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Study of the Productivity of the tractor TS 6000 with the AGI PEL 650 Sprinkler in the cultivation of sorghum (*Sorghum bicolor L. Moench*)

Miguel Escamilla López¹, Miguel Ríos Farías¹, Tejeda Castrejón Jesús Francisco ¹, Silva Medina Pedro Itzvan ¹, Mejías Brito Johann²

²Department of Industrial Engineering, Tecnológico Nacional de México / Instituto Tecnológico de Colima

¹Department of Electrical and Electronic Engineering, Tecnológico Nacional de México / Instituto Tecnológico de Colima

Abstract: The objective of this work is to perform an analysis of the behavior of the machinery that performs the tasks of phytosanitary control, this work deals with the productivity of the working day of the tractor TS 6000 with the sprinkler AGI PEL 650 in the cultivation of sorghum (*Sorghum bicolor L. Moench*). This study was developed in the municipality of Tepames in the state of Colima, Mexico. For this, 24 effective hours of work of the machines under study were evaluated. The analysis of the results allowed to determine the technical and exploitation indicators, as well as the productivity of the same.

Keywords: Productivity; sorghum; phytosanitary; agricultural machinery

I. Introduction

Sorghum (*Sorghum bicolor L. Moench*) is native to Central and Eastern Africa, probably from Ethiopia and Sudan (Maquieira et al., 2016). According to Chuk et al., (2011) it is one of the oldest crops and currently one of the most important cereals in the world (Serna, 2010). It is very efficient in warm environments and with high luminous intensity, such as those prevailing in semi-arid regions (Rooney & Serna, 2000). According to Taylor et al., (2006), it is the best cereal in terms of drought resistance. According to Serna (2010) these could be the "plants of the future" due to the increasingly scarce water available for irrigation and the highest level of CO₂ present in the environment. In regions with optimum climate it is possible to obtain several harvests of sorghum per year either directly from seed or from suckers (Saballos, 2008; Turhollow et al., 2010).

Mexico is the third world producer of fodder sorghum producing 4, 785,767 tons on average annually, this crop is of great importance for agriculture as it feeds a large part of the herd. For 2016, the main producing states of forage sorghum were Coahuila with a total production of 835,315 tons, Durango with 448,969 tons and Sonora with 382,655 tons (Navarro et al., 2017). In his work, Díaz et al., (2013) alludes to that the largest planting area is located in the northern region, with about 650 thousand hectares, where sorghum is a monoculture. Due to the low productivity of this cereal (2.2 t ha⁻¹), inorganic fertilization is an uncommon practice for the dry land producer, given the erratic humidity in the soil, as well as the high cost of its application (Williams et al., 2006; Díaz et al., 2007).

Knowing the lack of fodder that exists in the state of Colima, due to the geography of the region, especially because of the scarcity of water in mountainous areas, it is essential that new forage crops are found that adapt to this region. Sorghum is a crop that requires less water than corn, so it has potential as a forage plant that can be grown in most of the national territory, since its nutritional value is equal to or slightly higher compared to corn, and with a superior productive response (Bolaños et al., 2012). In spite of the above, and particularly under temporary conditions, the species by itself can not guarantee the achievement of high yields, so it is necessary to accompany its sowing with appropriate practices (Osuna & Martínez, 2017). Chemical fertilization is a high cost practice in the production of irrigation sorghum and, therefore, its use in rainfed conditions is not very common (Díaz et al., 2017; Salinas, 2006).

Therefore, the implementation of economic, sustainable and effective options are necessary to contribute to the nutrition of plants for their development, increase yields, profitability and competitiveness of sorghum production (Díaz et al., 2008; Williams et al., 2006). Similarly, other authors (Díaz & Garza, 2007; Magallanes et al., 2008) emphasized the need to develop agronomic practices that increase the profitability of sorghum production and promote a balance in agro ecosystems, as well as the realization of good agricultural practices. To understand the behavior of the machinery that carries out the tasks of phytosanitary control, this work deals with the productivity of the working day of the TS 6000 tractor with the AGI PEL 650 Sprinkler in the cultivation of sorghum (*Sorghum bicolor L. Moench*).

