ORIGINAL ARTICLE

Estimation of the Maintainability of Three Models of Rice Harvesters During Technical Maintenance

Estimación de la mantenibilidad de tres modelos de cosechadoras de arroz durante los mantenimientos técnicos

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ABSTRACT: The research was carried out under the conditions of harvesting and repair of the Agricultural Base Business Unit (UEBA) "Sierra Maestra", in the New Holland L-521, L-624, L-626 rice harvesters. The objective was estimating and checking the maintainability of the rice harvesters during daily technical maintenance, every 30 hours and during the harvest period under the conditions of "Los Palacios" Agroindustrial Grain Company (EAIG). Through mathematical analysis, average daily and periodic technical maintenance time every 30 h was determined. In the investigation, what the same authors did in 2017 was validated. Among the most significant results is that: for the harvesters evaluated, the maintainability curve shows that there is between 95.8...97% probability that the daily technical maintenance is carried out in two hours; while in technical maintenance every 30 hours the probability is 74...78% in the same period.

***Keywords*:** Maintenance Time, Daily, Periodic Every 30 h, Technical Availability.

RESUMEN: La investigación se realizó en las condiciones de cosecha y reparación de la Unidad Empresarial Base Agrícola (UEBA) "Sierra Maestra", en las cosechadoras de arroz New Holland L-521, L-624, L-626, con el objetivo de estimar y comprobar la mantenibilidad de las cosechadoras de arroz durante los mantenimientos técnicos diario, cada 30 h y en el período de cosecha en las condiciones de la Empresa Agroindustrial de Granos (EAIG) "Los Palacios". A través del análisis matemático se determinó, tiempo medio de mantenimiento técnico diario y periódico cada 30 h. En la investigación se validó lo realizado por los mismos autores en el año 2017. Dentro de los resultados más significativos se encuentra que: para las cosechadoras evaluadas la curva de mantenibilidad muestra que existe entre 95,8...97 % de probabilidad que el mantenimiento técnico diario se realice en dos horas; mientras que en el mantenimiento técnico cada 30 h la probabilidad es de 74...78% en igual período de tiempo.

***Palabras clave*:** tiempo de mantenimiento, diario, periódico cada 30 h, disponibilidad técnica.

INTRODUCTION

Within the technological process of rice production, the use of harvesting machines is a matter of undoubted interest. The deterioration and the years of exploitation of the means used during the technical assistance of these machines, has caused a decrease in their technical availability, which affects productivity during the harvest (Rodríguez-López *et al.*, 2022). Hence the importance of the correct execution of technical maintenance and repair operations; to guarantee the functioning of the machinery in operation, until they can be completely renewed, according to the economic possibilities of the country (Paneque *et al.*, 2018).

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In the EAIG "Los Palacios", as in the whole country, the deterioration of the machines requires greater demand for technical assistance. In addition, it implies the need of organizing the maintenance and repairing processes, drawing up strategies that ensure an optimal decision at all times, based on maintainability criteria (CAI Los Palacios- Cuba, 2011; Azoy, 2014; Herrera-González *et al.*, 2017; Mamani-Cabellos, 2019).

Grajales *et al.* (2006) point out that reliability, availability and maintainability are powerful tools that help maintenance personnel to make decisions. These tools provide the criteria for developing strategic maintenance management and in order to increase availability, priority must be given to maintainability (Shkiliova, 2004; Shkiliova *et al.*, 2011; Shkiliova y Fernández-Sanchez, 2011).

Miranda *et al.* (2008) state that the increase in combine harvester breakages is influenced by little attention to planned technical maintenance which should control and prevent failures and take measures to help increasing the productivity of the combines, once the parts that fail and the effect they cause are known. Another of the negative incidents during the maintenance work of the machines, is not having the organization, resources and trained personnel that respond to the current demands of improving the operating conditions and the improvement of the reliability indices (Fernández-Abreu y Shkiliova, 2012; Figueredo-Álvarez, 2018; Diaz-Restrepo, 2020).

