# Near accidents with agricultural vehicles, machinery and equipment in Austria in the year 2013

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**Abstract:**Near accidents are in the lowest stage of the accident pyramid. A near accident is defined as an unplanned event, which includes a potential accident risk, but does not bring any injury or property damage with it. The consideration of near accident plays a very significant role in accident prevention. Near accident research provides an acceptable tool to determine safety deficiencies, potential risks and hidden dangers in various work areas early enough to avoid actual accidents. The aim of the study was to identify safety weaknesses of agricultural and forestry vehicles, machinery and equipment which almost led to an accident with workers in agriculture and forestry in Austria. Also to detect weaknesses and deficits in the design to derive improvements in the safety design of machines and the associated prevention measures. The results showed that farm managers(mostly men), from 41 to 60yearswith agriculturalandnon-agriculturaltrainingweremost frequentlyaffectedbynearaccidentsonlivestocksidelinefarmwithafarmsizeof 10 to 50ha. Machine-specificworkingtoolsof hand-heldandself-propelledmachineryduringdirectworking process, influencedby unfavorableenvironmentalconditions (soil), physicaladversefactors(hurryand stress) andoperatingerrorsweremostfrequentlyinvolvedinnear accidents. The people surveyed mentioned as preventive measurestoavoidthenearaccidentsituationincreasedtrainingintheoperation, followed bymechanicaladaptations, safety equipmentwhenbuyingnew machines, training inthesafetydesign of machinesas well aseasy-to-understand andwrittenshortoperating instructions (manuals).

**Keywords:**Near accidents, Agricultural machinery, near accident analysis, statistical analysis

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## 1 Introduction

Thenumber ofserious accidents, some of them fatal, at workinagriculture and forestryisstillveryhighinAustria.In the year2013,920accidents per100,000 employeesoccurredintheentireagricultural sector, with14(per 100,000) of them fatal (SVB, 2013). Over the past10 years, the number of accidents at work has decreased by 3.40%, that of fatal accidents by1.84% (SVB, 2013) and that of farms by 4.64% in Austria (Statistik Austria, 2010).Today the most commoncause of accidents is slipping, stumbling and falling of a person (30.5%) followed by the loss of control of the machine, means of transport or handling equipment, hand-held tool, object or animal (28.7%) and objects breaking, bursting, splitting, slipping, falling and collapsing (19.5%) (SVB, 2013). For comparison purposes, in the year 2000 12.6fatal and 6,000 accidents at work were recorded per 100,000 employees inthe EU MemberStates(OSHA, 2014).

Due to the diversity of the cultural landscape and the high mechanization of farms (livestock, crop production, mixed farms, forestry and specialty crops), a large number of different activities need to be accomplished with various machines and devices over one production year. These range from cultivation and harvesting tasks with hitched, trailed and self-propelled machines to work for livestock and timber production. Because of the various machine types and differences in construction, the people operating them are subjected to a wide variety of injury risks. Despite the special regulations governing the safety design (Machinery Directive 2006/42/EC, DIN EN ISO 4254-1 and the respective machine-specific standard),

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the diverse machinery is subject to very strong signs of wear and tear in practice. In conjunction with careless maintenance and improper handling and operation, this poses a high injury risk for farmers (Quendler et al., 2014).

Because of this diversity of accidents, very great attention is paid to accident research not only in Austria but worldwide. The foundations for this area of research were laid during the First World War. In the 1960s, the research focus was extended to the systematic interaction between man-machine and environment to gain a better understanding of accident prevention (OSHA, 2002). Modern accident research focuses on the investigation of near accidents which are defined as unplanned incidents with a potential risk of accidents but no injuries or property damage. They rank the lowest in the accident pyramid (Phimister and Bier, 2004; Carter and Menckel, 1985). Near accident research is the early detection of misconduct, safety and organizational deficiencies as well as the identification of potential risks as an objective basis (Carter and Menckel, 1985).

Near accidentresearchis done in the areas ofroad and rail traffic, process technology,plantengineering,mechanicalengineering,building safety, medicine and the public area. Studies have been done byQuaraSalvatoreetal. (2014), WrightandSchaaf (2004),Uthand Wiese (2004), Nashimotoetal. (2001), Laitinen (1984), CarterandMenckel (1985), Jones et al. (1999), Wuetal. (2010).In theagricultural and forestrysector,studies on near accidentsituations have only been in done Sweden and Finland. These studies refer totheentireagriculturalaccidentsituation(machineandlivestock) andforestryaccidents(especially chain saws) (Carter andMenckel,1985; Gustafssonetal., 1991; LundqvistandGustafsson,1992; Laitinen, 1984).

Near accidentresearchinAustria is done invariouseconomic sectors(electrical, mechanical engineering, steelconstruction,etc.), public institutions(hospitals, universities, banks, etc.) as well asdifferentinstitutions relating to transport (AustrianNearMissAssociation(ANMA), Quality Austria, SafeWork, etc.) and various kinds(report forms, employee meetings, courses, seminars to raise awarenessandprevention, PC programs, etc.). In the agricultural sector, noresultsof near accident researchwithvehicles, machinery and devices have been availableinAustria to date.

Therefore, theobjective of thisstudywastodetermine personal, farm, work and machine-specific parameters, of near accidents as well as to find out to what extentdesigndefectsorhuman behavior lead to near accidents, what humanandenvironmentalfactorslead to near accidentsand how thesecould be avoided in orientationofanactualaccidentanalysis carried out as inAustria.Theseobjectivescouldbeserveassociated agricultural organizations (Sozial insurance investigations, agricultural schools, agricultural training and counseling services,etc.), Machine manufacturers anddealers, andevenfarmersfor detection andperceptionof risk potentialsatwork during operationswith agricultural and forestry vehicles, machineryand equipment in future.

## 2 Material and method

With astandardized onlinequestionnaire,which wassentto37,674email addressesfrom farms,occupationalinformation wasrequestedfornear-accidentsituation. Theemail addresses were providedbytheINVEKOS(Integrated Administration and Control System)database of theAustrianFederal Ministry of Agricultureforthiskind of research. Theselectionof thissamplebased on theassumption thatfarmersarereached which are open to newinformation and communicationtechnologies.Theonlinequestionnairewascompletedby2,865farmers;this corresponded to aresponse rate of7.60%.

