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EVALUATION OF LOSSES IN COTTON HARVEST AT DIFFERENT HARVESTER SPEEDS

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ABSTRACT

The losses generated during the harvest of agricultural products are common, being due to the most varied problems, among them the speed of movement of the harvester. Thus, the objective of this work was to diagnose the losses in the cotton harvest as a function of the harvester's travel speed, seeking to relate them to phenological factors directly linked to the operation and that can contribute to the improvement of the harvest quality. The data were analyzed through sampling and for their presentation, descriptive statistics were used, seeking measures of central tendency and the occurrence of variability to represent the results. By the simple random sampling technique, the confidence intervals for the mean were obtained. Two travel speeds were used, 5.0 and 6.6 km h-1. It was sought to evaluate, before the passage of the harvester, maximum productivity and the pre-harvest loss, manually collecting all the cotton from the sample area, and immediately after the passage of the harvester, the total loss was collected. It was observed that the pre-harvest loss of cotton is relatively low and close to the values found in the literature for the State of Mato Grosso. The average total loss found remained within the limit considered acceptable.

Keywords: Quantitative losses, Speed, Harvester.

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INTRODUCTION

The cotton crop (Gossypium hirsutum L.) is widely cultivated in more than 60 countries, with China, India, the United States, Pakistan and Brazil as the main producers. Brazil stands out as the second largest exporter in the world and leads in rainfed cotton productivity. In addition, the domestic market is promising, with the country being the fifth largest global consumer of cotton (ABRAPA, 2023).

The state of Mato Grosso leads cotton production in Brazil, accounting for 72.2% of seed cotton production in the 2023/24 harvest. Most producers in the region choose to plant second-crop cotton, due to the high volume of rainfall during the sowing period of first-crop cotton (CONAB, 2024).

Cotton has indeterminate growth, and its architecture can be adjusted to facilitate harvesting and increase productivity, depending on environmental and management conditions (OOSTERHUIS, 1999). In addition, factors such as ripening point, adjustment and speed of machines, plant size, soil type and variety influence harvest losses. According to Vieira et al. (2001), acceptable losses during the cotton harvest should be between 6% and 8%, with 10% being the maximum value tolerated.

Losses during the cotton harvest need to be monitored to identify possible flaws in the process and allow their correction. Among the examples of quantitative losses, the following stand out: cotton that falls to the ground, cotton that remains in the cotton plant after the harvester passes, and weight loss caused by delay in harvesting (FERRONATO et al., 2003).

According to Embrapa (2006), during the mechanized harvest of cotton, the quantitative losses vary between 15% and 17%, while in the manual harvest these losses do not exceed, on average, 5%. Regarding qualitative losses, mechanized harvesting can reach up to 35%, while manual harvesting registers only 5%.

The modernization of cotton farming, driven by large commercial plantations and the shortage of labor in rural areas, favored the intensive use of mechanization in cultivation. Harvesting by means of self-propelled harvesters has become one of the main factors to enable the exploitation of this crop in extensive areas. Mechanized harvesting has several advantages compared to manual harvesting, such as reduced operating costs, faster process, lower impurity content, reduced contaminants, and labor savings in the stages of receiving, weighing, and using bags. These factors make mechanization essential in large areas of cultivation (EMBRAPA, 2003).

Most of the machinery used in the cotton harvest in Mato Grosso is imported from the United States, where this technology was originally developed. However, adaptations are necessary for cotton grown in Brazil, since the plants here are larger in size compared to the American standard. To reduce crop losses, many growers have adjusted machine settings, which has resulted in an increase in the rate of impurities. This generated several complaints from the industry due to the presence of pieces of cotton stem bark, caused by the friction of the harvesting spindles with the stems of the plants (BELOT et al., 2002).

There are two main types of machines used in cotton harvesting: the picker harvester, which removes only the seed cotton, and the stripper harvester, equipped with a pulley system that removes both the whole bolls and the wrappers (EMBRAPA, 2006).

Most of the cotton harvested in Mato Grosso uses picker harvesters. However, according to Spurlock et al. (1991) and Faulkner et al. (2011), the stripper harvester has several advantages over the picker, including a significantly lower purchase price, fewer moving parts in the line units, which results in lower fuel consumption and maintenance. On the other hand, researchers such as Columbus et al. (2001), Willcutt and Columbus (2002) and Brashears and Baker (2000) highlight that the picker harvester collects less foreign material, such as leaves and branches, better preserving the quality of the fiber and being able to operate at higher speeds (Faulkner et al. 2011).

The cotton picker is a complex and delicate machine that must be handled by a skilled and responsible operator. Proper regulation of the harvester is essential to ensure the good performance of the process. The operator must consider several aspects, such as the harvesting speed, the moisture of the plume at the time of harvesting, the cleanliness of the machine, the adjustment of the distance between spindles, brushes and shredders, as well as the percentage and amount of water and detergent applied to the spindles. The pressure plates also need to be correctly regulated to maximize the removal of the plume, avoiding the removal of branches and bark from the stem (BRUNETTA, 2005).

