the fatal outcome was due to the lack of retention of the driver inside the clearance zone. It was clearly stated in the narrative report that the driver was thrown out of the driver seat and/or repeatedly bumped into the ROPS frame. More precisely, 37.8% of deaths ($n = 14$) were because the driver was crushed by the tractor on impact with the ground, while in 24.3% ($n = 9$) of the cases, the driver hit the ROPS. One fatal event (2.7%) was because the driver drowned while trapped inside the ROPS cab, and in one case (2.7%) the driver was crushed in the collapsed ROPS cab. In the remaining rollover events, 32.4% ($n = 12$), the accident narrative texts did not detail the cause of the fatalities. The literature suggest a collapsed ROPS is very rare in agricultural operations (Reynolds & Groves, 2000; Pessina & Facchinetti, 2017) and our analysis supports this.

Tractor rollover fatalities where environmental factors clearly contributed to the accident were 16.6% of the recorded accidents ($n = 34$). The most frequent causes of overturning were due to the presence

Table 2
Fatal tractor rollovers with respect to ROPS fitment, tractor activity and driver age (205 accidents, from 2002 to 2012).

	Total			Over 65 years			Under 65 years		
	In field	In transfer	Undefined	In field	In transfer	Undefined	In field	In transfer	Undefined
ROPS	21	15	1	5	6	0	16	9	1
No ROPS	77	63	7	34	29	5	43	34	2
Undefined	9	10	2	4	4	0	5	6	2
Total	107	88	10	43	39	5	64	49	5

ROPS, fatalities involving tractors with ROPS; No ROPS, fatalities involving tractors without ROPS; Undefined, fatalities involving tractors for which the ROPS fitment was not defined in the records.

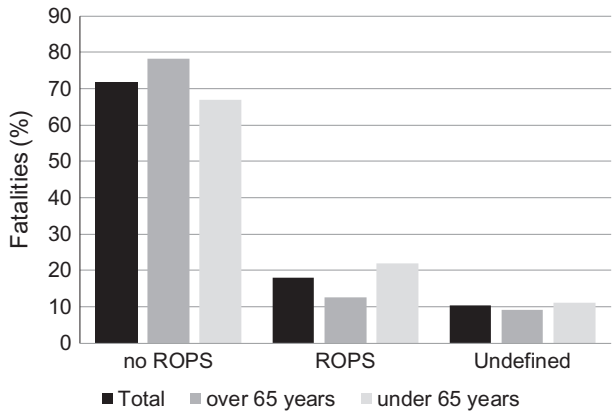

Fig. 4. Tractor fatalities (%) related to worker age (over and under 65 years) and ROPS installation. Tractors non-ROPS equipped (no ROPS); Tractors with ROPS (ROPS); ROPS not assessed (Undefined).

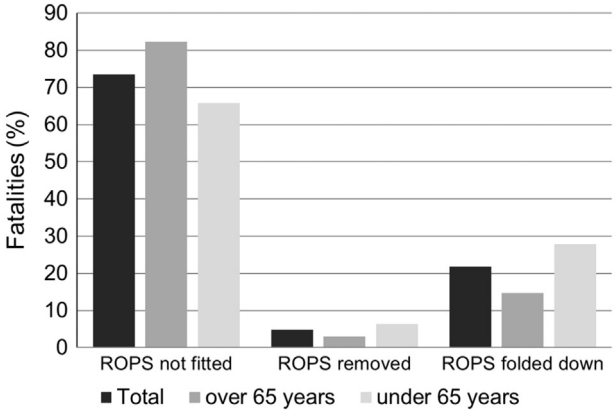

Fig. 5. Fatalities related to tractor rollovers without ROPS protection with respect to driver age. Tractors non-ROPS equipped (ROPS not fitted); tractors manufactured with foldable ROPS but ROPS was removed (ROPS removed); tractors manufactured with foldable ROPS and the ROPS was in the inoperative folded-down position (ROPS folded down).

of slopes, ditches, or embankments (27%), an excessive or unbalanced load on the tractor (16.2%) and mechanical problems (8.1%). In field operations the main environmental contributions were tractors sliding into ditches or bumping against obstacles, sometimes not visible, and tractors working on slopes or slippery ground. In tractors driving on roadways, the main environmental factors involved were the lack of road maintenance and steep slopes adjacent to the tractor path. As already reported, the tractor rollover accident occurrence is frequently affected by environmental risk factors (Arana et al., 2010; Degroot, Isaacs, Pickett, and Brison, 2011).