Theperson-specificinformation captured information about the gender, ageandeducationof persons involved in near accidents. This comprised 76.9% (2200/2862) of

men and 23.1% (662/2862) of women in the age groups from 41 to 60 years (67.1% (1911/2847), from 21 to 40 years (28.1%, 801/2847), over 60 years (4.57%, 130/2847) and under 20 years (0.18%, 5/2847) with (52.1%, 1493/2865) and without (47.9%, 1372/2865) agricultural education. Thefarm-specificinformationincludedthefarm type and size. This corresponded to 33.1% (946/2859) of mixed agricultural farms (cropland, grassland and forest), followed by livestock farms with grassland and forestry (26.8%, 765/2859), arable farms with forestry (12.2%, 349/2859), farms with grassland, farmland and forestry (5.21%, 155/2859) and other farms (<5.00%, <118/2859) with a size of 59.6% (1704/2857) between 10 and 50 ha, followed by farms with more than 50 ha(21.6%, 616/2857) and those with fewer than 10 ha (18.8%, 537/2857) total area. 52.0% (1487/2862) of them are managedas sideline and 48% (1375/2862) as full time farms.

Machine-specificinformation (multiple answerswere possible) included machine category, additional equipment, working process, machine part, handling, and measures to avoidthenearaccidentsituation.

Regarding the machine category hand held (36.4%, 3559/9780), followed by self-propelled (22.2%, 2170/9780), three pint linked (21.7%, 2118/9780) and towed (15.7%, 1533/9780) machinery were leading frequently to near accidents in Austria. The most common near accidents occurred during the direct operation with the machines (67.0%, 5863/8756), followed by other working processes (for example mounting/dismounting, hitching/unhitching, maintenance, etc.)(10.9%, 955/8756) and multiple answers to different working processes (for example cleaning and maintenance, direct opartion and maintenance, etc.) (7,67%, 672/8756).

As the most frequently machine parts witch were causing near accidents, machine specific working tools 35.6%, 2424/6812), followed by the entire machine (19.1%, 1303/6812), machine-specificconveying parts (8.84%, 602/6812), machine-specific drive components (4,99%, 340/6812), hitching or coupling systems (4,59%, 313/6812) as well as steps, ladders and plattforms to operating positions (4.55%, 310/6812) could be detected.

As reasons for accident causing handling human factors (like wrong workflow and incorrect operation of the machine out of habit) (73.8% (6373/8639)), machinedesign (23.6% (2036/8639)) (design andconstruction) and a combination of human factors and machinedesign up to 2,66% (230/8639) could be mentioned.

Asmeasures to avoidnearmissesof all machinecategories the training in theoperation(44.1%, 3782/8574), followed by mechanicalfactors (improved design and construction, etc.) (31.5%, 2702/8574) and other measures(19.8%,1694/8574)and mechanicalfactorsassociatedwith the traininginthe operation(4.62%, 396/8574) weremost often cited.

Thecollecteddatawerespecificoccupationalsafetyenvironmentalconditions, impairments, safety equipment, training insafetytechnologyandinformationabout operating instructions.The variable"Others" includedclassificationsthat did not fitinto any of thecategorieslisteddue to lowfrequenciesanddifferences. It waspossible to give single and multipleanswers.

The parameters recorded online were analyzed descriptively and analytically in SAS 9.2® according to the above parameters to find out which people on which farms with what kind of agricultural and forestry machine category often affected by near accidents during different types of working processes, handlings and operations as well as to find out associations, dependences or correlations between the working processes, machine parts, additional equipment and measures to avoidthenearaccidentsituation.

Therefore always two parameters were tested together with the intention to recognize facts, trends and tendencies of the near accident situation in Austria to derive preventive measures.

As statistical test methods for identifying significant relationships between the parameters the chi-square test, for equality of two proportions or association of two

categorical variables as well as for testing significant correlations (contingencies) of qualitative (discrete) features as well as the Wilcoxon two-sample test and Kruskal-Wallis test were used, since these statistical test methods are suitable for testing contexts (contingencies) of qualitative (discrete) features (Stahel, 2008). Javadi and Rostami (2007), Linderoos et al. (2008) and Tsioras et al. (2012) used the chi-square test for the analysis of agricultural and forestry machinery accidents.

## 3 Results

### 3.1 Near accident situation according to personal and farm-specific parameters

Significantly, the results demonstrated that the farm managers who were faced with near accidents in the past increasingly led livestock farms as a sideline (p-value <0.0001). The nearly injured persons over 40 years worked mainly on farms with under 10 or over 50 hectares, and those under 40 years on farms between 10 and 50 ha total area (p-value <0.0009). A differentiation regarding the education level of the gender of the surveyed participant showed that women often had a school-leaving degree from a secondary school, no further agricultural degree with any other training in comparison to male participants. Men were educated as agricultural master at a higher proportion than women. As regards the educational level of agricultural skilled workers or those with professional training, a diploma or college degree, there were no significant differences between the two genders (p-value <0.0001).

Farm managers on farmsbetween10 to 50andover 50haofagricultural area most frequently had master-level education. High school diplomas anduniversitydegreeswere more commononfarmsunder 10 and over50ha(p-value <0.0001). Onfarms withmalefarm managers,most likely themanagers andtheirfamilymembers, followed by thesuperintendent, parents, foreignworkersandotherpeople(friends,neighbors, etc.) were affected. Onfarms with femalefarm managers, the farm manager and family members,followedbyspouses, familymembers excluding themanagerandthe manager were most frequentlyinvolvedperseinnear accidents(p-value<0.0001 in thechi-square test).

On farms with managers over and under 40 years of age, the managers including family members, followed by the managers per se were those most frequently involved in engineered near accidents (p-value <0.0001). The most frequent near accidents occurred on farms with 10 to 50 ha of agricultural and forest area (59.6%, 1704/2857), followed by those with more than 50 ha (21.6%, 616/2857) and 10 ha (18.8%, 537/2857). More than three-quarters of the farms where near accidents occurred kept livestock (76.3% (2180/2589), the remaining did not keep any livestock (23.7%, 679/2859).

