Engenharia Agrícola

ISSN: 1809-4430 (on-line)

www.engenhariaagricola.org.br

Doi: http://dx.doi.org/10.1590/1809-4430-Eng.Agric.v39n3p391-399/2019

TECHNICAL PAPER

ERGONOMIC AND SAFETY CONDITIONS ASSESSMENT OF TRACTORS USED BY SMALLHOLDERS ACCORDING TO BRAZILIAN LEGISLATION AND CURRENT STANDARDS[1]

Ângelo V. dos Reis[2*], Aline S. Pereira[3], Mauro F. Ferreira[3], Laurett de Brum Mackmill[3], Márcio W. Timm[4]

[2*]Corresponding author. Universidade Federal de Pelotas/ Pelotas - RS, Brasil.
E-mail: areis@ufpel.edu.br | ORCID ID: https://orcid.org/0000-0002-9765-1816

KEYWORDS

operator's seat, noise level, tractor operator.

ABSTRACT

This article aimed to select items with which to evaluate the ergonomic and safety conditions in tractors used by smallholders and family farmers, based on standardization research and legislation for the sector. Brazil has a comprehensive set of technical standards and legislation for the agricultural machinery sector intended to guarantee product standardization and to promote the health and safety of the users. Therefore, the initial step of this research was to review the technical norms and legislation for the product in order to develop instruments to assess their ergonomic and safety conditions. Twenty-eight Brazilian Technical Standards (NBR) and four Regulatory Norms (NRs) were investigated, in addition to CONTRAN (the Brazilian Traffic Council) Resolution No. 227/2007, which establishes requirements for vehicle lighting and signaling systems, generating 57 safety evaluation items and 35 ergonomic items. These evaluating items were applied to six tractor models commonly sold to smallholders with a rated engine power of 37–57kW. The results indicate levels of safety unconformities as high as 39.7% for the worst case and 44.7% ergonomic-related problems for the same tractor model. These data point to the need for improvements, especially in lower power tractors.

INTRODUCTION

Mechanization in smallholder farms is fundamental for providing profitable production alternatives for farmers by improving practices of soil and water management along with product processing, in addition to reducing the hardship of the tasks performed. One of the machines that has contributed to increasing productivity and efficiency of smallholder's farms is the tractor. It is widely used in agriculture and they have been acquired by smallholder farmers through funding sources such as the National Program for Strengthening Family Agriculture (PRONAF). The purchase of agricultural tractors with funds from PRONAF has proceeded with little or no technical background. It should be noted that the farmer's possibility of payment of the financing installments is the main, if not the only, criterion used. However, other factors are important. Reis et al. (2014) used the multicriteria methodology to identify and evaluate a basis for purchasing decisions using PRONAF resources about low-power tractors that could be used by smallholders in the region of Pelotas, RS. The results were gathered into six main categories: operational cost (weight 0.20), acquisition cost (weight 0.22), ease of maintenance (weight 0.10), tractor capacity (weight 0.26), ergonomics (weight 0.14), and safety (weight 0.08).

Mechanization entails gains in productivity and efficiency, which are easy to measure. On the other hand, we must understand that there are aspects related to farmers' quality of life in regards to occupational health. That was showcased by a survey carried out in the state of Paraná's countryside on accidents related to agricultural activities. They identified 115 accidents, among which 45% were associated with the use of agricultural machinery. The main causes of the accidents identified in this study were distraction, overconfidence, and the absence of personal and collective protective equipment

[1] This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001.
[3] Universidade Federal de Pelotas/ Pelotas - RS, Brasil.
[4] Instituto Federal Sul-rio-grandense/ Pelotas - RS, Brasil.
Received in: 10-10-2018
Accepted in: 3-18-2019

(Ambrosi & Maggi, 2013). Another similar work, executed by Flores et al. (2015) in the Juiz de Fora city region in the state of Minas Gerais among agricultural machine operators, found that the most common types of accidents were lateral or longitudinal overturning of the tractor, found in 66% of the accidents. According to the authors, the operators themselves believe that these accidents occur because of their lack of attention and not because of the absence of training of tractor drivers.

Tractor safety parameter analysis was attempted by Oldoni et al. (2017). These researchers created a checklist comprising 45 of what they called "Components and Security Systems" that were ranked to obtain a "safety index", classifying the included tractors by their safety levels, thus enabling the tractor buyer to choose a model that offers a lower risk of accidents.