The investigations carried out previously reflect the need to comply with quality maintenance to increase the reliability of exploitation and, although it is characterized by the expenses of time and resources for the maintenance of its working capacity, they are limited to consider the expenses of time, living labor of people, spare parts and other materials for repairing. (de la Cruz-Pérez *et al.*, 2013; Rivero & Suárez, 2015; Figueredo-Álvarez, 2018; Pérez-Olmo *et al.*, 2018). Expenses in maintenance are even minor if all the characteristics and previous events that occur before reaching the normal state are taken into account when evaluating the management and maintenance operation (Herrera-González *et al.*, 2017). They are design, assembly, operations, operator skills, modifications made, previous repairing, operating capacity, reliability, maintenance carried out throughout the useful life of the equipment, environment, legislation or indications, quality of spare parts, cleanliness and environmental impact it generates.

According to the existing problem, the objective of the research was to estimate and verify the maintainability of the rice harvesters during daily technical maintenance, every 30 hours and during the harvest period under the conditions of the Grain Agroindustrial Company (EAIG) "Los Palacios". That is, the ease and economy in the execution of maintenance of the rice harvesters, which in turn, allows having a methodological foundation for the solution to this scientific and practical problem in the organization and rationalization of maintenance and, consequently, in the work capacity of the harvesters (Herrera-González *et al.*, 2017).

MATERIALS AND METHODS

The experimental research was carried out at the EAIG "Los Palacios", Pinar del Río Province. The fieldwork and the characterization of the experimental site, is carried out under the repairing and harvesting conditions of the UEBA "Sierra Maestra. The evaluation of the factors that influence maintainability was carried out in three models of New Holland L-521, L-624, L-626 combine harvesters, during daily technical maintenance (10 h) and periodic MT-1 (every 30 h), in June-July and September-November 2020 rice harvest periods.

Methodology for Collecting Information on Maintenance Times

For collecting information on the cost of time to carry out maintenance, a series of measuring instruments was necessary (digital stopwatches with an accuracy of 1/10s (1%), work control models of the harvest brigade (area worked, amount of grain harvested, fuel consumed and duration of the day). In addition, documentation from the UEBA prepared by the plot manager (field, area, field yield, variety cultivated) and a set of tables prepared previously for primary data taking (Herrera-González *et al.*, 2017)

Table 1 reflects the types of technical maintenance carried out. Column 1 shows the model and chassis number of the machine; column 2 indicates the type of maintenance and column 3 the tools used. Average time spent on maintenance (main and auxiliary time) is entered in columns 4 and 5. Column 6 provides information on the number of people involved.

Phototiming begins with the first task of the day, which is daily technical maintenance, which in some cases may coincide with the MT-1 periodic technical maintenance (every 30h). With the help of the clock,

TABLE 1. Technical Maintenance Performed

Machine	Type of Maintenance	Tools Used	Average Time Used		Personnel
			Principal	Auxiliary	
1	2	3	4	5	6

the start and end time is taken and with the stopwatch the duration of each maintenance operation is taken into account.

Before beginning the observation, it is necessary for each machine to collect the data related to its characteristics (name and brand, date of manufacture or repairing, name of the production or repair plant, place where the observation is made, start dates and termination of observation). Besides, working conditions and useful work of the machine, cases and causes of machine stoppages due to technical problems (carrying out technical maintenance, troubleshooting and repairs) are also referred.

Table 3 is the control model of daily work in exploitation, it is used to register the daily work of machines. The information about the field is obtained of the UEBA documents (technological chart of the area) and the amount of initial and end fuel is measured with the graduated rod that each machine has. The volume of work is taken from the report of the harvest issued by the leader of the brigade and then corroborated with the document issued by the reception center (receipt chart), the data of clean work time, shift hours and other harvesting materials are also referred.

