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Performance of the mechanical harvesting of unburned sugarcane

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Abstract: *In the present investigation a study of the performance of a combined machine for the harvest of sugar cane is realized, with the purpose of determining the technological and productive indexes of this machine in conditions of green cane harvest. The study was carried out in the southern state of Jalisco, México, from November to December 2016. The study consisted of the evaluation of two CASE IH 7000 harvesters during approximately 216 working hours. The methodology used for the study was established in NC-34-37: 2003 and elements of the methodologies used by several authors. The results of the technical and operating indicators determined in this study are below the parameters established for these machines, negatively affecting the use of clean working time, which only reaches 5.5 hours, 46.63% and the working time. Stop for other causes that rose to 1.09 hours, 9.11% of the total time of observation. The analysis of the results determined that the productive potential of the sugarcane harvesters under study is not optimally exploited.*

Keywords: *Unburned sugarcane; mechanical harvesting; sugar industry; performance.*

I. Introduction

México is among the top 10 sugarcane producing and consuming countries (Pérez & Rappo, 2016), at 5 984 961 tons, this productive activity is carried out in 51 sugar mills, 15 states and 227 municipalities, 9.2% of all municipalities in México, that are grouped into six production areas. Since its introduction in Mexico, sugarcane has become an integral part of the national economy (Senties et al., 2014). Sugarcane agroecosystems in Mexico are one of the most important agricultural activities, due to their rural economic and social relevance (Guerrero et al., 2015), generating more than 930 000 direct jobs and 2.2 million indirect jobs (Gómez, et al., 2014).

Sugar cane burning has been a practice applied for decades (Meyer et al., 2005) driven by the lack of labor for the harvest (Meneses, 2012) and by the ease of doing this work. The diffusion of this practice allowed increasing the productivity, turning the burning into a traditional activity. According to Sánchez et al., (2014), worldwide, to harvest sugar cane is used the system of burned reed, manual cutting and mechanical hoisting by 60%.

In some countries the mechanization of this crop has been extended, in Australia 100% is done with harvesters (Narimoto et al., 2015). In Brazil, in 2013, more than 80% of the area was harvested mechanically (Braunbeck et al., 1999), and the burning of cane for mechanized harvesting after 2014 (Rosetto et al., 2010); and in 2017 for manual cutting areas (Sánchez et al., 2014). According to Isas et al. (2016) in Argentina one of the most important recent changes in the management of sugarcane cultivation was the adoption of the "green" harvest. In this system, the sugar cane crop is harvested without burning leaving a stubble cover on the ground. Several authors (Fernández et al., 2012, Isas et al., 2016) estimate that 80% of the area under cultivation in this country is made with a green harvest and 20% with a semi-harvest mechanized.

Currently there is worldwide pressure on sugarcane producers to adopt 'green cane' harvesting systems that do not involve burning (Gilbert et al., 2010). In some countries the mechanized sugarcane harvest without burning has been increasingly adopted (Cardoso et al., 2013), mainly due to environmental and legal issues (Fortes et al., 2012), and labor shortage (Cardoso et al., 2013). In view of the above, the green sugarcane harvest is a viable and sustainable alternative to the traditional harvest in Mexico, and can be grown on land with adequate relief conditions, with advantages in reducing cutting time and the labor employed. In addition to reducing pollutant emissions from combustion and its direct effects on worker health Ma et al. (2014).

The cultivation of sugarcane in México is managed mainly under the system of burned sugarcane, manual cutting and semi-mechanized harvesting (Vejar et al., 2009; Ortiz et al., 2012; Salgado et al., 2015). This practice prevents the reinsertion of organic matter in the soil and degrades physical and chemical properties, so this management is not sustainable in the long term (Naranjo et al., 2006; Ortiz et al., 2012). Of the 780 544 ha have been planted with sugarcane in México, only 188 000 ha are harvested in green, implying that more than 75% of the area is burned before harvest (Gómez et al., 2014).

Recent studies have investigated the factors associated with cane cutting performance in terms of worker characteristics (Florencio et al., 2008, Todd, 2008, De Sousa et al., 2014). In the work of Weekes (2004) a detailed

review of the sugarcane harvest is carried out, where the yield is evaluated according to different aspects, such as the type of cutting tool for burnt or green cane, according to this author for the latter the productivity of work decreases by 20%. In the present investigation the evaluation of 2 sugar cane harvesters CASE IH 7000 is carried out with the objective of determining the technological and productive indexes of this machine in green cane harvesting conditions.

II. Materials and Methods

The present investigation was carried out in the southern state of Jalisco, Mexico, from November to December 2016. The sugar cane variety present in the study area is the ColMex 94-8. The evaluation of 2 harvesters CASE IH 7000 was developed, during 9 effective days, observing in total 216 hours approximately of the working day of the machines under study. The method of movement was back and forth with a major turn in turns of 180 ° depending on the particularities of the edges of the field at harvest.