One of the most important systems to increase product reliability and to promote consumer protection is compliance assessment. In Brazil, the traditional mechanisms of compliance assessment are practiced through a specially developed methodology that takes into account tools of risk analysis that are based on legal, environmental, social, technical, and economic-financial aspects. This approach allows for selection of the best suited product-specific compliance assessment mechanisms available in the Brazilian Compliance Assessment System. These are: Certification, Supplier Declaration, Labeling, Inspection, and Testing (Inmetro 2017).

This article aimed to present tools developed for conducting assessments on tractors used on smallholder family farms in regards to recommendations of ergonomics and safety present in the normalization and in the current legislation. In addition, we discuss the aspects related to the results obtained by the application of these instruments on five models of tractors that can be financed with PRONAF funds.

SUBJECT DESCRIPTION

Methodology

It was necessary to first select the machine types to be analyzed according to the models available for governmental financing and by geographical region. Selected agricultural tractors for the study were acquired by PRONAF between the years 2011 and 2013 with a nominal engine power of 37–57kW. Based on this, we chose the following tractor models: Massey Ferguson 4275 (56kW) and 255 (37kW), Valtra A750 (57kW), John Deere 5075E (55kW), and New Holland TL 75E (57kW).

We then proceeded to the documentary study of the printed technical standards available at the Innovation Center for Agricultural Machinery and Equipment (NIMEq) of the Federal University of Pelotas (UFPel) and the Institution's website with free access to the online consultation database of ABNT. We researched 28 Brazilian Technical Standards (NBR) and four Regulatory Standards (NRs) in addition to CONTRAN (the Brazilian Traffic Council) Resolution No. 227/2007, which establishes requirements for vehicle lighting and signaling systems. These standards and resolutions will be presented in the results of this proposal. The legislation and standards consulted are listed in Table 1.

TABLE 1. Legislation and standards consulted.

DOCUMENTS USED	
NBR ISO 26322-1:2011	Tractors for agriculture and forestry - safety - Part 1: Standard tractors
NBR ISO 26322-1:2013	Tractors for agriculture and forestry - safety - Part 2: Narrow tracks and small tractors
NBR ISO 4252:2011	Agricultural tractors - Operator's workplace, access and exit - Dimensions
NBR ISO 4253:2015	Agricultural tractors - Operator's seating accommodation - Dimensions
NBR ISO 12003-1:2011	Agricultural and forestry tractors - Roll-over protective structures on narrow track wheeled tractors - Part 1: Front-mounted ROPS
NBR ISO 12003-2:2011	Agricultural and forestry tractors - Roll-over protective structures on narrow track wheeled tractors - Part 2: Rear-mounted ROPS
NBR ISO 5700:2013	Tractors for agriculture and forestry - Roll-over protective structures (ROPS) - Static test method and acceptance conditions
NBR ISO 3776-1:2009	Tractors and machinery for agriculture - Seat belts - Part 1: Anchorage location requirements
NBR ISO 3776-2:2013	Tractors and machinery for agriculture - Seat belts - Part 2: Anchorage strength requirements
NBR 10152:1987	Noise levels for acoustic comfort - Procedure
ISO 13857:2008*	Safety of machinery - Safety distances to prevent hazard zones being reached by upper and lower limbs
NBR NM ISO 13854:2003	Safety of machinery - Safety distances to prevent danger zones being reached by the upper limbs
NBR 14009:1997	Safety of machinery - Principles for risk assessment
ISO 500-1:2014*	Agricultural tractors - Rear-mounted power take-off types 1, 2, 3 and 4 - Part 1: General specifications, safety requirements, dimensions for master shield and clearance zone
NM 273:2001	Safety of machinery - Interlocking device associated with guards - Principles for design and selection