4. Discussion

Fatal and non-fatal tractor injury are often difficult to compare among different countries because the injury rates are related to the approach and the objective of the data source. Traditional reporting systems often refer only to insured workers, thus accounting for just a proportion of the actual victims of accidents in agriculture (Franklin, Mitchell, Driscoll, & Fragar; 2000; Mayrhofer, Quendler, & Boxberger, 2013). The underestimation of fatal accidents by data sources related to occupational injuries is quite common in the reporting systems of many countries (Arana et al., 2010; Murphy & Yoder, 1998). In the current data analysis the average annual number of tractor-related fatal accidents recorded by the INAIL Operational Archives was only 41% of that recorded by the INAIL_ASL Surveillance System, while the value reported by the INAIL Observatory is, respectively, 4 and 10 times higher than the Surveillance System and Operational Archives data.

In the literature, tractor-related fatalities recorded in agriculture are quite consistent with the data of the Italian Surveillance System: 43.7% of total farm fatalities were tractor fatalities, as depicted in Table 4 that shows an international overview of the tractor accident rate. Day (1999) refers to a higher percentage (72% from 1985 to 1996) based on data obtained by the Workcover Authority Health and Safety Division of the state of Victoria, Australia; while Jones, Day, and Staines (2013), based on the same data source, propose a lower percentage (56.5%) because a longer period of time was considered, including more recent data (1985–2010) denoting a significant decrease of the recorded tractor fatalities in the more recent years; this may be due to the increase of ROPS equipped tractors. For the period 2000–2010, tractor fatalities were 46% of farm fatalities, a result consistent with data shown in the present study (Table 4).

Based on the INAIL_ASL Surveillance System, 25.1% of fatalities in agriculture and 57.4% of tractor fatalities were due to a rollover event, which is data consistent with the international literature (Table 4). According to Bunn et al. (2008), data from the Kentucky Fatality Assessment and Control Evaluation (FACE), rollover fatalities were about half of total tractor fatalities, a value similar to the 57.4% reported in the present study. Arana et al. (2010) showed a higher value (70.1%) for Spanish agriculture in 2004–2008, basing their analysis on 388 fatal accidents recorded in newspaper articles and from an internet search.

The performance of the ROPS protection in tractor rollover is widely documented in the literature (Browning, Westneat, Truszczynska, Reed, & McKnight, 1995; Kelsey, May, & Jenkins, 1996; Reynolds & Groves, 2000; Myers, Cole, & Westneat, 2008; Jones et al., 2013). Springfeldt et al. (1998) verified a 93% reduction of rollover fatalities in Sweden, from 12 to 0.2 fatalities per 100,000 tractors over 30 years, with ROPS equipped tractors increasing from 6 to 93% in the period 1957–1990. The incidence of non-ROPS equipped tractors in many countries is estimated (NHIOSH, 2010; INSHT, 2009; MAPA, 2006; Cole, 2003; Hoy, 2009; Loringer & Myers, 2008); this is not the case for Italy because official data are not available. Nonetheless, tractor ROPS fitment has the aim of minimizing the risks for the driver; therefore the potential fatal outcome in the case of a rollover event is not excluded. In the current study, the fatalities with ROPS equipped tractors were 18% of total rollover fatalities; in just one case the ROPS collapsed; in almost all these

Table 3
Fatal tractor rollovers with respect to ROPS fitment, tractor activity and driver age (147 accidents, 2002–2012).

	Total			Over 65 years			Under 65 years	
	In field	In transfer	Undefined	In field	In transfer	Undefined	In transfer	Undefined
Not fitted	51	52	5	26	26	4	26	1
Uninstalled	4	3	0	1	1	0	2	0
Folded down	22	8	2	7	2	1	6	1
Total	77	63	7	34	29	5	34	2

Not fitted, fatalities involving non-ROPS equipped tractors. Uninstalled, fatalities involving tractors with ROPS removed. Folded down, fatalities involving tractors with the ROPS in the inoperative folded-down position.

Table 4
Tractor accidents rate, an international overview.