Due to the scarcity of studies on losses in the cotton harvest, SILVA et al. (2007) suggest that a parallel should be drawn between losses in this crop and in other agricultural crops. Although they have distinct phenological characteristics, these crops share some similarities, such as the reduced time for harvest, the influence of adverse climatic factors, and the lack of proper management of machinery, among others.

Silva et al. (2011), when evaluating the losses in the cotton harvest in the municipality of Ipameri-GO, observed that, in the properties studied, the losses in the soil were higher than the losses in the plant, representing about 59% of the total losses. These results are in line with the studies by Khalilian et al. (1999) and Ferreira (2013), who also identified greater losses in the soil during the cotton harvest.

According to Ferronato et al. (2003), the climate can influence losses during the cotton harvest. When comparing the total losses of the same cultivar in different municipalities, significant differences were observed. As these municipalities are located in regions with altitude variations, it is reasonable to assume that agroclimatic conditions have interfered with the results. In addition, other factors such as management and harvest speed cannot be disregarded, which can also impact losses.

During the harvest, the person in charge must carefully monitor the losses, which include the cotton that falls to the ground and the remnants on the plants. Normally, this evaluation is carried out daily, with the collection and weighing of cotton from 5 rows of 5 meters each (BELOT and VILELA, 2006). In the conditions of the Brazilian cerrado, losses during harvest vary between 9.4% and 12.5% (FREIRE, 2011).

When evaluating the losses in mechanical cotton harvesting in the municipality of Juscimeira-MT, Ferreira et al. (2013) observed that the displacement speed of 7.2 km h-1 resulted in the highest total losses, reaching 14.1%.

Rangel et al. (2003) state that losses during mechanized cotton harvesting can vary from 5% to 15%. However, these losses can be reduced to less than 5% when machines are well regulated and operators are trained.

According to Eleutério (2001), the transformations in Brazilian agriculture were significant, especially in cotton cultivation, which quickly evolved from a family activity, which demanded a lot of labor, to large-scale production with large capital investments and high technology, especially in the cerrados of the Midwest region. Harvesting is a crucial step in the cotton production process, and when carried out inadequately, it can result in both quantitative and qualitative losses in the final product.

Cotton harvesting is a critical stage for producers, as the cost associated with this phase represents a significant portion of the total cost of production. Factors such as the higher cost of production, the agricultural calendar, and the harvesting method can substantially impact both crop quality and productivity.

The objective of this study was to diagnose cotton harvest losses as a function of displacement speed, seeking to relate them to phenological factors directly linked to the operation and that can contribute to the improvement of harvest quality.

THEORETICAL FRAMEWORK

The experiment was carried out in the production field of Mutum Farm, located in the municipality of Nova Mutum-MT. The municipality of Nova Mutum is located at the following geographic coordinates: 13°05'04" south latitude and 56°05'16" west longitude, with an average altitude of 450 meters. The Köppen classification for the region is an Aw-type climate, tropical savannah, proper, with summer rainfall and dry winter, characterized by average temperatures of 24°C, with average annual rainfall of 2,200 mm.

The data were analyzed through sampling and for their presentation, descriptive statistics were used, seeking measures of central tendency and the occurrence of variability to represent the results. By the simple randomized sampling technique, confidence intervals for the mean were obtained (VALE et al., 2008, VALE et al., 2009, VALE et al., 2010). Two travel speeds were used, 5.0 and 6.6 km h-1, and a total of 48 samples were performed. The sampling points were chosen at random, and the total area used in the experiment was 29,412.20 m² (2.94 ha).

The John Deere cotton picker, model 7760, with 394.96 kW (537 hp) of engine power, platform with 6 rows of harvesting unit, year of manufacture 2012 and using the picker harvesting system, was used. The variety cultivated on this property was FMT 705, sown with row spacing of 0.76 meters.

The FMT 705 cultivar, belongs to the Mato Grosso Foundation and is recommended for cultivation throughout Brazil, with a late cycle, is pointed out as an alternative for opening planting. It has RX technology, which is tolerant to nematodes and confers resistance to the disease caused by Ramularia areola (FUNDAÇÃO MATO GROSSO, 2013).

For the phenological characterization of the crop, plant height (AP), height of the first boll in relation to the soil (APCS), number of bolls per plant (NCP), final population (PF), actual yield (PR) and maximum yield (PM) were determined.

To estimate the variables (AP, APCS, NCP, PF, PR and PM) a template of 0.5 meters wide and 3.8 meters long (1.9 m²) was used. On the property, a plot was selected that represents the property as a whole, in this plot was carried out the sampling of plants contained within the template, at five random points.