NBR ISO 5008:2015	Agricultural wheeled tractors and field machinery - Measurement of whole-body vibration of the operator
NBR 14154:1998	Safety of machinery - Prevention of unexpected start-up
NBR 5413:1992	Interior lighting–Specification
NBR 9999:1987	Measurement of noise at the operator's position of agricultural machinery and tractors
NBR ISO 11684:2013	Tractors, machinery for agriculture and forestry, powered lawn and garden equipment - Safety signs and hazard pictorials - General principles
NBR ISO 4254 -1:1999	Tractors and machinery for agriculture and forestry - Technical means for ensuring safety - Part1: General
NBR NM ISO 5353:1999	Earth-moving machinery, tractors and machinery for agriculture and forestry - Seat index point
NBR NM 213-1:2000	Safety of machinery - Basic concepts, general principles for design - Part 1: Basic terminology, methodology
NBR NM 213-2:2000	Safety of machinery - Basic concepts, general principles for design - Part 2: Technical principles and specification
NBR ISO 3864-1:2013	Graphical symbols–Safety colors and safety signs Part 1: Design principles for safety signs and safety markings
NBR 5556:1986	Road vehicles, and tractors and machinery for agriculture and forestry - Symbols for controls, indicators and tell-tales–Symbology
NBR ISO/TR 16982:2014	Ergonomics of human-system interaction - Usability methods supporting human-centered design
NBR ISO 9241-143:2014	Ergonomics of human-system interaction - Part 143: Forms
NR 31	Occupational safety and health in agriculture, livestock, forestry and aquaculture
NR 17	Ergonomics
NR 12	Safety at work on machines and equipment
NR 15	Unhealthy activities and operations
Resolution Nº 227/2007	Requirements related to lighting and signaling systems of vehicles

* Adopted by ABNT.

From these resources we have developed data collection instruments to evaluate tractors commonly used by smallholders. We then validated these instruments, first through a pilot test, which used one of the tractor models available at UFPel in order to evaluate its theoretical construction effectiveness. The pilot test allowed for instrument adjustments, legitimizing quantitative data collection performed during the year 2015 at four tractor dealers of Pelotas in the Rio Grande do Sul state. We used new tractor models to avoid including machines that could be worn or adversely affected by misuse.

The materials used in the measurements were: Bosch laser beam, model Professional GLM 30, with a measurement error of ± 2mm; a digital camera with 16.1 Mp and a decibel meter with a 4-digit liquid crystal display, resolution: 0.1dB, IEC 61672 type 2, weighing: A.

For noise measurements, we performed three readings with the tractor engine idling, three readings on the engine speed indicated to produce 540 rpm in PTO (unloaded) and three readings accelerating the engine to full throttle speed, also in a no-load condition. The noise was measured in accordance with the procedures laid down in ABNT NBR 9999. This standard establishes that the test site must have a radius of 20m free from interference (buildings, walls, trees, and other vehicles), the wind speed should not exceed 20km h^{-1}, and the temperature should be between 5 and 30°C. It also explains why it is necessary to measure background noise, which should not exceed 10 dB (A). The microphone of the decibel meter has to be located 250 mm ± 20 mm from the lateral-central plane of the seat, where the highest sound pressure level is found. The evaluated tractors were invariably located in the external area of the dealerships due to these requirements.

It was also necessary to make a device for measuring the operator's station (Seat Index Point - SIP), following the guidance of the standard ABNT NBR NM ISO 5353. In order to simulate the sitting operator, the SIP was used to make measurements that corresponded to the intersection of the central vertical plane passing through the center line of the seat in the theoretical axis rotation between the torso and the operator’s pelvis. In this way, the described measures were taken using the SIP, a horizontal and vertical reference ruler, and a bubble level. To determine the SIP, the operator's seat must be in the vertical with horizontal adjustments at intermediate positions according to the ISO 5353 standard. Figure 1 shows the measurements for the free interior space of the tractor cab and Figure 2 shows the location of the SIP on the operating station.

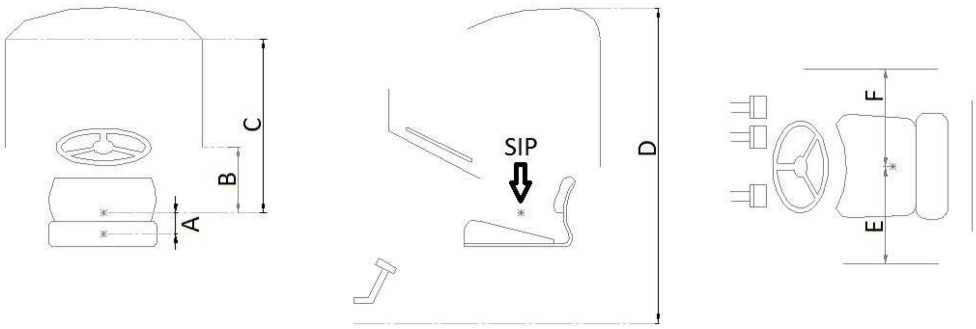

FIGURE 1. Dimensions established by NBR ISO 4252: 2011, where: A - from the center of the SIP to the center of the backrest; B - SIP to steering wheel; C - SIP from the instrument panel; D - from the platform base to the bottom surface of ROPS; E - from the SIP to the left mudguard; F - from the SIP to the right mudguard.

