Full Length Research Paper

Ergonomic characterization of three sugar cane harvester machinery models

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Due to the latest expansion on Brazilian agricultural area, there has been growing demand for field machinery usage aiming at increasing operational efficiency along with cost reduction on production as well as searching for improvement of working conditions. This paper aimed at ergonomic characterization comparing three models of agricultural harvesters on sugar cane plantations in order to provide information to help decision takers. Each harvester was analysed in 157 items. Results showed that ergonomic design in the three analyzed harvesters had high safety level to operators. Nevertheless, there is the necessity of improvement in some analysed items within operator’s working place.

Key words: Anthropometry, agricultural mechanization, ergonomics, Saccharum species, safety.

INTRODUCTION

Agricultural mechanization within Brazilian agriculture has great importance for competitiveness (Peloia and Milan, 2010). Therefore, agricultural machinery usage is essential and crucial for Brazilian agribusiness for minimizing worker’s physical effort, improve operational productivity, and also add quality and reliability in field work.

Considering sugar cane as one of the most important Brazilian agricultural products which has been growing and having high demand on production, is likely to occupy vast farming areas and thus mechanized harvesting has high importance for such cultivation (Pezzin Junior et al., 2013; Silva et al., 2011).

Agricultural machinery operators have driving position in the cabin as their main activity, therefore, the importance for observing ergonomic criteria which may establish the correct adaptation within man-machinery components (Fontana and Seixas, 2007).

Within the current agricultural development farming, machinery industries have been closely observing operator’s workplace through technical ergonomic knowledge. However, several requirements are still neglected (Nietiedt et al., 2012).

Ergonomics is the science which studies man and working environment interaction, considering the positive and negative effects of such relationship (Almeida, 2011). Recently, the inclusion of ergonomics into the design of products has gained importance (Souza et al., 2012).
Table 1. Technical specification of evaluated sugar cane harvester machineries.

<table>
<thead>
<tr>
<th>Technical characteristic</th>
<th>Harvester brands and models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hour meter (h)</td>
<td>CASE IH 8800</td>
</tr>
<tr>
<td>Motor (brand/model)</td>
<td>CASE IH C9</td>
</tr>
<tr>
<td>Power (HP)</td>
<td>330</td>
</tr>
<tr>
<td>Wheel sets</td>
<td>Crawler</td>
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</table>

Villarouco and Andreto (2008) consider that a full ergonomic evaluation covers a wide range of variables requiring efforts from several different areas.

According to Leite and Carvalho (2011), ergonomics covers the study of previous working conditions, that is, the concept of work as well as its consequences which interact in the relation of man, machine, and environment, while relating with such production system.

Pizo and Menegon (2010) also say that the interaction which occurs among such parts of the process leads to increased knowledge or consciousness level of activity which will be key factor when implementing ergonomic actions resulting from the diagnostic as well as from proposed transformation.

For Silva et al. (2009), it is the employer’s duty to conduct ergonomic analysis in workplace taking into account the working conditions according to Regulatory Convention 17 – Ergonomics, established by Ministry of Labour through Ordinance No. 3751, of November 23rd, 1990, which defines the parameters that allow the adaptation of working conditions to worker paraphysiological characteristics aiming at generating maximum comfort, safety, and efficient performance.

In this context, by means of ergonomic analysis, it is also possible to identify physical, cognitive and social risks and also to provide actions aiming at improving comfort and safety for the worker. Therefore, this paper aimed at compared ergonomic characterization of three models of harvester machinery used at sugar cane plantation in order to provide information to help decision makers.

MATERIALS AND METHODS

Ergonomic data from three harvester machinery (Table 1), from sugar and ethanol plant, were collected from March to May, 2014. Harvester machinery is used in sugarcane (Saccharum species) plantations in the Midwest of São Paulo State.

According to Volpato et al. (2012) due to the lack of a specific manual for ergonomic evaluation for sugar cane harvester machinery, the methodology proposed by Eriksson et al. (2006) was used. One hundred and fifty seven items were measured in order to obtain an overview of ergonomic profile of harvesters according to the following aspects:

Access to cab: 19 items were evaluated, highlighting height measurement of the first step for accessing the cab as well as measurements of the other steps, stair width and depth, height and diameter of access handle, dimensions of access door, and emergency exit;

Cabin: for this step, 10 items were evaluated such as cabin height, distance between dashboard and seat, front and rear windshields in relation to height of operator’s head, room for legs, place for personal items storage, and sharp corners or edges among other items;

Visibility: eight items were evaluated such as viewing distance between operator and the ground and vice-versa, viewing angle, windshield cleaning systems, view obstruction points;

Operator seat: 22 items were evaluated in this section emphasizing height, depth and width of the seat, backrest height, type of suspension, size and moving angles of armrest, seat position configurations;