More than half of these farms were sideline businesses (52.0%, 1487/2862), 48% of them were full-time farms (48.0%, 1375/2862). The farms with fewer than 10 ha were mainly conducted as sideline businesses and farms with over 50 ha predominantly as full-time farms. Half of the farms with a farm size between 10 and 50 ha were conducted as full-time businesses and half of them as sideline businesses (p-value <0.0001 in the chi-square test). Farms with 10 to 50 ha of total area were significantly more frequently livestock farms and farms under 10 and over 50 ha were predominantly without livestock (p-value <0.0001 in the chi-square test).

### 3.2Machine characteristics

Near accidentshappenedmostoftenwithhand-held machinesanddevices(3559/9780). 10% ofnear accidents involved self-propelled(2170/9780), three-point linked(2118/9780) andtowed(1533/9780) machines. Stationary machineswere involved in lessthan 5% of the near accidents (400/9780).See Table 1 please.

accidents. In stationary machines, drive and conveyormachinepartswere those kinds of machine parts

**Table 1 Categories and types of agricultural and forestry vehicles, machinery and equipment involved in near accidents**

| Machine category/-type | Number (%) |
|---|---|
| **Hand-held machines and equipment**<br>Chainsaw > Circular saw > Hand-held cut-off machine > Others | 36.4 |
| **Self-propelled machines**<br>Tractor > Loader >Transporter> Combine harvester > Others | 22.2 |
| **Three-point linked machines**<br>Cable winch > Wood splitter > Front loader >Rotary mower > Others | 21.7 |
| **Towed machines**<br>Trailer > Timber loader incl. trailer > Slurry tank > Manure spreader > Others | 15.7 |
| **Stationary machines**<br>Hay blowers > Hay crane > Slurry mixer > Manure removal > Others | 4.09 |

The machinery parts most frequently involved in near accidents were machine-specific working tools (2424/6812), followed by the whole machine (1303/6812), moving machine parts (942/6812) (machine-specific conveyors (602/942), machine-specific drive components (340/942)), towed and three-point linked devices (313/6812) as well as lifts and operator places (310/6812).See Table 2 please.

**Table 2Ivolved machine parts of agricultural and forestry vehicles, machinery and equipment involved in near accidents (n=6812)**

| Parameters | Number (%) |
|---|---|
| **Involved machine parts** | |
| Working tools (machine-specific) | 35,6 |
| Whole machine | 19,1 |
| Moving machine parts | 13,8 |
| Coupling devices | 4,59 |
| Ladders, steps, ramps | 4,55 |
| Others* | <4,00 |

Note: *Others included: machine parts (wheels and tires, equipment and material, hydraulic system (machine-specific)), braking systems, tractor with towed or hitched machines, guards and safety devices, supports (stability), folds and covers, controls (machine-specific), protective equipment and adjusters. Its shares were below 4.00% (2 to 238/6812) of the responses

In self-propelled, towed, three-point linkedandhand-held machines, setting, coupling andsupporting devices, protective covers, liftsandothermachine-specificparts could be detected as the machine parts that most frequently cause near (p-value<0.0255 in thechi-square test).

### 3.3 Human-machine-interaction

For allmachinegroups(self-propelled, towed, three-point linked, hand-heldandstationary machines), thedirectoperationof the machine(5863/8756), followed byother activities(955/8756) andmultipleresponsestovarious operations(672/8756) most frequently led tonear accidents. Coupling(340/8756), cleaning (240/8756), maintenance(236/8756), uncoupling(234/8756)andrepairs(216/8756)were further near-accident-causing activitiesthatoccurredlessfrequently.

Fortowed, three-point linkedandstationary machines, an increased number of near accidentsoccurredduringmaintenanceworkas well asduring coupling and uncoupling.For hand-held machines, most near accidentsoccurredduringthedirectoperationofthemachine.

For self-propelled machines, an equal number of near accidents occurred during operation,maintenancework,thecoupling and uncoupling ofmachines (p-value<0.005 chi-square test).See Table 3 please.

**Table 3 Specific tasks during near accidents with agricultural and forestry vehicles, machinery and equipment (n=8756)**

| Parameters | Number (%) |
|---|---|

| **Tasks** | |
|---|---|
| Directoperation(machine-specific) | 67,0 |
| Others* | 10,9 |
| Multiple answers ** | 7,67 |
| Coupling and uncoupling | 6,55 |
| Cleaning and maintenance | 5,44 |
| Repairing | 2,47 |

Note: *Others = Driving, ascend and descend, loading and undloading, others
**Multiple answers = combination of direct operation (machine-specific), Coupling and uncoupling, Cleaning, maintenance and reparieren

Significantly more often near accidents occurred during the direct operation of self-propelled and hand-held machines. Coupling and uncoupling, maintenance and other activities were the tasks that caused most near accidents with towed, three-point linked and stationary machines (p-value <0.003 chi-square test). For 23.2% (1912/8256) of those surveyed, the inappropriate operation of the machinery led to near accidents. Up to 38.1% (3147/5256) operated the machines either wrongly or inappropriately. Almost a third (31.9%, 2630/8256) of the surveyed was of the opinion that the machines were not inappropriately operated. Only 6.87% (567/8256) did not know if wrong or improper operation caused the near accident.

Reasons for thenear-accident-causinghandlingwere up to 73.8% (6373/8639) humanfactors, such astheincorrectworking process andinappropriateoperationof the machineout of habit. In up to23.6% (2036/8639) of the cases, themachine design (design andconstruction) and in upto 2.66% (230/8639) of the cases, human factorsincombinationwiththemachine design related to anear accident situation. Male farm managersweresignificantly more frequently involved in near accidentswiththree-point linked and towedmachines. Farms with female managersrecordedmorenearaccidentswithself-propelledan dstationarymachines.Almostthe same amount ofnearaccidentsoccurredwithhand-held machines on farms with male and femalefarmmanagers(p-value <0.0035 chi-square test).

The over 40-year-olds were almost injured nearly significantly more frequently with three-point linked, hand-held and stationary machines and the under 40-year-olds with towed machinery. No essential differences between these age groups could be detected for self-propelled machines. Near accidents with towed and three-point linked machines were more prevalent in the presence of the farm manager and with self-propelled, hand-held and stationary machines in the absence of the farm manager (p-value <0.0001 in the chi-square test).