FIGURE 2. Device for determining the SIP positioned on the seat of a sampled operating station.

RESULTS

By analyzing the legislation and standards for agricultural tractors, we have identified 57 safety items and 35 ergonomic items. The scale selected for evaluating the tractor for these items was: conforms (complies with standard), non-conforming (does not meet the standard–stating the reason) or does not apply. Tables 2 and 3 present the items used for the safety and ergonomics evaluations, respectively.

TABLE 2. Legislation and standards elements used to collect safety data on tractors.

N°	Safety Components and Systems (SCS)
1	Operational controls (steering wheel or levers, shift levers, cranks, pedals and switches must have easy and safe control. They cannot obstruct access)
2	Handrail / handhold (means of support such as handles or handrails, bars, footrest or non-slip steps)
3	Minimum dimensions of internal space
4	Sharp or smashing points while sitting
5	Reach of the operator's feet (it may jeopardize tractor control)
6	Reach of the operator's hand (it may jeopardize tractor control)
7	Presence of a seat that supports the operator and instructions for its use and adjustment in the manual
8	Two-point seat belt
9	Auxiliary seat for instruction
10	Flammability rating of the cabin material (only observe material and take note)
11	Protection at the PTO (check whether it is reversible, if any)
12	Requirements and resistance of protections and shields

13	Electrical equipment (see standard NBR ISO 26322-1, access, protection)
14	Hydraulic components and connections (see NBR ISO 26322-1, access, protection)
15	Ballast (take note of the present weights)
16	Leveling adjustments - three-point hitch system (see standard NBR ISO 26322-1, if automatic, access inside the cab)
17	Fuel systems (see standard NBR ISO 26322-1, operating manual)
18	Roll-over protective structures (ROPS)
20	Hot surfaces (see standard NBR ISO 26322-1, exposure, symbology)
21	Exhaust gas (see standard NBR ISO 26322-1)
22	Manuals - should be provided by the manufacturer
23	Safety and warning signs (alert flashes)
24	Emergency exit (number, location and signaling - at least two), applicable for cabin tractors only
25	Starting and stopping devices must be designed, selected and installed to prevent accidents (i.e.,: start only when the gearbox is in neutral)
26	Electrical or safety interfaces commands - do not cause loss of safety due to failure
27	Simple and unmonitored mechanical interlocking device for protection of the engine compartment
28	Safety sensors (optoelectronic presence detectors, multi-beam laser, optical barriers, area monitors, or scanners, backstops, mats and position sensors)
29	Batteries located for easy exchange and security to prevent accidental contact and short circuits
30	Headlights, taillights, horn, rear view mirror and automatic reverse beep
31	Trailer coupling system must have easy and safe coupling and uncoupling (see if semiautomatic attachment connectors are available)
32	Access permanently fixed and safe at all points of operation and supply, among others
33	Safe access must be indicated in the operating manual
34	Means of access if the height of the workstation is greater than 0.55m
35	Means of access must be designed, constructed, and fixed firmly
36	Means of access must be resistant
37	Fuel tank filling
38	Electrical installations shielded, isolated, and grounded
39	Safe electrical supply (resistance against abrasive materials, suitable materials, etc.)
40	Prohibited in machinery and equipment: general switch acting as an on and off device
41	Prohibited in machinery and equipment: exposed energized parts
42	Starting devices, drive and stop: located outside the hazardous zone
43	Starting devices, drive and stop: they can be switched off in emergencies by others
44	Starting devices, drive and stop: should prevent accidental activation
45	Starting devices, drive and stop: cannot be overridden
46	The controls must have devices that prevent their automatic operation when energized
47	Emergency stop devices
48	Protection of hoses in pressurized systems
49	Exhaust tubes (location and direction to avoid harmful gases or smoke entering the cab, observing the plane of the operator's head and the cabin air inlet)
50	Warning signs and lights (signaling)
51	Shields, components, handrails–yellow
52	Shutdown and maintenance warning–blue
53	Machinery and equipment must include manufacturer's information
54	Qualitative or quantitative indicators or safety controls to warn workers about hazards (cognitive aspect such as a buzzer)
55	They must not allow errors in assembly or reassembly in a way that does not generate risks (design, manufacture, import, sale, use)
56	Fuel, flammable, explosive and substances that react dangerously
57	Accessible hot surfaces that present a risk of burns

TABLE 3. Legislation and standards elements used to collect data on ergonomics in tractors