Based on the Manual of Use and Care of Harvester (New Holland L series), data taken from the timing of daily maintenance operations, periodic every 30 hours settled in the Tables 1 and 2, are referred in Table 4, (columns 1 and 2). In column 3, the location of the point to be attended to is referred (At the side of the machine, P1; Top of the machine, P2; Under the machine, P3; Front of the machine, P4; Back part of the machine, P5). Column 4 provides information on the work positions of maintenance personnel, according to Kopchikov (1980) cited by Herrera-González *et al.* (2017). They are:

A: standing, working at shoulder height

B: standing leaning forward

C: standing working overhead

D: crouched

E: knee with straight spine

F: knee bent forward

G: lying on the back

H: seated leaning back

I: sitting leaning forward

J: lying face down

Columns 5...8 record the time spent at work, the item to be worked on, the tools used and the people involved in the operation. These data are taken from Tables 1 and 2.

Once these data are ordered, they are averaged by operation and machines, which will allow the analysis based on the theoretical basis (Minag-Cuba, 2002; 2008; Morejón-Rivera *et al.*, 2012; Herrera-González *et al.*, 2017).

TABLE 2. Timing of Maintenance Operations

	Time Used /days, min									
Times	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Maintenance Start										
Maintenance Operations Daily and/or Every 30 h										
Maintenance End										

TABLE 3. Control of Daily Work in Operation

Model No._____Date_____ Name of the Operator_____ Crop_____

Company_____ Region or District_____ Field _____ Labor _____

Brand of the Machine_____ Model_____ Serial No._____

Fuel_____ Start_____ Final_____ Shift_____

Volume of Work Performed t, ha_____ Fuel L_____

Time of Work (h/clean)_____Hours/shifts_____Other Materials Used_____

TABLE 4. Times Used for Maintenance Operations Taking into Account the Position of Personnel per Machine

Operation	Maintenance	Location of the Operation	Position of the Working Personnel	Time of Work in Minutes	Element or Set to Work	Tools Used	Amount of Persons
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**

Methodology for Processing Data that Influence Maintainability Levels

To process the indicators that influence on maintainability, they are grouped into tables that allow calculating the data of technical maintenance by type (Table 2), which will allow the preparation of graphs necessary to show the results of the investigation.

Using the Mathcad 2000 professional calculation software, the average daily technical maintenance times, periodic every 30 h and the maintainability estimate are calculated. They are grouped in a Microsoft Excel database, which will allow the statistical processing of the arithmetic means, standard deviation, coefficients of variation, Kolmogorov's test for goodness of fit, and probability plots in the statistical program STATGRAPHICS PLUS, Version 5.1.

Determination and Evaluation of the Economic Effect

The economic effect is based on the data obtained during the 2020 harvest period with the evaluation of the machines in operation there and the amount of grains left to harvest, it was determined by the equations:

$$Adcpm = TMdmd \times W_{exp} \times N$$

$$Adcpm = TMdm30h \times W_{exp} \times N$$

where:

Adcpm-amount of grains left unharvested
TMdmd-Mean time of extra daily maintenance
TMdm30h-Mean time of maintenance every 30 extra hours
Wexp-Productivity
N-Number of maintenance

RESULTS AND DISCUSSION

Estimation of the Maintainability of Technical Maintenance

In the L-521 combine, there is a 97% probability that daily technical maintenance is carried out in 2 hours, 96% for the L-624 and 95.8% for the L-626. (Figure 1). It demonstrates that the two standard hours of daily maintenance is not enough time to carry out daily maintenance, which causes more time to be used (2.40 h), producing loss of harvester operating time (Herrera-González *et al.*, 2017).

For the periodic maintenance every 30 h, the L-521 combines have a 78% probability that the technical maintenance every 30 is carried out in 2 hours, 75% for the L-624 and 74% for the L-626. It shows that the two hours regulated to perform periodic technical maintenance every 30 hours is not enough.Therefore, it is necessary to increase the time up to 3 hours, which causes a loss of operating time of