For the determination of the laboral times, the photo-timing method described in NC 34-37: 2003 was used. This timing process is developed with an Ace model digital timer with accuracy of 0.01s. To perform the processing and analysis of the experimental data, obtaining the graphs and the regression equations that characterize the variables and processes studied, the Microsoft Excel tool was used. In order to calculate productivity indexes, the methodology established in NC-34-37: 2003 and elements of the methodologies used by several authors such as Matos *et al.* (2010); Matos *et al.* (2014); Miranda *et al.* (2013); Miranda *et al.* (2015); Daquinta *et al.* (2014); Farias, *et al.* (2016).

The methodology developed consisted in the determination of the times during the operations of the machine, allowing the calculation of the technological and exploitation indicators derived from the timing of the working day. This procedure allowed to record in a chronological order the operations and the observed times observed, these are: Clean working time (T1), Auxiliary time (T2), Technical maintenance time (T3), Time for fault elimination (T4) (T5), Time of transfer in empty (T6), Time of maintenance of the means of transport (T7) and Time of stops by causes outside the machine (T8).

III. Results

The analysis of the time elements of the working day generated the results shown in Table 1. The working time (T1) represents 46.63% of the average working day, in this case 5.5 hours; this is a low value, caused by the loss of time due to non-machinery. The auxiliary time (T2) with 11.87%, on average 1.42 hours is due to the characteristics of the harvested plots, which prevented the use of rational turns methods. The technical maintenance time of the test machine (T3), represented 4.52%, was devoted to this important item 0.54 hours, caused by the lack of technical means to perform corrective maintenance tasks.

Table I Photo timing results.

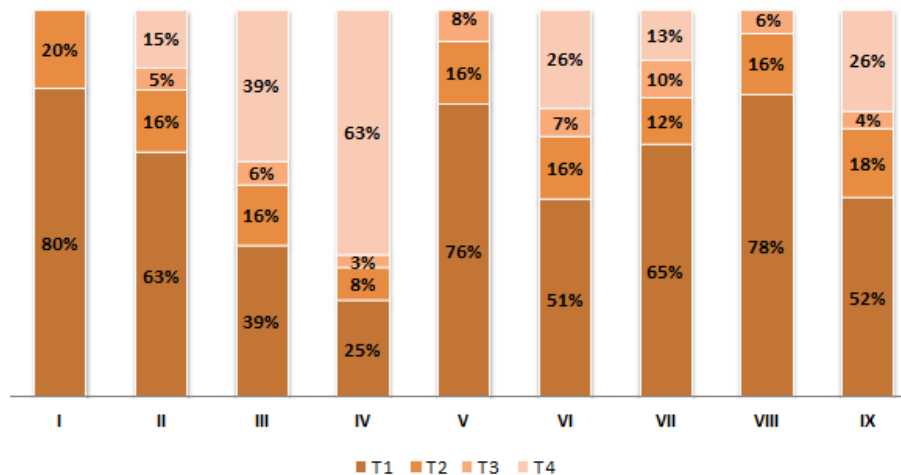
Technological Times (Hours)	Photo Timing Results									Statistical Analysis		
	I	II	III	IV	V	VI	VII	VIII	IX	Sample Mean	Variance	Standard Deviation
T1	5.1	5.8	4	1.5	8.1	4.8	6.6	9	4.7	5.5	4.99	2.24
T2	1.3	1.5	1.6	0.5	1.7	1.5	1.3	1.8	1.6	1.42	0.14	0.38
T3	0	0.5	0.6	0.2	0.9	0.7	0.9	0.7	0.4	0.54	0.09	0.29
T4	0	1.4	4	3.8	0	2.4	1.4	0	2.4	1.71	2.43	1.56
T5	0.5	0	1.09	0.4	0.65	0.35	0.56	0.43	0.51	0.50	0.07	0.29
T6	0.44	0.59	0.56	0.6	0.52	0.4	0.71	0.57	0.63	0.56	0.01	0.09
T7	0.6	0.69	0.63	0.78	0.51	0.63	0.52	0.75	0.68	0.64	0.01	0.09
T8	0.89	1.31	0.9	1.22	1.1	1.4	0.8	1.34	0.86	1.09	0.05	0.23

The time for the elimination of failures (T4) reached 14.30% of the day, in average 1.71 hours, caused by the damages that were taken before continuing with the activities, this indicator could have been diminished with the accomplishment of the maintenance tasks technical daily. The behavior of the rest time of the personnel (T5) was low, with respect to the established in the regulations of the agricultural work, with a value that represents the 4.18% of the time of the day, that is to say 0.5 hours.