N°	Ergonomics Components and Systems (ECS)
1	Visualization and operation (having height and work surface characteristics compatible with the type of activity)
2	Field of vision of the eyes on the work field (seated manual work)
3	Seat height adjustment (seated manual work)
4	Having the work area within an easy reach and view
5	Proper positioning and movement (seated manual work)
6	Conditions of proper posture
7	Positioning and dimensions (use of feet)
8	Height adjustable to the stature of the worker and the nature of the function performed (the seats)
9	Characteristics of little or no deformation in the seat base
10	Rounded front edge of the seat base (seats)
11	Backrest with a shape slightly adapted to the body to protect the lower back
12	Footrest
13	Noise levels according to NR15 (<85 dB for 8 h working)
14	Static or dynamic muscle overload in the neck, shoulders, back, and upper and lower limbs
15	Lifting and manual transport of loads, transport and unload of material (60 kg), lifting (40 kg) in the case of tractor ballast
16	Respect to the postural, cognitive, movement, and physical efforts demanded from the operators
17	Video monitors, signals, and commands should enable clear and precise interactions
18	Icons, symbols, and instructions should be consistent in their appearance and function
19	Reduction of the force, pressure, hold, flexion, extension or twist requirements of the body segments
20	Lighting should be appropriate and be available in emergencies (taillight)
21	Location and distance to allow easy and safe operation (commands)
22	Accessible to the operator (commands)
23	Visibility, identification, and signaling
24	Allow posture alternations and proper movement
25	Must not have sharp corners, rough surfaces, sharp edges, or burrs
26	They must allow the integral support of the feet’s soles on the floor (workstations)
27	Meet anthropometric and biomechanical characteristics of the operator (dimensions of workstations)
28	Ensure proper posture, so as to ensure comfortable positions (dimensions of workstations)
29	Avoid bending and twisting the trunk in order to respect the natural angles and trajectories of body movements (dimensions of workstations)
30	Solid, liquid, or gaseous chemical agents (fuels, dust, fumes, mists, haze, gases, or vapors)
31	Non-ionizing radiation (heat: sunlight, communication systems, microwaves)
32	Symbols, inscriptions, light or sound signals
33	Highlighted, visible and easy to understand (signaling)
34	Symbols, inscriptions, and illuminated signs should follow the normative standards (signaling)
35	Be readable and be in Portuguese (signaling)

The research of Vilagra (2009) emphasizes that assessment tools should be developed and applied to various stakeholders such as farm tractor operators, engineers, specialists, and farmers. This author evaluated 14 comfort elements (ergonomics) and 20 safety items, which were used as a reference. Similarly, Debiasi et al. (2004) proposed an important tool for quantitative ergonomic and safety conditions evaluation of agricultural tractors. Presenting the sensitivity to the variations indicated by the tractors to these characteristics, the Partial Coefficient of Ergonomics and Safety in agricultural tractors (COPES) totaled 43 features in the safety area and 13 in ergonomics.

The research presented in this article used the standardization and legislation of the tractor sector as a data development basis for collection of instruments, selecting 55 safety items and 37 ergonomic ones. After data collection using the previously selected instruments on the chosen tractors at dealerships, we obtained the following results that are presented in Figures 3 and 4, ordered by engine rated power. It is important to note that these values do not include measurements made at the operator's workstation. These will be presented later in the text.