For all machine groups a partially inappropriate or inappropriate operation was relevant to the near accident situation. According to inappropriate operation, significant differences between the machine categories could be detected (p-value <0.0133 in the Kruskal-Wallis test). The results demonstrated that male farm managers were significantly more frequently of the opinion that they partially inappropriately or inappropriately operated the machines than females (p-value <0.0006 chi-square test). Significant differences were also given according to the education level of the manager (agricultural and not agricultural training). Managers without agricultural training more frequently were of the opinion that they hadn’t operated machines inappropriately than those with agricultural training (p-value <0.0019 chi-square test).

Wrong or inappropriate and partially wrong or inappropriate operation of machinery, which was the cause for the occurrence of the near accident, was significantly more frequent in the presence of the farm manager. Near accidents caused by wrong or inappropriate operation of the machines prevailed in the absence of the manager (p-value <0.005 chi-square test). The most significant near accidents occurred with hand-held machines as a combination of human factors (incorrect work process and operation out of habit) and machine-related causes (construction and defects). For self-propelled, towed, three-point linked and stationary machines, near accidents only occurred because of human factors (workflow and operation) (p-value <0.0068 in the Kruskal-Wallis test).

Near accident causing handling of machines due to human factors (workflow service) occurred significantly more often in the presence of the farm manager, and near accident causing handling because of mechanical factors (construction defects) and because of the combination of mechanical and human factors in the absence of the manager (p-value<0.0257 chi-square test). Significant differences were found in the handling of machines and the additional equipment of the machines involved in near accidents by farm size (under 10, 10-50, over 50 ha) (p-value<0.0005 in the Kruskal-Wallis test).

Onfarmswithfewer than 10ha significantly more near accidentswithhand-held machines, on farmswith between 10 and 50hawithstationarymachinesandonfarms with more than50hawith towedandthree-point linkedmachines were observed. The same number ofaccidentsoccurredwithself-propelled machinesinallthreesizeclasses(p-value<0.0001 in thechi-square test). Near accidentsoccurredonfarmswithlivestockfrequentlyduringdirectoperationof the machineandonfarms without any livestock oftenduring maintenance work, coupling and uncouplingof machines and during thecombinationof coupling and uncoupling as well as maintenance work. Nosignificantdifferenceswere noted inlivestock farms and those without livestock in thesenearaccidentcausingactivities(p-value<0.0001 in thechi-square test).

### 3.4 Environmental factors

Environmental factors thatinfluencedthenear accident situationwithagricultural machines and devices existed in 27.6% (3707/13421) of the cases completely and in 20.4% (2742/13421) partially during the near accident.In51.9% (6972/13421) of the cases environmentalfactorshadno specific influence onthenear accident situation. Environmentalfactorsthatimpactedthenear accident situationwereoftenslopedterrain(1218/3707), followed bywet, slipperyground(924/3707), snowandice(365/3707), cold (311/3707), wetorsoiledmachine parts(279/3707), heat(223/3707)andrain(196/3707).See Table 4 please.

**Table 4Adverse environmental conditions during near accidents with agricultural and forestry vehicles, machinery and equipment (n=3707)**

| Parameters | Number (%) |
|---|---|
| **Adverse conditions** | |
| Slopedterrain | 32,9 |
| Slipperyground | 24,9 |
| Snowandice | 9,85 |
| Cold | 8,39 |
| Wetorsoiledmachine parts | 7,53 |
| Heat | 6,18 |
| Rain | 5,29 |
| Other environmental conditions | 3,13 |
| Wind | 1,86 |

The statistical analyses showed that women had significantly more near accidents in difficult environmentalconditions than men (p-value<0.0317 chi-square test). Peoplewithoutagriculturaltrainingwereaffectedmore often byadverseenvironmentalconditionsandpeoplewithagriculturaltrainingwerepartiallyor not affected by adverseenvironmentalconditions in near accident situations (p-value<0.0265 chi-square test). Near accidentsduetoadverseenvironmentalconditionswere more commonin the absenceof the farm manager.Near accidents partially withandwithoutadverseenvironmentaleffectsoccurredmostlyin the presenceofthefarmmanager(p-value<0.0155 chi-square test).Onfarmswithlivestock,adverseenvironmentalconditionsmoreoftenandonfarms without livestockadverseenvironmentalconditions partially or not led tonear accidents(p-value<0.0001 in thechi-square test).

#### 3.4.1 Impairments

The three most common behavioral and mental adverse effects in near accident situations with agricultural machinery and equipment included hurry or stress (1678/6233), misjudgment of the machine (979/6233) and poor concentration (904/6233). Other adverse effects were physical stress (565/6233), distraction (546/6233) and inexperience (416/6233).

Fatigue (282/6233), work aggravating factors (151/6233), others (146/6233), previous conflict (67/6233), disease (67/6233), alcohol (9/6233) and medication (6/6233) were mentioned less often. Only in a few cases (461/6233) psychological effects influenced the near accident situation with agricultural vehicles, machinery and equipment.See Table 5 please.

**Table 5 Influence of behavioral and mental adverse effects on near accidents with agricultural and forestry vehicles, machinery and equipment (n=6233)**

| Parameters | Number (%) |
|---|---|
| **Psychological effects** | |
| Hurry or stress | 26,9 |
| Misjudgment of the machine | 15,7 |
| Poor concentration | 14,5 |
| Physical stress | 9,06 |
| Distraction | 8,76 |
| Inexperience | 6,67 |
| Fatigue | 4,52 |
| Work aggravating factors | 2,42 |
| Others | 2,34 |
| Previous conflict | 1,07 |
| Disease | 0,37 |
| Alcohol | 0,14 |
| Medication | 0,10 |
| No psychological effects | 7,40 |

Menwere significantly more oftenaffected in case of a near accident situation byfatigue,poor concentration, diseases, drugs, alcoholandconflicts than women.Inwomenoftenmisjudgmentofmachines, inexperience, distractions, factors that aggravated the execution of the task, others andno adverse effects led tonear accident situations. Stressandphysicalstressaffectedmenandwomenequally(p-value<0.0014 chi-square test). For personsunder40 yearsphysicaloverload, hurryand stress andphysicalfatigue,conflicts, lack of concentration, diseases, medication andalcoholconsumptionas well as non-interference ledtonear accidents. For those over40yearsmore likelyinexperience, misjudgment ofmachines, distractions, factors that aggravated the execution of the task andotheradverse effects were responsible for the near accidents(p-value<0.0018 chi-square test).