Commands and instruments: 13 items were collected such as the distance from primary and secondary controls, control identification and positioning, distance among commands moved by the feet, strengths for moving commands;

Machinery operation: 7 items evaluated the operator’s control over automatized functions, movement of grip controls, break reliability, number of platform activation, and speed;

Machine information: 6 evaluated items of circumstances in which the operator can hear, see or feel alert signs of danger, an overview of control dashboard, color and symbols on operation displays;

Operator’s position: 4 items were evaluated for seat adjustments, armrest, controls and instruments, adequacy of operator station for different biotype operators;

Noise: 4 different situations were evaluated on working conditions according to noise level. Equivalent level (Leq) was obtained from Regulatory Convention 15, established by Ministry of Labour, presented by Atlas Team (2014);

Cabin climate control: among 6 evaluated items, temperature was highlighted as well as solar radiation controls;

Gas and particles: 6 evaluated items of air inlet, dust removal filters, pollen and soot, and regulation of gas emission which are of greatest importance in this section;

Lighting: 10 items were evaluated, emphasizing on lighting within operational and conduction area, lighting reduction, lighting direction, reflection on glass or on parts of the machine;

Instruction manual: in this section, 13 items were evaluated: scope of instructions, language, level of instructions, diagnosis of
Table 2. Ergonomic classification of evaluated harvesters according to used methodology.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Characteristics</th>
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<tbody>
<tr>
<td>A</td>
<td>Operation is highly productive in all kinds and conditions of geographical relief, with high level of safety</td>
</tr>
<tr>
<td>B</td>
<td>Operation can be developed within a highly productive operational efficiency but under easier cultivation and smoother relieves conditions than those elicited in classification A, with a higher safety level but not as class A pattern</td>
</tr>
<tr>
<td>C</td>
<td>This classification is considered within medium safety level. Operation should be developed under easy working conditions. Thus, it should be in a lower operational pace, within a shorter time and lower safety level than in B classification</td>
</tr>
<tr>
<td>D</td>
<td>Operation requires easy working conditions, lower operational pace and shorter time than C classification</td>
</tr>
<tr>
<td>E</td>
<td>Machinery either does not meet mandatory safety requirements or has a high level of injury for the operator being necessary the correction of such items to be used</td>
</tr>
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failures, maintenance routine, safety, ergonomics, warranty conditions;

Maintenance: this section had the highest number of evaluated items totaling 29, emphasizing failure diagnosis graphic, diagnosis on engine problems, auxiliary lifting devices and lighting, hood or protective covers, floor on maintenance platform, among others. Result interpretations (Table 2) were based according to Eriksson et al. (2006) classification.

For evaluation development, the following materials were used: digital sound pressure measurerInstrutherm, DEC-416 model, used for noise level evaluation; digital light intensity Lux measurerInstrutherm, LDR 208 model; tape measure light intensity Lux measurer, Instrutherm, LDR 208 model; tape measure, scale and measuring tape with millimetric records and a protractor for measuring curvature degrees.

Goodman test with multiple comparisons within and among multinomial populations (Goodman, 1964, 1965) was carried out for section proportion comparisons in each evaluation score (classification) among evaluated harvester machinery as well comparisons of section proportions within the same classification among harvesters. It was considered a 5.0% significant level and each section evaluation was independently conducted.

RESULTS AND DISCUSSION

Due to great physical effort to get in and get off the operation platform in agricultural machinery, it is necessary for the development of technical-scientific studies which may result in improvement of access and exit at workplaces.

So access to cab, in the three evaluated harvester models, were classified as E score for showing high injury risk to operators due to height of the first step in relation to the ground as well as the distance between stair steps. This is endorsed by Mattar et al. (2010) when affirming that national agricultural machinery do not meet minimum requirement of Regulatory Norm NBR 4252 regarding access and exit from operating platform.

Monteiro (2010) defines the cabin on agricultural machinery as a place to protect the operator from the sun or from the rain, cold, dust, emissions, noise as well as minimize vibrations thus providing thermal comfort.

Within such context, the main detected problem in evaluated cabs was the distance from the rear windshield with the height of operator’s head, which has an inadequate distance what may cause injury to operator (average 575 mm). It was also observed that the lack of a place to keep personal belongings or even first aid items may jeopardize operational safety for these items may shift due to machinery jerking. Thus, this section was rated C for the three evaluated harvesters.

Visibility from operational platform, that is, from the cabin is extremely important; for it can decrease or eliminate accidents besides providing an adequate positioning, which may consequently result in a lower physical effort from the operator. For Fiedler (1995), operator’s visibility must not have interference from fogged, small or even badly distributed windshield glass. Visibility must also not be obstructed by narrow screens, hydraulic hoses or by windshield wiper.