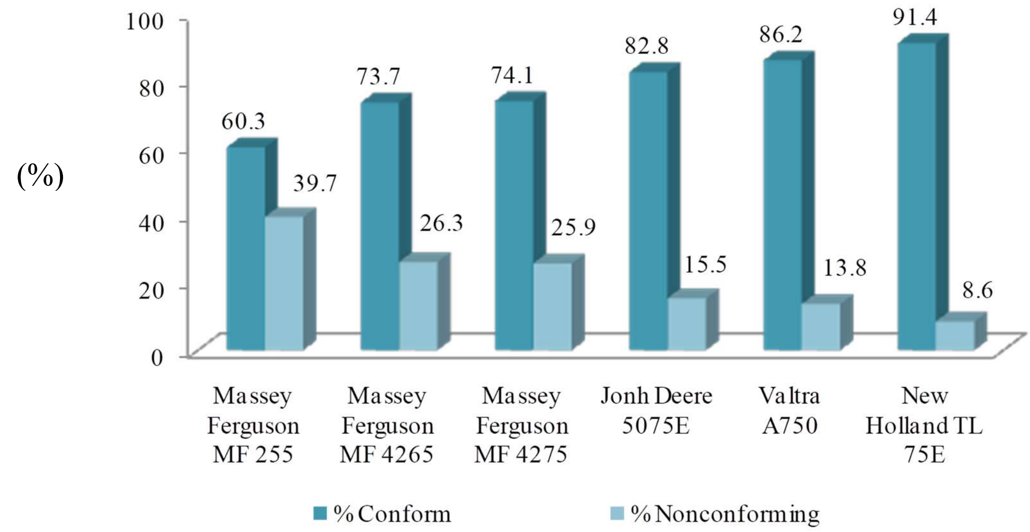

FIGURE 3. Percentages of compliance for safety criteria for each tractor model.

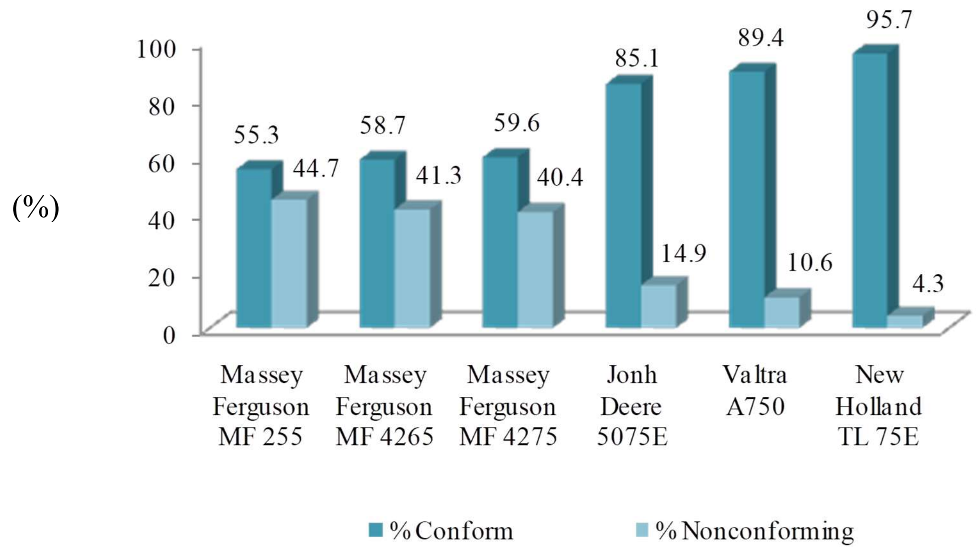

FIGURE 4. Percentages of compliance for the ergonomics criteria for each tractor model.

The criteria that do not meet either the norms or the safety legislation pertinent in the surveyed tractors are: pedal location; position and type of access ladder; reach from the operator's hand to the control panel; adjustable seats; protective structures against falling objects and access to danger points; exposure to sharp points or crushing sites while the operator is seated; lack of symbology (with higher occurrence for hot surfaces and chemicals); inadequately located exhaust pipe; lack of safety sensors (such as sound signals that could be installed to alert to the risk of overturning); and adequate fuel supply (a location that favors supply). In Figure 3 we can observe that the level of compliance with safety standards and norms increases along with the rated power of the tractors. The tractor model MF 255 (37 kW) had the lowest safety compliance rate according to our tool and the tractors with a higher power that were evaluated (NH TL 75E and Valtra A750) achieved the highest levels of compliance. These findings agreed with the conclusions of Oldoni et al. (2017) that an increase of safety indexes occurs proportionally to engine power increases in tractors sold in Brazil, which is possibly related to the increased machine price.

Among the items that do not meet the legislation or the standards relevant to the ergonomics we have highlighted: consideration of the body dimensions to design the workplace; possibility of bad posture for the operator causing him or her to perform flexion and rotation of the torso and not respecting the natural angles and trajectories of the body movements; control panel display (that is, hampered by the steering wheel); safety control devices to warn workers about the hazards (NR12); and environmental comfort.

Regarding ergonomics, in Table 4 we present the results of measurements made at the operator's workstations of five models of tractors of the main brands marketed in Brazil. This evaluation was performed in accordance with NBR ISO 4252:2011 Agricultural Tractors - Operator's Workplace, Access and Exit - Dimensions, which specifies agricultural tractor cabs free internal space dimensions for agricultural tractors having a minimum track width exceeding 1,150 mm.

TABLE 4. Dimensions of the operator's workplace.