For people without agricultural training, mainly inexperience, misjudgment of equipment, distractions and aggravating factors and other factors, as well as no adverse factors caused the near accident situation. For people with agricultural training, physical overload, hurry and stress and physical fatigue, conflicts, lack of concentration, illness, taking medication and alcohol consumption more commonly caused near accidents (p-value <0.0001 in the chi-square test). Near accidents of workers on the farms caused by fatigue, conflicts, lack of concentration, diseases, medication and alcohol consumption occurred significantly more often in the presence of farm managers. Near accidents in the absence of the farm manager occurred significantly more frequent because of inexperience, misjudgment of machines, distractions, and aggravating factors and no other adverse factors. Hurry and stress occurred in the presence and absence of the farm manager with similar frequency (p-value <0.0001 chi-square).

On full-time farms near accidents often occurred due to physical overload, hurry and stress. On sideline farms near accidents occurred because of inexperience, misjudgment of machines, distractions, aggravating factors and no other adverse effects. Near accidents due to fatigue, conflicts, lack of concentration, diseases, medication and alcohol consumption occurred on main and sideline farms with similar frequency (p-value <0.0208 chi-square test). On livestock farms near accidents were significantly more often caused by fatigue, conflicts, lack of concentration, illness, medication, alcohol and inexperience, misjudgment of equipment, distractions and aggravating factors and other adverse factors. On farms without livestock near accidents were caused more frequently by physical stress, hurry and stress. No adverse factors were found on livestock and farms without any livestock in equal shares (p-value <0.0156 chi-square test).

On farms with a total area of 10 to 50 hectares near accidents were mainly caused by physical overload, hurry and stress and on farms less than 10 ha frequently by inexperience, misjudgment of machines, distractions, aggravating factors, others and no interference. On farms with over 50 ha physical fatigue, conflicts, lack of concentration, diseases, drugs and alcohol consumption caused the near accident situation (p-value<0.0006 chi-square test).

3.4.2 Prevention measures

Asmeasures to improvepreventionofnearaccidentswithagriculturalmachines the training in theoperation(3782/8574), followed bymechanicaladaptations(2702/8574)andother measures(1694/8574)andmechanicalfactorsinconnectionwiththetrainingintheoperation(396/8574)were mentioned. Fora small proportion oflistednearaccidents(4.61%, 414/8988) there was noinformation given on measures to avoid the near accident situation. Asmechanicaladaptationsthe improvement inconstruction(52.7%, 1424/2702), followed byadditionalequipmenttoincreasesafety at work(43.0%, 1161/2702) andadditionalequipmentof advanced design(117/2702) were cited.See Table 6 please.

**Table 6 Measures to avoid near accidents with agricultural and forestry vehicles, machinery and equipment (n=2702)**

| Parameters | Number (%) |
|---|---|
| **Prevention measure** | |
| Training in theoperation | 44,1 |
| Mechanicaladaptations | 31,5 |
| Oher measures | 19,8 |
| Combinations (mechanicalfactors/ trainingintheoperation) | 4,62 |

Theimprovement in operating (attention, avoidingdistractions, etc.) (54.1%,574/1061), the driving behavior(terrain,road) (13.0%,138/1061), thesafetyof the workplace(repair,work tools) (8.01%,85/1061) andchanges in the machinery(construction) (7.63%, 81/1061) were mentioned by the respondents as further measures to prevent near accidents. Less than 5.00% mentioned other measures(<12-52/1061). Other measures without any further information were also mentioned by 37.4% (633/1694).

Thewillingness to purchasesafetyequipmentofmachines(10145/19898) and facilities forease of operation of machines (9753/19898) wasgivenamong respondents at almostequal amounts. Thesafetyequipmentfor which there wasawillingness to buyincludedbrakingsystems(compressed air, ABS, ESP), personal protective equipment (7.19%, 811/11287), automatic stop of moving partswhen leaving thedriver's seat (7.51%, 762/10145), lifts(6.37%, 646/10145), person recognitionsystems(6.25%, 634/10145), slope sensors(5.96%, 605/10145), specialtires(5.65%, 573/10145),monitorsandcameras(5.30%, 538/10145), tilt sensors(5.12%, 519/10145) and overload protection systems(5.01%, 508/10145).

As regards the equipment for the ease of operation, there existed an increased willingness to buy forquick coupling systems(10.1%, 983/9753), followed bycomfort cabins(9.14%, 891/9753), quick changesystems(8.24%, 804/9753), additionalwork lights(7.94%, 774/9753)and central lubricationsystems(6.08%, 593/9753). Themajority of respondents (2599/2853)considered training in or instructions on how to use the technology, particularly relating to thesafetyrelevant operation, when buyinga new machineas necessary. Only few(254/2853)of the near accident victimsconsideredtraining in or instructions on how to use the technology when buying a new machine as not necessary.See Table 7 please.

**Table 7 Acceptance to use selected safety and working comfort equipment to increase safety at work**

| Parameters | Number (n) |
|---|---|
| **Additional equipment (n=19898)** | |
| Safety-related equipment | 51.0 |
| Operating comfortequipment | 49.0 |
| **Necessity of safety instruction (n=10145)** | |
| Yes | 91.1 |
| No | 8.90 |
| **Reading the user manual (n=2858)** | |
| Completely | 49.0 |
| Partially | 34.4 |

| | |
|---|---|
| When problems | 15.2 |
| Not read | 1.43 |

59.9% (1555/2598) of the near accident victims whoconsideredsafety training as a necessity said thatthisshould be provided bythe machine manufacturer. Theother40.1% (1043/2598) expecta machinery dealer to provide this.Almost half(1401/2858)of the near accident victims read the operating manualin its entiretybeforethefirstuseof machinery. About a thirdofthem(983/2858)readtheoperatinginstructionspartially (selected parts) before thefirst useand15.2% (433/2858) onlyupon the occurrenceofproblems.Failuretoreadwas true ofonly1.43% (41/2858) of the near accident victims. In0.24% (7/2865) of casesnoinformationexistedon the reading habitsbeforethefirstuseof machinery.