Reference	Rate	Country	Data source years
Tractor fatalities with respect to total fatalities in agriculture (%)			
Bunn et al., 2008	48	Kentucky, USA	1994–2005
Day, 1999	72	Victoria, Australia	1985–1996
Jones et al., 2013	56.5	Victoria, Australia	1985–2010
Murphy and Yoder, 1998	32.1	USA	1992–1995
NHIOS, 2010	36	USA	2003–2007
Pickett, Hartling, Brison, and Guernsey, 1999	47.5	Canada	1991–1995
Present study[a]	10.6	Italy	2002–2014
Present study[b]	43.7	Italy	2000–2012
Tractor rollover fatalities with respect to total fatalities in agriculture (%)			
DeGroot et al., 2011	20.4	Canada	1990–2005
Jones et al., 2013	23.7	Victoria, Australia	1985–2010
NHIOSH, 2010	16.4	USA	2003–2007
Present study[b]	25.1	Italy	2002–2012
Tractor rollover fatalities with respect to total tractor fatalities (%)			
Arana et al., 2010	70.1	Spain	2004–2008
Bunn et al., 2008	52.2	Kentucky, USA	1994–2004
Day, 1999	61	Victoria, Australia	1985–1996
Dogan et al., 2010	37.2	Turkey, Konya	2000–2007
Jones et al., 2013	42.0	Victoria, Australia	1985–2010
NHIOSH, 2010	45.2	USA	2003–2007
Present study[b]	57.4	Italy	2002–2012
Rollover fatalities referred to ROPS equipped tractors with respect to total rollover fatalities (%)			
Arana et al., 2010	0.4	Spain	2004–2008
Day, 1999	17	Victoria, Australia	1985–1996
Myers et al., 2009	4	Kentucky, USA	2002
Present study[b]	18	Italy	2002–2012

Authors' elaboration based on
[a] INAIL, Operational Archives
[b] INAIL_ASL Surveillance System

cases the driver not wearing the seatbelt did not remain protected inside the ROPS clearance zone.

The percentage of fatalities with ROPS equipped tractors is significantly higher than the values reported by other authors. Myers et al. (2009) noted 4% of fatalities in rollover accidents involving ROPS fitted tractors; Arana et al. (2010) evaluated 272 fatal overturns and only one involved a ROPS equipped tractor; Day (1999) showed a higher percentage, 17%, close to the value obtained from the Italian Surveillance System (Table 4).

In relation to the age of the driver involved in fatalities the international literature shows that in agriculture the frequency of the elderly is higher than in the other fatalities (Table 5). The percentage of elderly victims ranged between 20 and 40% in agriculture while the data of the Italian INAIL Operational Archives showed a percentage of 17%. As already mentioned, the gap could be due to the fact that the elderly population is generally not insured and is therefore not recorded in the archives. Concerning tractor fatalities, the percentage of elderly victims in the literature is generally higher than those of the INAIL Operational Archives while the INAIL_ASL Surveillance System refers to data more in line with the international statistics. The low rate documented by Dogan et al. (2010) could be related to the fewer ROPS equipped tractors in Turkey, as evidenced by Cavallo et al. (2014), which aligns the risk conditions of all drivers independently of age and working operations. Arana et al. (2010) explained the higher risk of death, increasing with driver age, by hypothesizing that elderly people drive older, non-ROPS equipped tractors.

5. Conclusions

In Italy, as in many European countries, complete workers compensation archives and complementary monitoring systems are the reference databases for workplace injuries and fatalities. Considerable differences emerge in the accident data according to the reporting system considered. Many official accident archives consider only insured workers. As a consequence, injuries involving categories such as self-employed, retired, and part-time workers or unpaid family members, are in many instances not recorded causing a huge lack of information in agriculture.

Tractor-related fatalities in Italian agriculture range from 10.6 to 43.7%, depending on the data source. Total average number of tractor fatalities per year ranged from 16 to 128 for the INAIL Operational Archives and INAIL Observatory, respectively. The INAIL Observatory data source probably provides the most reliable number of tractor-related fatalities with respect to the other two Italian data sources. Nevertheless, despite its incompleteness, data of the INAIL_ASL Surveillance System, which has short narrative text reports, provides information on accident scenarios.

Regarding the tractors involved in fatalities, 71.7% of the fatal tractor-related accidents involved non-ROPS equipped vehicles. Concerning tractors manufactured with a ROPS protection, a result worth highlighting is the high number of tractor rollover fatalities associated with tractors equipped with front foldable ROPS in the inoperative folded-down position (21.8%) or even removed (4.8%) during the rollover event.