II. Materials and Methods

The study was conducted in the municipality of Tepames, located southeast of the state of Colima, Mexico at 19 ° 05'38 "N 103 ° 37'21" W. In this region the rotation of the crop is sorghum-rest, that is, an annual crop followed by fallow period, to retain moisture in the soil. Four plots were established for this study and the criterion for the selection of the sites was that they show uniformity of relief and soil. The phytosanitary control of the weed was carried out with Prosulfuron solution at 30 g / ha, a herbicide that controls the main species of broadleaf weeds in post-emergence, for which it was applied in full coverage when the sorghum plants presented between 5 and 8 leaves and undergrowth with a height of less than 10 cm. It is recommended that before the application of any herbicide product the existence of good humidity in the soil is verified, otherwise the control will be deficient. The movement method of the aggregate Tractor TS 6000 with the AGI PEL 650 Sprinkler (As show as Fig. 1.), the one of career and the type of turn in form of U (180°). To obtain fuel consumption, the amount of fuel in the tank was measured at the start and at the end of the work with a gauge rule, in which 1 cm = 0.1286 L. The difference between the initial and final reading is multiplied for this value and fuel consumption is obtained.

Figure 1 Tractor TS 6000 with the AGI PEL 650 Sprinkler in phytosanitary activities.



For the development of this research the main methodologies for evaluation of machines and / or agricultural equipment were studied, taking as a basis the NC: 34-37 (2003) and ISO Standard 8210 (1989), as well as some of the most representative studies (Matos et al, 2010; Miranda et al, 2015; Matos et al, 2014) made in this area. The methodology is focused on determining the time in different conditions and operations of the machine, allowing the calculation of technological and operational indicators derived from the timing of the workday. This procedure allowed to record in chronological order operations and observed times employees, these are: clean Working time (T_1), Auxiliary time (T_2), Time maintenance (T_3) Time for removal of faults (T_4) , staff rest time (T_5), vacuum transfer time (T_6) Time of maintenance of means of transport (T_7) and time stops for no fault of the machine (T_8). Control, processing, organization, analysis of experimental data, obtaining parameters, graphs and regression equations that characterize the variables and processes investigated were performed with the electronic tabulator Excel. Measuring instruments used were: digital stopwatches, tape measures and odometers machines. After making the comments, we proceeded to determine the average balance of time structure, by which it was determined the actual balance of the working day, for this computational techniques were applied. Finally productivity rates and operating ratios set out in the rules for this studio attended were determined.

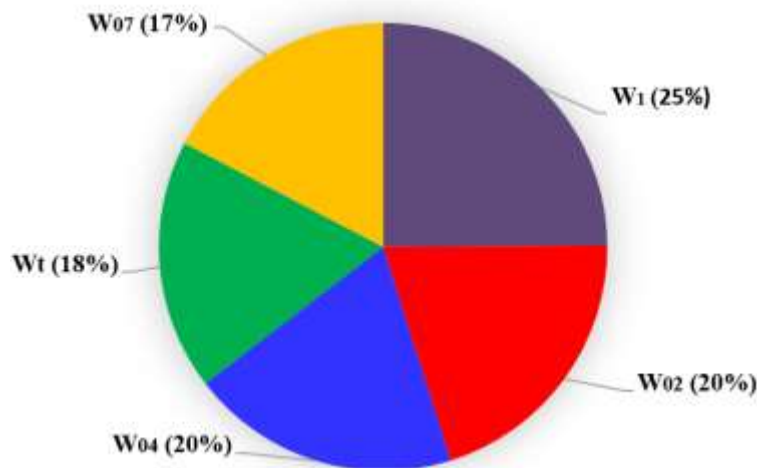
III. Results

The clean work time (T_1) presented a total of 24 working hours and the time of technological stops (T_{23}), presenting a total value of 4.58 hours. The turning time (T_{21}) reached a total value of 1.55 hours. The time of transfer in the workplace (T_{22}) was consumed mainly in the transfer of the fertilizer machine to the place of loading the material and return to the field to continue the work, with a total of 0.16 hours. The time of technological stops (T_{23}) linked to the execution of the technological service was 2.87 hours. Technical maintenance time of the machine under test (T_3) reached a value of 1.17 hours, of which a total of 0.58 hours were consumed in the execution of the daily technical maintenance (T_{31}) and for the start-up and heating of the engine, to carry the machine in its transport and work position, change the technological scheme as well as to attach and remove the agricultural implements and others, a total of 0.59 hours. The resting time of the service personnel of the machine under test (T_5) divided in time

for the physiological and rest needs of the service personnel, accumulated 0.62 hours. The empty transfers (T_6) consumed 0.52 hours.