Dimension	A* (mm)	B (mm)	C (mm)	D (mm)	E (mm)	F (mm)
As specified by ISO 4252: 2011	90	< 310	> 810	> 900	> 300	> 300
Tractor Model						
Massey Ferguson 4275 (56kW)	70**	468	730	1,420	362	370
Massey Ferguson 255 (37kW)	90	470	660	1,450	371	390
Valtra A750 (57kW)	90	570	940	1,200	320	380
John Deere 5075E (55kW)	150	440	710	1,590	321	378
New Holland TL 75E (57kW)	90	270	890	1,720	465	505

* See Figure 1.
** The underlined dimensions are outside the range established in NBR 4252: 2011.

We found that the tractor models surveyed do not fully meet the standardized dimensions. Those models that meet the dimensions, only meet them for D (distance from the platform base to the lower ROPS surface), E (distance from the SIP to the left mudguard), and F (distance from the SIP to the right mudguard). It is worth highlighting the fact that the New Holland TL 75E brand model meets all dimensions of the operator's workplace as determined by the standards.

It should also be noted that some measures were not executable, since the standard NBR ISO 4252: 2011 is applied only to cabined tractors; however, those acquired through PRONAF in the years surveyed had no cabin. Concerning this aspect, a similar research study carried out by Peripolli et al. (2017) using the same standard in tractors with an engine power of 56 to 123kW indicated the internal free space of the cabins were in accordance with this standard. On the other hand, the research by Mattar et al. (2010), performed on national tractors with a rated power between 36 and 132kW, found that these did not meet the minimum requirements of the same standard involving the access and exit of workplaces. The authors also observed a trend towards the conformity of the workplace to standards of accesses and exits with an increase in the analyzed tractor's engine rated power.

Before presenting the results on noise, it is important to note that NR 15 establishes a maximum sound pressure of 85 dB (A) up to a working day of 8 h or 90 dB (A) for a period of 4 h. Additionally, exposure to noise levels above 115 dB (A) is not permitted for individuals who are not adequately protected. NR 17 indicates that noise levels must comply with NBR 10152, observing an acceptable noise level for comfort up to 65 dB (A) and a noise evaluation curve of a value not exceeding 60 dB (A). The NR15 standard was selected as a reference in this work since it supports the Brazilian legislation to provide guidelines on mandatory procedures related to safety and occupational health. Table 5 summarizes the results found during noise measurements of the tractors evaluated in this study.

TABLE 5. Noise measurements at the operator's workplace.

	Tractor model														
	NH TL75E			A750			JD5075E			MF4275			MF255		
	Engine speed*														
Statistics	Idle	540 rpm	Full	Idle	540 rpm	Full	Idle	540 rpm	Full	Idle	540 rpm	Full	Idle	540 rpm	Full
Mean (dB)	73.5	82.0	89.5	58.2	80.9	85.8	79.8	89.5	93.4	66.5	80.0	89.7	71.3	89.6	95.3
Sd (dB)	8.5	4.9	3.0	3.6	0.3	8.4	1.0	0.2	0.2	10.7	6.9	2.7	12.8	6.5	3.6
Cv (%)	11.6	6.0	3.4	6.3	0.4	9.8	1.3	0.3	0.2	16.1	8.6	3.0	17.9	7.3	3.8

* Idle- engine idling; 540 rpm- engine speed set to generate 540 rpm at PTO; max- engine full no-load speed.

From the tests, we noticed that at idle speed the noise ranged up to 80 dB (A). For this speed, the lowest measured value was for the Valtra A750 with 58 dB (A), and the highest value reached almost 80 dB (A) in the John Deere brand model JD5075E. At an engine speed to provide 540 rpm at the PTO shaft (unloaded), the Massey Ferguson MF 4275 tractor had the lowest value at 80 dB (A) and the Massey Ferguson MF 255 tractor along with JD5075E had the highest value exceeding 89 dB (A). In the measurement performed when accelerating the tractor until it reached maximum unloaded rotation, the Valtra tractor model A750 again presented the lowest value with less than 86 dB (A), and the tractor Massey Ferguson model MF 255 had the highest value of 95 dB (A). For the noise tests we noticed a high coefficient of variation (CV) for the data from the Massey Ferguson models MF 4275 and MF 255 in idle conditions and for the tractor Valtra model A750 in the measurement with the engine at full speed. The other tests had a CV lower than 8.6% for the two highest rotations.

The results show that the noise levels do not always meet the NR 15 values, mainly for the maximum rotation measured. It should be noted that in smallholder's agriculture there is no formal working relationship, so it is necessary to make farmers aware of the need for safety equipment since it is often not used.