The most commonreasons for notreadingmanualswas their extent (48.2%, 1017/2108), followed bylack of time and incomprehensibility (20.4%, 431/2108). As preferredmediato ensure that the manuals are read, more thanone-third(2267/5747) favored thewrittenform of the manualas a shortandconcisehandbookfollowedbyavideoclip(881/5747)and the electronic formas a shortfile(688/5747). Thedesignofoperatingmanualsasadetailedversion(544/5747), mobile app(457/5747), electronicallyas a filein a long version(426/5747), partof a driver informationsystem(411/5747)and otherdesigns(73 /5747) were consideredof less relevancefor practical use.See Table 8 please.

**Table 8Preferred media for manuals to increase safety at work (n=5747)**

| Parameters | Number (%) |
|---|---|
| **Design of operatingmanual** | |
| Handbook (shortandconcise) | 39.4 |
| Videoclip | 15.3 |
| File (shortandconcise) | 12.0 |
| Handbook (in detail) | 9.47 |
| Mobile app | 7.95 |
| File (in detail) | 7.41 |
| Driver informationsystem | 7.15 |
| Others | 1.27 |

As design forms of media the surveyednear accident victims preferred operating instructions in written form with pictures (24.3%, 17/70), a detailed, clear shape in the official language (21.4%, 15/70), directly on the machine (storage) (11.4%, 8/70), a short written version (11.4%, 8/70), as a movie or video clip (YouTube) (10.0%, 7/70) and in two-part form (short and long version) (8.57%, 6/70). The remaining responses were below 5.00% (<1-3 / 70).

### 3.5 Acceptance of safety measures

When purchasing new machines, mentendtochooseoperatorcomfort systems more frequently whilewomen tend to choose safety-related equipment (p-value<0.0420 chi-square test).Menwere more willingtopayup to10% and20% of the original value forsafetyequipmentwhenbuyinga new machine.Women showedanincreasedwillingness to pay up to10% andmore than20% of the original value.The proportionof those who were not willingtospend any additional money on safety-related equipment were significantly more women than men(p-value<0.0457 chi-square test).Theneedforsafety technology training and operationdifferedsignificantlyby gender. Menwere more likelythan women tobelievethata safety-technologicaltrainingisnot required (p-value<0.0040 chi-square test).

Peoplewithoutagriculturaltrainingfrequentlyaffirmedthe necessity of thesafety training, particularlyinthesafetyoperation,whenpurchasinga new machine. Person with agricultural training were more likelythanthosewithoutagriculturaltrainingto say that safety training was notrequired(p-value<0.0135 chi-square test). Men mainly read the operatingmanual when application or functional problems occurred while women usually read the manual in full. For reading the manual in parts or not at all, no significant differencesbetween men and womencouldbeobserved (p-value<0.0314 chi-square test).Fortheunder40-year-old victims,increasedreading when application andfunctional

problems occurred as well asfrequently reading parts of the manual or not at all could be found. The over 40-year-old victims readthe operating instructions, however, significantly more frequently in full (p-value<0.0001 in thechi-square test).

Persons without agricultural training significantlymorefrequentlyreadtheoperatingmanuals in full.Frequent reading of the operatingmanuals application orfunctional problems occurred as well asincreasedreading of parts was done bypersonswithagriculturaltraining.Theproportionofnotrea ding the manualwassimilarlyhigh for botheducational levels (p-value<0.0075 chi-square test). Inthe group of the under40-year-old victims notreadingtheoperatingmanualwassignificantlymore often found because of lack of time.For those over40years of age the lack of timepreventedreading the manual onlypartly(p-value<0.0009 chi-square test). Asmeasures to prevent the near accident situationtheunder40-year-olds mentioned additional safety equipmenttoincreaseworkplace safety and the over 40-year-oldsconstruction and designimprovementsonthe machines (p-value<0.0359 in theWilcoxontwo-sampletest). For livestock farms, not reading manuals was frequently observed due to lack of time. In farms without livestock lack of time only partially prevented the reading of manuals (p-value <0.0478 chi-square test).

On full-time farms therewasagreaterwillingnesstopurchaseoperatingcomforte quipment and on sideline farmsfor safety-related equipment in the course of buying new machines (p-value <0.0134 chi-square test). On livestock farms a higher willingness to purchase safety-related equipmentand on farms without livestock operating comfortequipment could be recorded in the course of buying new machines(p-value<0.0193 chi-square test). For near accident victimson medium and largersizedfarms(50 and 10 to 50acres) the willingness to purchase operating comfortequipmentandonsmallerfarms(under 10hectares) the willingness to purchase safety-related equipment dominated significantly (p-value<0.0041 chi-square test).

Awillingness to pay morethan 20% of the replacement valueforadditional safety-related equipment was significantly higher amongnear accident victimsfromlivestock farms. Onfarms without livestock a significantlyhigherwillingness to payup to10% and20% of the replacement value foradditional safety-related equipment could be detected. No differencesbetweenlivestock farms andfarms without livestock could be found as regards the willingness to payup to5% of the replacement value foradditional safety-related equipment.Thelack of the willingness to purchase safety-related equipmentwasfrequently found innear accident victimsfromlivestock farms(p-value<0.0264 chi-square test). Among sideline farmers there exist a higherneed for safety-relevant training, particularlyinthesafety-relevant operation than among full-time farmers when purchasinga new machine(p-value<0.0066 chi-square test).

For small and medium size farms (under 10 and 10 to 50 ha) a higher necessity for safety-related trainings was found than for farms with more than 50 ha (p-value <0.0275 chi-square test). Near accident victims from full-time farms represented significantly more often the opinion that the safety-related training should be done by the machine manufacturer and those of sideline farms by machinery dealers (p-value <0.0119 chi-square test). Near accident victims from medium and large farms (10 to 50 and over 50 ha) reported significantly more often that the safety-related training should be done by machine manufacturers. Victims from small farms (under 10 ha) named machinery dealers and manufacturers as responsible for safety-related training to equal shares (p-value <0.0001 in the chi-square test).