Nonetheless, the ROPS fitment did not guarantee the protection of the driver in all overturning situations; indeed 18% of rollover fatalities concerned ROPS equipped tractors. In this respect, it should be underlined that an additional 10.2% of tractor-related fatalities was uncertain because the ROPS fitment was not clearly stated in the reports, so that percentage was not categorized. Data recorded for ROPS equipped vehicles included just one fatality associated with the ROPS collapsing on impact with the ground, confirming the very positive performance of the ROPS in rollovers. In ROPS equipped tractors, the main cause of fatalities was the driver being thrown outside the clearance zone, crushed beneath the tractor, or colliding with the ROPS mountings, because the victim was not restrained in the seat. As already stated in the international literature (Day, 1999; Molari & Rondelli, 2007; Myers & Pana-Cryan, 2000) the seatbelt is confirmed as a necessary safety component for effective ROPS performance. No records denoted the use of the driver restraint system at the time of the accident. Fatal accidents were often associated with an inadequate perception of the rollover risk, mainly on sloping or slippery areas and/or in the presence

Table 5
Elderly fatalities rate, an international overview.

Reference	Rate	Country	Data source years
Fatalities for elderly workers with respect to total agriculture fatalities (%)			
Gross et al., 2012	30.7	USA	2011
NHIOS, 2010	40	USA	2003–2007
Pickett et al., 1999	36	Canada	1991–1995
Present study[a]	17	Italy	2002–2014
Rissanen & Taattola, 2003	>20	Finland	1988–2000
Tractor fatalities for elderly workers with respect to total tractor fatalities (%)			
Arana et al., 2010	44.6	Spain	2004–2008
DeGroot et al., 2011	43.6	Canada	1990–2005
Gross et al., 2012	40	USA	2011
Pickett et al., 1999	46.7	Canada	1991–1995
Present study[a]	22	Italy	2002–2014
Present study[b]	42.4	Italy	2002–2012
Rissanen & Taattola, 2003	36	Finland	1988–2000

Authors' elaboration based on
[a] INAIL Operational Archives and
[b] INAIL_ASL Surveillance System

of obstacles. Concerning the age of the victims in tractor rollovers, the percentage of elderly was higher for the non-ROPS equipped tractors.

As a general conclusion it should be highlighted that the approach adopted by the INAIL_ASL Surveillance System based on data with short narrative text was shown to be highly advantageous for characterizing the accident scenario. Although the recorded events underestimated the number of tractor-associated fatalities, its value is due to the rigorous method adopted in accident reporting. Unfortunately, the data source did not record non-fatal cases nor information deriving from farmer's surveys or hospital reports. Nevertheless, this costly and time-consuming approach could allow public prevention policies to be defined, such as massive training campaigns among farmers on the correct use of ROPS equipped tractors. This approach could also help researchers and tractor manufacturers enhance the effectiveness of ROPS on modern tractors. Additionally, a strict requirement to retrofit ROPS on all tractors could increase the survival chances of drivers in rollover accidents.

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Uncited references

EC, 2003

Italian Legislative, 2008

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Valda Rondelli earned her degree in Agricultural Science, from Faculty of Agriculture, University of Bologna, (First class honours, 1987). She earned her Doctorate in Agricultural Mechanisation from University of Bologna. She has been a Researcher at the University of Bologna, Department of Agricultural and Food Sciences (DISTAL) since October 1999. She has been as head of the Laboratorio di Meccanica Agraria of the DISTAL, official OECD Testing Station for tractor performance and ROPS strength since December 2008. She is an Associate Professor at the University of Bologna, Department of Agricultural and Food Sciences (DISTAL) since September 2014.

Camilla Casazza earned her degree in Materials Engineering from University of Ferrara. She earned her PhD in Agricultural Engineering from University of Bologna. Her areas of experience include experience in the materials quality, performance evaluations, Risk Analysis and homologation of agricultural Machinery He collaborated with CNR_ Imamoter and Laboratorio di Meccanica Agraria, OECD TEST Station, Department of Agricultural and Food Sciences of the University of Bologna.

Roberta Martelli has been an Adjunct Professor of the University of Bologna and the University of Modena and Reggio Emilia. She carries out his research in the field of Mechanical Engineering and agricultural mechanization. Research interests are particularly focused on integrated mechanical solutions for organic farming; qualitative aspects of vegetables connected with mechanical harvesting; harvest mechanization of energy Crops; physical-mechanical properties of vegetables during storage; Precision Agriculture; viticulture innovative equipment. She is the Author of about a hundred publications.