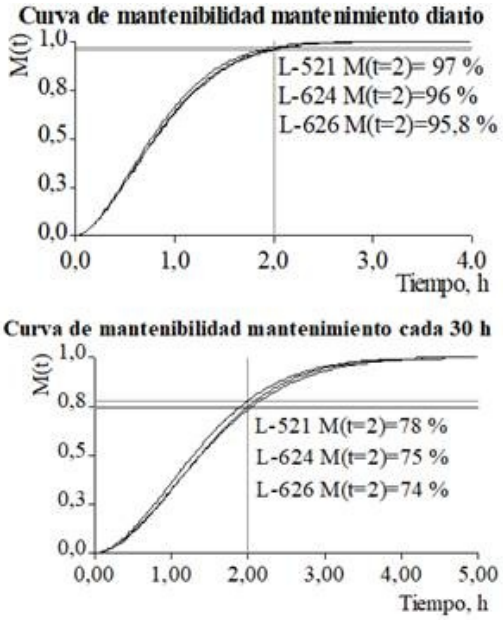

FIGURE 1. Maintenance Curve of New Holland L-521, L-624, L-626 Combines During Technical Maintenance.

the combine. Hence, the probability of carrying out maintenance at zero time is zero. As the carrying out time is extended, the maintainability curve increases to become a maximum in a greater or infinite time. This reveals that as a larger and maximum time is assigned to carry out maintenance, the probability of doing so grows. Similar results were obtained by the same authors in 2017.

Evaluation and Determination of the Economic Effect

As observed in Figure 2, the greatest loss occurs in the L-624 harvesters, which failed to harvest 112 7.86 t, which represents 225,571.08 Cuban pesos (CUP) and of these, 129,601.08 CUP belonging to the extra daily maintenance time. While the L-626 harvester stopped harvesting 779.46 t, which represents 155,892.8 CUP and of these, 90,518.40 CUP belonging to overtime for daily technical maintenance. The L-521 combine has more discrete values, the loss of rice left unharvested is 621.99 t, which represents 124,396.65 CUP, of which 33,533.01 CUP belonging to the extra daily maintenance time. Therefore, the situation could improve if overtime of daily technical maintenance caused by the deficiency of the logistical system (spare parts, tools and devices to carry out maintenance in the field) decreases. It is also necessary to train maintenance personnel, which would contribute to reduce the losses due to unproductive stops. These data coincide with the results obtained by the same authors in 2017 (Herrera-González *et al.*, 2017).

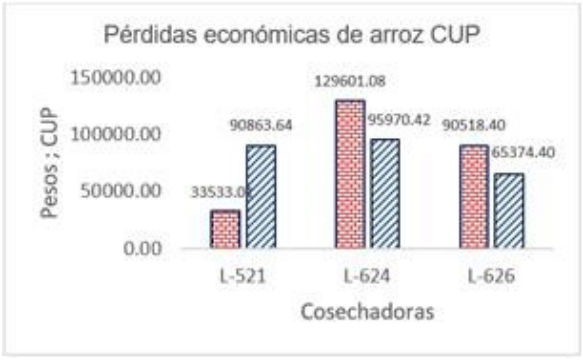

FIGURE 2. Economic Losses of Rice in CUP.

CONCLUSIONS

- From the results of estimation calculation, the probability that the daily technical maintenance is carried out in 2 hours is 97% for the L-521 combine, 96% for the L-624 combine and 95.8% for the L-626 combine.
- The probability that the technical maintenance every 30 hours will be carried out in 2 hours for the L-521 combine is 78%, for the L-624 combine, 75% and for the L-626 combine,74%.
- The probability of carrying out maintenance in a zero time is zero, as the carrying out time is extended, the maintainability curve increases to become a maximum in a greater or infinite time. This reveals that as a larger and maximum time is assigned to carry out maintenance, the probability of doing so grows.
- The greatest loss occurs in the L-624 harvesters, which failed to harvest 112 7.86 t, that represents 225,571.08 Cuban pesos (CUP) and of these, 129,601.08 CUP belonging to overtime for daily maintenance. While the L-626 harvester stopped harvesting 779.46 t, which represents 155,892.8 CUP and of these, 90,518.40 CUP belonging to overtime for daily technical maintenance. The L-521 combine has more discrete values; the loss of rice left unharvested is 621.99 t, which represents 124,396.65 CUP, of which 33,533.01 CUP belonging to overtime for daily technical maintenance.

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