The empty transfer time (T6) represented 4.68% for an average of 0.56 hours, caused by the distances traveled when moving between the plots to be harvested. The time of maintenance or repair of the support equipment (T7) reached a value of 0.64 hours, 5.35% of the day. The percentage of non-machine downtime (T8) amounted to 1.09 hours, 9.11% of the day; this is caused by various effects, largely due to poor organization of production activities. The Figure 1 shows the behavior of productive times T1, T2, T3 and T4 during the 9 days observed. The statistical analysis can be observed in Table 1, where it is clearly perceived that the greatest dispersion of the standard deviation was presented in the clean working time (T1) and in the time for failure elimination (T4). Figure 2 shows

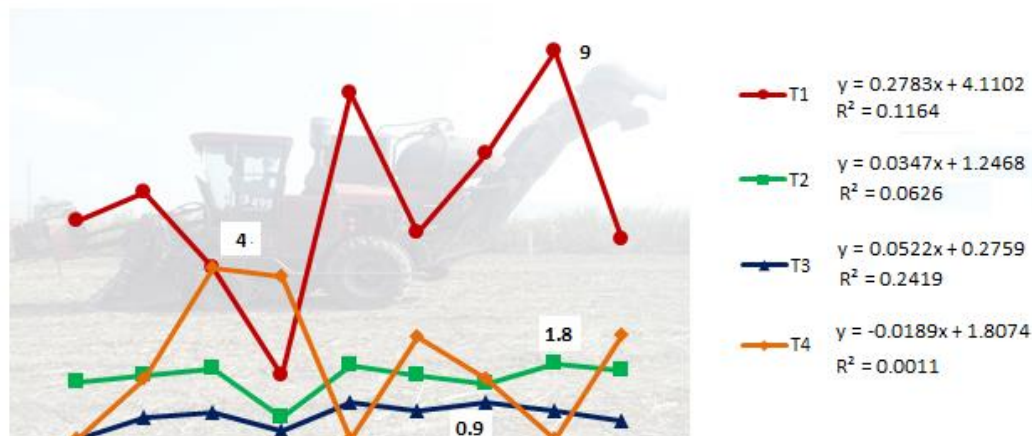
the equations that describe the productive times (T1, T2, T3 and T4), the analysis of these allows to determine the value of each of these times as a function of the number of hours that are worked with the machinery, in the range determined by the curve shows that there is a weak relationship between productive times and length of working day; Indicating also the maximum values of exploitation of each one of the observed days.

Figure 1: Productive times (T1, T2, T3 and T4).



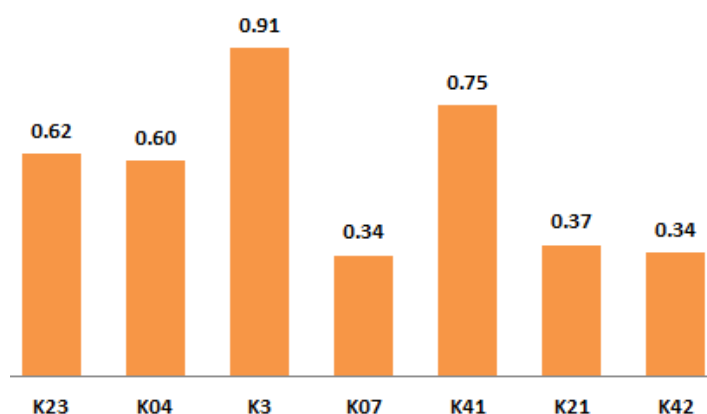
On the other hand, the productivity of the clean time was determined, ranging from 0.48 to 0.71 ha h⁻¹, and a yield of 48 to 62 t h⁻¹, a value lower than the one established by the manufacturer (80 t h⁻¹) and to which other authors refer. Derived from the processing and analysis of these values, it can be concluded that the productive capacity of the machine is not taken advantage of, in this way, the time of stoppages due to causes outside the working day and the irregularities of the land under study, as well as bad design of the fields.

Figure 2: Statistic Analysis of productive times T1, T2, T3 and T4.



The analyses of the technical and operational coefficients of the harvester, shown in Figure 3, demonstrate the existence of inefficiencies that prevent a correct development of the harvesting process. The utilization coefficient of exploitative time K07 and that of technical safety K42 reached the lowest values, 0.34 both. The value of Technical Maintenance Coefficient K3 reached the highest value, 0.91 this originated because little time was spent in these activities due to the lack of technical means to carry out these tasks. The values of the technological service coefficient (K23), technological safety (K41) and technical safety (K42) reached values of 0.62 and 0.75, which reaffirms that the reliability level of the machine under study under green cane conditions is within the parameters set for these machines.

Figure 3: Technical and operational coefficients of cane sugar harvester.



IV. Conclusion

The technical and operating indicators determined for the harvesters under study are below the set parameters of this machine, negatively affecting the use of clean working time, which only reaches 5.5 hours, 46.63% and the stop time for other reasons that rose to 1.09 hours, 9.11% of the total observation time.

The analysis of the results determined that the productive potential of the sugarcane harvesters under study is not optimally exploited because factors such as the layout of the plots and the relief of the terrain have a negative impact.

The study allows concluding that there are reserves of time in the technical organizational aspect of the working day.

Productivity per hour of clean working time during observations, behaved below the real possibilities of harvesters and those determined by different authors

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