According to evaluations, it was observed that the three studied harvesters provide operator with a vertical viewing angle (on working position) ≥ 65°. The three machineries also have windshield and side window defroster systems as well as a cleaning system. However, visibility is blocked in rear view due to a structure on the machinery used for operation and it also has limitation for viewing ratoon cane, that is, distances of 2 m inferior from the side of the harvester resulting in a C rating for evaluated harvester models.

Agricultural machinery is relatively complex and is made up of several compounds. Operator’s seat is one of this important compound. If it is not correctly adjusted to the different biotypes, it may cause tiredness or even
Agricultural machinery operation is an activity which encompasses basically two factors: man (operator) and engine (tractor) (Debiasi et al., 2004). Such performance carried out for long hours can be considered hard chore. Therefore, the correct body posture directs to an adequate comfort for the operator who will consequently have a better operational efficiency. Thereafter, operator's position in the three analysed harvesters is not impaired and was rated B.

Noise is a sound wave, or a complex of waves, which can cause discomfort and gradual hearing loss (Cunha et al., 2009). Constant or recurrent noise can also be defined as any undesirable sound being that for agricultural machinery the greatest noise sound comes from the engine. For Alves et al. (2011), agricultural machinery engine noise along time may cause hearing problems for operators. It is observed that noise levels are much higher than the one established by Brazilian Legislation in the three analysed harvesters especially when air conditioning is on, thus rating them as C. Facing such situation is necessary either the use of earplugs for noise level reduction or working time reduction for operators.

One of the main causes of working stress is laid on adverse climate conditions as hot or cold in excess (Lima et al., 2005). Poorly ergonomic designed cabins may impair internal climate control causing unsteadiness and may compromise the internal climate control, making them unstable or even complex in addition to solar radiation that can reach directly the operator causing discomfort or even an accident. John Deere harvester was rated A for this evaluated item for it had the best climatic conditions in the cabin. The other analysed harvesters were rated B for they do not offer solar radiation protection.

Exposure to airborne particles and machinery exhaust emissions may cause several health damages to operators. Silva (2007) states that gas or dust inhaling oil smell may cause headaches, nausea, eye and mucous irritation, allergies and breathing pathologies. In this section, the three analysed harvesters were rated B for exhausting gases from engine may go into the cabin.

Regarding lighting, illuminance (lux) was the used standard. Its correct light dosage helps reduce accidents, keeps trained personnel within the company and decreases operational failures (Brito, 2007). Nowadays, agricultural operations are also carried out at night shifts making it a must that the adequate illumination of all operational areas specially for avoiding operator's sight tiredness. The three analysed harvesters were rated A for this section thus showing no problems.

Manuals of agricultural machinery are intended to give information in order to guide operators as well as machinery managers, having detailed descriptions on technical, ergonomic, and safety data and also information on maintenance.

For Eriksson et al. (2006), it is of high importance that the operator can identify and manage engine mechanic failures from manual information. Therefore, the analysed harvester manuals were rated B for none of them showed detailed information on ergonomic items.

Agricultural machinery maintenance may be considered a procedure set which aims at maintaining the equipment within the best working conditions which may lead to lifespan increase avoiding premature damages, solving the current ones and tending to higher work safety (Reis et al., 2005).

When maintenance on agricultural machinery occurs, it should be considered, among other items, access to stairs and maintenance platform, failure system indicators, auxiliary lighting equipment, essential tools for maintenance and especially fast and safe accessibility for power sources. Under such conditions, the three analysed harvesters showed acceptable safety conditions and were B rated.

Table 3 shows results on comparisons of multiple proportions according to section evaluation scores (classification) for different harvesters. Due to the sample size, it was decided to reduce evaluation score numbers,
thus using three classifications. Therefore, classification was grouped according to safety level offered by harvesters during operation as follows: A and B (optimum and good security level); C (medium security level); D and E (low security level).

Goodman test for proportions among and within multinomial populations where different capital letters indicate significant difference (p<0.05) among harvesters for each classification group and different lowercase indicate different group proportion classification (p<0.05) among harvesters.

Analyzing A and B classification groups, statistical difference (p<0.05) was observed being that Santal harvester showed lower evaluation percentage for this safety level (optimum and good). Regarding medium safety harvester classifications (C), Case and John Deere machinery showed lower percentages, statistically different from Santal machinery. Concerning low safety level (D and E), the three analyzed harvesters were similar. Regarding classification groups, there is statistical difference (p<0.05) for all analysed harvesters.

### Conclusions

The three analyzed harvesters showed high safety levels for operators concerning ergonomics design. However, Case and John Deere machinery show predominance. In the three analysed harvesters, it is necessary to review accessibility conditions for the three of them showing high injury risk for operators. The distance from rear wind shield in relation to the height of operator’s head, level of noise, visibility blocking in some parts of harvester as well as limiting of ground viewing are the highest deficiencies on evaluated machinery.

### Conflict of interests

The authors have not declared any conflict of interests.

### REFERENCES


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