## 4 Discussion

Studies of agricultural and forestrynearaccidentsareonly available fromSwedishandFinnishstudies.These relate

toselectedagriculturalareas, such asindividualtypes of machines(tractors, self-propelled harvestingmachines, chainsaws) and sectors(livestock, forestry, greenhousemanagement) (Gustafssonetal., 1991; Klen, 1997; Laitinen,1984; CarterandMenckel,1985). The observedfrequenciesofnearaccidents(by machine type) reflectthe current trendoftheaccidentfrequencieswithagricultural and forestrymachines(Klen, 1997)althoughtheydifferwith regard to differentresearchquestionsandresearchpriorities(selected machineryaccidents, animalaccidents, overall agriculturalsituation) by country of origin.

The distribution of victims of near accident with vehicles, machinery and equipment in the Austrian agriculture and forestry (77% men, 23% women) by gender is very similar to the national ratio of farm managers (Statistik Austria, 2010). The higher proportion of male casualties is also documented in studies of accidents in the agricultural and forestry sector (human, animal and machine) by Akdur et al. (2010), Bernhardt andLangley (1999), Gerberich et al. (1998), Hartling et al. (1997), Horsburgh et al. (2001), Lee et al. (2012) and Ünal et al. (2008). The age structure of the near accident victims corresponds with a share of the age group from 41 to 60 years to that of the Austrian agriculture and forestry, where 66% of all farm managers (men and women) are over 45 years and 34% under 45 years old (Statistik Austria, 2010). Comparative studies of near accidents in the agricultural and forestry sector show age structures of victims to be 19 to 65 years (Gustafsson et al., 1991). In studies on actual accidents in the agricultural and forestry sector an increased accident rate of the age group under 45 years was found (Bernhardt and Langley, 1999; Gerberich et al., 1998; Lee et al., 2012; Narasimhan et al., 2011; Pickett et al., 2001).

The results for the otherpersonswhowereinvolvedinthenearaccidentsituations howed the same distribution offamily-owned(84.5%) andnon-family members (15.5%) as in the Austrian agriculture and forestry(Statistik Austria, 2010). Gustafssonetal. (1991), Doyle (1988) andThelin (2002)alsoshowhigheraccidentfrequenciesofnearaccidents and actual accidents withagricultural machinery and equipment involving farm managers andfamilymembers. The percentageshare of persons withagriculturaltraining(52.2%) whichwere affected bynearaccidentswas significantly higher thanthat of theAustrian agriculture and forestry(37.6%). The share of those withprofessionaltraining(19.5%) corresponded totheshareof those in theAustrian agriculture and forestry(15.6%). The percentageofnear accident victimswithoutagriculturaltraining(28.3%) was significantly lower thanthat of thenationalagriculture and forestry (46.8%) (Statistik Austria, 2010).Itcanbeconcludedthat respondents from agriculture and forestry which use online media have a higherlevel of education.

Accidentstudiesin the agricultural sectorbyHwangetal. (2001)andGerberichetal. (1998)documentedshares of 53-63% with(general) school educationwithouthighschooldegree and37-47% withhighereducation such as completion ofhighschooloruniversity.Theagriculturaleducationdegree isnot apparent fromthecomparativestudies due to differentspecificationsandthedifferenteducationsystemsof different countries. According to thepercentagedistributionof near accident victimstotheirfarm size,59.6% of accidents occurred onmedium-sized farms(10 to 50 ha), whosepercentage share is above that of theAustrianfarm situation(47.3%). Theshareofnearaccidentfrequencyfor farms ofabout50ha(21.6%) wasslightly higher thantheirpercentageshareof 14.3%. The percentage ofsmallfarms (less than10ha) (18.8%) was significantly lower thanthat of thenationalsituation(38.3%) (Statistik Austria, 2010).

The distribution of farms of the near accident victims into full-time (48%) and sideline (52%) businesses is very similar to that of the national Austrian situation with 41.6%

full-time and 58.4% sideline farms (Statistik Austria, 2010). From studies of accidents in agriculture, it could be derived that similar to near accidents (76% animal husbandry, 24% no animals), persons mainly on livestock (44-75%) than on farms without any livestock (35-56%) were affected by accidents (Hwang et al., 2001; Gerberich et al., 1998; Narasimhan et al., 2011).

Studies ofnearaccidentsintheagriculture and forestryin other countriesshowthatnear accidents, asinAustria(>45%),often occur withhand-held machines(chainsaws) (KlenandVayrynen,1984;Klen,1997). Wearingornotwearingprotectiveclothingwas of great relevance.From the perspective ofthe near accident situation, protectiveclothing(mainly headandfaceprotectioninthe form ofhelmetand visor30%) is essential for avoidinginjuryorserious accidents. Adversefactorsof wearing PSA werenegligent, careless and reckless ways of working(KlenandVayrynen,1984). Near accident victims showed an awareness of theimportanceofwearingprotective clothing and the willingness to buy it was higher than the willingness to buy additional technicalequipment when purchasingnew machines.

ComparativestudiesonagriculturalnearaccidentsfromS wedenshowthatself-propelled machinery(tractors86%), asinAustria, are the most commontypesofalmostaccident-causing machines(Gustafssonetal., 1991). In this context, the most common activities leading to a near accidentwere, asinAustria, the operationof the machine(32%), theascending and descending fromthemachine(26%) and thecoupling and uncouplingofthree-point hitched and towedmachines(11%). Near accidentswithself-propelled harvestingmachines(14%) correspondedtothefrequencyof the Austrian situation(Gustafssonetal., 1991). Thisalsooccurredmostlyduringdirectoperation(46%) as well asservice and maintenance(23%) work.Forbothtypes of machines,similar to near accidentsintheAustrian agriculture and forestry, unfavorable environmentalconditionssuchassloped terrain, rocksandsuddenchanges in directionto avoid obstaclessignificantly contributed to the near accident situations (Gustafssonetal., 1991; Hammeretal., 1990).

The majority of accidents occurred with tractors, followed by three-point hitched and trailed machines (20-40%), hand-held (8-15%) and stationary machines (5%). The most common causes of accidents were the roll- and runover of the machine, accidents caused by coupling and uncoupling as well as during maintenance and repair work (Gil Coury et al., 1999; Cooper, 1971; Doyle, 1988). In Austria near accidents with agricultural and forestry machinery predominantly occurred during direct operation of machines in combination with improper handling, construction defects, adverse environmental influences (sloped terrain) and human factors (hurry, fatigue, stress). According to Gustafsson et al. (1991) and Klen (1997), adverse environmental conditions for self-propelled machines for field work and for chainsaw work led to near accident situations. Narasimhan et al. (2011), Lilley et al. (2008) and Kidd et al. (1996) refer to human factors (work overload, fatigue, haste and stress) in connection with work time constraints as accident causes.