It is important to emphasize that noise testing for new tractors such as those tested at dealerships is not simple to perform, and the standard testing procedures apply only for controlled environments, which could bias the results. This could happen because when the tractor is in the field, performing routine activities, the environmental conditions are not the same as those during testing. Factors such as climate (temperature, humidity, and wind), the soil characteristics, and the tractor operator (habitual driving practices), among others, may alter the noise levels. Baesso et al. (2017) assessed the noise level of 22 different models of tractor sold in Brazil between 1977 and 2013 in the power range of 48 to 158 kW, using the same testing methods presented here. They found that most of the tractors emitted noises higher than the threshold established in NR 15. Also, Nascimento et al. (2013) reported the results of a work with a walking tractor, disclosing that the tractor presented unsatisfactory high levels of noise and, therefore, suggested that the operators of these machines should use personal protective equipment full time.

FINAL CONSIDERATIONS

Research into Brazilian standards and legislation on agricultural machinery and the like made it possible to develop an assessment tool for brand new tractors concerning their safety and ergonomics issues, comprising 57 safety and 35 ergonomic evaluation items. The application of this tool to evaluate tractors commonly sold to smallholders in the power range of 37 to 57 kW indicates a level of safety unconformities as high as 39.7% for the worst case and 44.7% ergonomic-related problems for the same tractor model. These results highlight the necessity for improvements, especially in lower power tractors. The most frequent problems were the following: internal dimensions and access to the operator's workstation, a seat with limited adjustments, lack of protection against falling objects, unprotected exposure to hot surfaces, and an inadequately located exhaust pipe.

The noise measurement showed that the evaluated tractors generate levels of noise outside the boundaries set by NR15 and therefore require the use of personal protective equipment during their operation.

REFERENCES

Ambrosi JN, Maggi MF (2013) Acidentes de trabalho relacionados às atividades agrícolas. Acta Iguazu 2(1):1-13.

Baesso MM, Modolo AJ, Baesso RCB, Fischer C (2017) Níveis de ruído emitidos por tratores agrícolas. Brazilian Journal of Biosystems Engineering 11(3):229-238.

Debiasi H, Schlosser JF, Willes JA (2004) Acidentes de trabalho envolvendo conjuntos tratorizados em propriedades rurais do Rio Grande do Sul, Brasil. Ciência Rural 34(3):779-784.

Flores FJS, Rinaldi PCN, Alvarenga CB, Fernandes HC, Cidrini IA (2015) Acidentes com tratores agrícolas em Rio Pomba, zona da mata de Minas Gerais. Revista Árvore 27(6):887-895.

Inmetro. Avaliação da conformidade. 6 ed. Available: http://www.inmetro.gov.br/inovacao/publicacoes/acpq.pdf. Accessed: May 16, 2017.

Mattar DMP, Dallmeyer AU, Schlosser JF, Dornelles ME (2010) Conformidade de acessos e de saídas de postos de operação em tratores agrícolas segundo Norma NBR/ISO 4252. Engenharia Agrícola 30(1):74-81.

Nascimento EMS, Viliotti CA, Mion RL, Albiero D, Monteiro, LA (2013) Avaliação do nível de ruído emitido por um microtrator em condição estática e dinâmica. Semina: Ciências Agrárias 34(3):1121-1128. DOI: 10.5433/1679-0359.2013v34n3p1121

Oldoni A Spagnolo RT, Morais CS, Rocha MAN, Machado ALT, Reis AV (2017) Safety index for agricultural tractors. Acta Scientiarum Technology 39(1):9-15. DOI: 10.4025/actascitechnol.v39i1.27359

Peripolli JLZ, Alonço AS, Possebom G (2017) Conformidade do espaço interno livre de tratores agrícolas e itens de segurança obrigatórios segundo as normas NBR/ISO 4252 E NR 12. Tecno-Lógica 21(2):103-107.

Reis AV, Machado ALT, Gomes MC, Andersson NLM, Machado RLT (2014) A multicriteria model to assess tractors used in family agriculture. Engenharia Agrícola 34(4):727-737.

Vilagra JM (2009) Adequação ergonômica de trator agrícola de média potência: construção e validação de um instrumento de avaliação a partir do construto de conforto, segurança e eficiência. Tese Doutorado, Florianópolis, Universidade Federal de Santa Catarina, Programa de Graduação em Engenharia de Produção.