The behavior of the average productivity per hour of clean time (W_1) was at an average value of 6 ha h^{-1} , a result that is higher than the norm proposed by the NC 34-37:87 (2003), which is 5 ha h^{-1} . This value is due to the good use of the different times during the working day. In the same way, the organization of the service personnel positively influenced this productivity. The productivity per hour of operating time (W_{02}) presented a value of 4.90 ha h^{-1} . This is due to the good use of clean work time and also to the auxiliary time was within the parameters established for this work (Matos et al, 2010; Miranda et al, 2015; Matos et al, 2014; NC: 34-37, 2003; ISO Standard 8210,1989; Chuck et al., 2011),

Figure 2 Tractor



It can be observed in Table 1, that the coefficient of work passes obtained was 0.94, it is considered to be good since it is between 0.80 to 0.95 (Matos et al, 2010; Miranda et al, 2015; Matos et al, 2014; NC: 34-37, 2003; ISO Standard 8210,1989; Chuck et al., 2011). It is important to note that the turnaround time was below the established, which means that there is no loss of time depending on the turn, in addition there were no interruptions due to nozzle clogging and also because there were no interruptions due to technological stops. The coefficient of technological service is equal to 0.87. The coefficient of technical maintenance behaved at 0.95, considered as good (Matos et al, 2010; Miranda et al, 2015; Matos et al, 2014; NC: 34-37, 2003; ISO Standard 8210,1989; Chuck et al., 2011).

The coefficient of technical safety behaved with a value of 1 for all the days. This is because there were no interruptions due to unforeseen breakages, which meant that there was no loss of time to eliminate the faults. The coefficient of utilization of the productive and exploitative time obtained were 0.44 and 0.43, respectively, values that were much lower than what was established in the aforementioned literature (Matos et al, 2010; Miranda et al, 2015; Matos et al, 2014; NC: 34-37, 2003; ISO Standard 8210,1989; Chuck et al., 2011), negatively influencing the high time consumed in staff rest.

Table 1 Technological and exploitation coefficients.

Coefficients	Workdays				
	1 ^{ra}	2 ^{da}	3 ^{ra}	4 ^{ta}	Media
Work passes (K_{21})	0.92	0.93	0.94	0.95	0.94
Technological service (K_{23})	0.76	0.93	0.84	0.95	0.87
Technical maintenance (K_3)	0.92	0.92	0.97	0.98	0.95
Technological safety (K_{41})	0.99	0.99	0.99	0.99	0.99
Technical security (K_{42})	1	1	1	1	1
Utilization of productive time (K_{04})	0.4	0.44	0.45	0.47	0.44
Exploitative time use (K_{07})	0.38	0.43	0.44	0.45	0.43

The machines evaluated in a quadrant of 11.7 ha, reached a time of 1.17 hours (70 minutes), which means 0.1 h ha^{-1} (6 min ha^{-1}) with a fuel consumption of around 16 liters, where it was possible to appreciate a fuel expense of 1.37

L ha⁻¹. On the other hand, also from the analysis carried out it was possible to determine that in one hour of work without relevant interruptions, the set consumes 13.7 L of fuel. In each working day the tractor started the tasks with 60 liters of fuel in the tank approximately. The highest fuel expense was verified on the 4th working day, due to the lack of water supply and another cooperative had to be dislocated to supply it.

In Table 2 you can see the real speed of the set reaching an average value of 1.84; 1.85 m and 1.68 m s⁻¹ (6.62, 6.66 and 6.04 km h⁻¹) on the 3rd and 4th step, reached on each pass during work an average time of 217, 216 and 211 seconds in quadrants 1, 2 and 4 respectively.

Table 2 Determination of the work speed.

Quadrant	Media length (m)	Media Time (s)	Media speed (ms ⁻¹)
1	400	217	1,84
2	400	216	1,85
4	355	211	1,68

IV. Conclusions

The analysis of the results determined that the productive potential of the soil preparation machines under study is not optimally exploited because factors such as the design of the plots and the terrain relief 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 the soil preparation machines under study and those determined by different authors.

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