The influenceofimproper handling or construction deficits cannot be concluded from the comparativestudiesofnear accidents. Throughadditionalstudies on the influenceof these parameterssubstantialbenefitsof prevention measuresto avoid accidentscould be derived as a result in future. The riskofa near accidentduringdirectoperationbyunfavorableenvironmenta lconditionscould be confirmedby the high numberof accidents which resultedin the operationof a machine(Mayrhoferetal., 2013; Ventspils,1998; Picketetal., 1999). The influenceofhumaninterferencewasnot substantiated by theresultsof these investigations. From the accident causes, such asbecoming trapped andbeingcaughtbetweenmachines(or machine parts), it

cannot definitely be concluded that improperhandling,machine parts and theiradverseconstruction were responsible for an accident(Mayrhoferetal., 2013; Ventspils,1998; Picketetal., 1999; Hartling,1997).

To avoid near accident situations, measures relating to training in machine operation, followed by mechanical factors, other measures and training in the operation in combination with mechanical factors, the revision and adjustment of design requirements of standards and the development of new machine components or assistance systems were mentioned as prevention measurements in similar studies of near accidents with machines (Gustafsson et al., 1991). In studies of near accidents with hand-held machines (chainsaws), the combination of work instructions, training in the operation and the associated safety management (wearing protective clothing) were cited (Klen, 1997; Carter and Menckel, 1983).

Studies ofaccidentswithfarm machinery yielded the same findings.Toavoidnear accident situationsintheAustrian agriculture and forestry,thecombinationofwearingprotectiveclothing,trainingintheoperationandimplementation of security measures as well as the revisionoftechnicalstandardsof machinery was mentioned (Lee etal., 2012; Angoulesetal., 2007; Linenetal., 2008). Thederivationofspecificpreventivemeasureswasexamined through the accident-causing machine typeor group.When determining thepreventive measures, a differentiationwas made according to types of machines, workareas, peopleandeconomic activity (Akduretal.,2010; Leeetal., 2012; Angoulesetal., 2007; Linenetal., 2008). Narasimhanetal. (2011)referred to thecooperationofmanufacturerswith users andstakeholdersin the design ofmachinestocloseinformationgapsas regards perceptionandbehaviorin the use ofmachines. Laitinen(1984) referred to thedifferentiationofnear accidents according to the degree of exposurein determining thepreventivemeasurestoavoidserious accidents.

Besides the above-mentioned preventive measures of comparative studies on near accidents and real accidents, other parameters can be collected and integrated into the definition of specific measures to prevent accidents. These include surveys of consumers as to their willingness to buy safety-related equipment or ease of use means to integrate specific protective clothing and safety devices in the consumer's purchasing decision for new machines. An accurate determination of who is responsible for the implementation of trainings in the safe operation of equipment would protect the user from encountering application problems of the machines caused by ignorance. The design and construction of electronic and video-based instruction manuals (mobile app, driver information system) could in future serve to reduce application problems and system failures in the practical use of machines.

Comparativestudiesalso showed that, similar to therespondents to surveys on near accidentsintheAustrian agriculture and forestry, older persons tend to read manuals in full and more attentively than other users, and that there were differencesbetweenthesexesand for reading manuals before the first use. Deficitsexistinformalversions (small font, complicated terminology).As afuturedesignofoperatingmanuals, a user-specificdifferentiation, according to customer requirementsandageandmachine type, inelectronic and printed form was determined(Norbey, 2007; MüllerandSchniedewind,1998; GöbelandYoo,2005;Hermann,2008).

## 5 Conclusion

The agriculture and forestry in Austria is characterized by diversity in the natural production conditions and by a high intrinsic level of mechanization of farms. The number of serious accidents at work, in parts with fatalities, resulting from a wide variety of agricultural and forestry activities is still very high. The accident

scenarios, despite ever-improving technology, coordinated prevention measures and better education, where people suffer these injuries are very diverse. Accidents occur during various activities and human-machine interactions in agriculture and forestry.

Regarding this fact near accident research represents a promising tool in accident research which can be used for safety optimization in every area of work. Through the collection and descriptivelyandanalytically, using the chi-square test method, theWilcoxontwo-sampletestandKruskal-Wallis test, analysis of information about near accidents in the agricultural sector, person-specific as well as operational and machine-specific details which reveal potential risks can be identified. The combined analysis of personal and machine- and user-specific data, which shows that regarding personal and farm specific parameters farm managers(mostly men), followed by theirfamilymembers, from 41 to 60yearswith agriculturalandnon-agriculturaltraining weremost frequentlyaffectedbynear accidentsonlivestocksideline farmswithfarm sizesbetween 10 and 50ha, helps to derive and develop measures to prevent accidents and near accidents. As away forward, thepublicationofthe results ofthisstudy should be published for awareness of farmersinagriculturalnewspapers, integratedinthe education systemofagricultural schools and in information sessionsin the contextofadulteducation in the agriculturalsector. Furthermore, therelevant institutions (Social Insurance of farmers) shouldincludethe results of thestudyintheir workspace.

Also, the collection of information about near accidents causing machine parts and human machine environment interaction, which showed that machine-specificworking toolsof hand-heldandself-propelledmachineryduringdirectworking process, influencedbyunfavorableenvironmentalconditions (soil), physicaladverse factors(hurryand stress) andoperatingerrorsweremostfrequentlyinvolved, can help to identify mechanical deficiencies such as design weaknesses, gaps in information and accident-causing man-machine interactions and further needs-based research on prevention measures. In exchange the results of the study shouldreachdirectly manufacturers and distributors of agricultural machinery and the relevant committees which deal with the creation and revision of machines guidelines and standards.

The dissemination of the results could be lead, among other improvements to increasedtrainingintheoperation, followed bymechanicaladaptations, safety equipmentwhen buyingnew machines, training inthesafetydesign of machinesas well aseasy-to-understand andwrittenshortoperating instructions (manuals).

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