Plant height was performed by obtaining the average of the measurement between the soil level and the apex of the plant in all plants contained within the template.

The height of the first bollly in relation to the ground was obtained by averaging the distance between the ground level and the height of the first bollly in all plants contained within the template.

The number of bolls per plant was obtained by the average of the bolls in all plants contained within the template.

The sampling to survey the losses was divided into two stages, the first consisted of the collection of data regarding the estimate of Pre-Harvest Losses (PPC), before the mechanized harvest, and the second stage was carried out after the mechanized harvest through the collection of data from the estimates of Total Losses (TP).

To determine the pre-harvest losses, all the material that was fallen on the ground inside the template was manually collected. To determine the total losses, all the material that was within the same template used to determine the pre-harvest losses and that remained in the soil and in the plant after the passage of the harvester was manually collected.

The final plant population was determined by counting the number of plants at the time of harvest, contained within the template.

To determine the yield, all bolls present in all plants contained in the space delimited by the template were manually collected, before the passage of the harvester, that is, without post-harvest losses, thus representing the maximum yield.

The material properly identified upon arrival at the laboratory underwent a cleaning process, was weighed and the humidity of the samples was determined. The humidity was determined by the gravimetric method, and the samples taken for this purpose were weighed moist, and dried in a forced air oven, at 70º C, up to constant weight (FERRONATO et al., 2003).

The results obtained for the phenological characterization of the crop were analyzed by means of descriptive statistics to identify behavior and variability. Measures of central tendency (arithmetic mean and median) and dispersion (coefficients of variation, asymmetry and kurtosis) were calculated using the statistical application SAEG 9.0 (RIBEIRO JÚNIOR, 2001).

The results of the losses obtained were submitted to analysis of variance with applications of the "F" test and the means were compared by Tukey's test at the significance level of 5% probability, using the statistical application SAEG 9.0 (RIBEIRO JÚNIOR, 2001).

METHODOLOGY

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RESULTS AND DISCUSSIONS

Table 1 presents the values of the descriptive statistics parameters containing the mean, median, amplitude, standard deviation, coefficients of variation, asymmetry and kurtosis related to the phenological characteristics of the cotton plant.

Table 1. Phenological data of cotton plants

Factors	Average	Median	Amplitude	Standard deviation	CV (%)	Ck	Cs
AP (m)	1,09	1,09	0,07	0,03	2,48	1,60	+0,51
APCS (m)	0,61	0,61	0,11	0,04	6,37	1,60	-0,52
NC	7,16	7,16	3,08	1,11	15,51	1,60	+0,37
PF ($^{\text{ha-1}}$ plants)	152.631	152.021	26.315	9.846	6,45	1,60	-0,55

Coefficient of Variation. Cs: Asymmetry coefficient. Ck: Kurtosis Coefficient

Initially, it is observed that the mean and median values (Table 1) are equal or very close, for the variables plant height (AP), height of the first boll in relation to the ground (APCS) and number of bolls per plant (NC), they are equal. This is an indication that the values are symmetrically distributed around the mean and the median and that these measures can be considered as typical values of the set of observations, that is, the observed results can be summarized by one of these measures.

For the AP, APCS and PF variables, it is observed that the amplitude (Table 1) of variation in the data is not very pronounced, when compared to the respective mean and median values. In other words, the data are not far from these measures of central tendency, which reinforces the hypotheses of less dispersion between the data and the symmetry of the distributions. For the final population (NC) variable, the total amplitude is higher, indicating that there is relatively greater variation between the observed values, which may influence their symmetry around the measures of central tendency.

The observation is confirmed by the coefficient of variation values (Table 1), which can be considered low, especially for the AP, APCS and PF variables. The NC variable, on the other hand, has a coefficient of variation of medium variation. The variables of the present study can be classified, according to Warrick and Nielsen (1980), as low and medium variation, since these authors established an interval in which they classified as low variation – CV < 12%; of medium variation – 12% ≤ CV ≤ 52%; and high variation – CV > 52%. Ferreira (2013) reported coefficients of variation of 7.3, 9.9 and 11.2% for the AP, NC and PF variables, respectively, most of them are above those found in this study, while for the APCS variable, no report was found.

According to Rosolem (2001), the maximum height of cotton plants should not exceed 1.5 times the spacing between rows of the crop, to avoid self-shading. The average height of plants was 1.09 m (Table 1), considering that the row spacing was 0.76 meters for the property. Ferreira et al. (2013) observed plant heights of 0.92 m, a value close to that found in this study. The average height value fits within the quality standards indicated by Rosolem (2001). Anselmo et al. (2011) point out that plant height is a genetic characteristic that varies according to the cultivar, and the heights obtained by each cultivar vary according to the application of growth control regulators.

Like plant height, the height of the first bollly in relation to the ground (APCS) is a characteristic that varies depending on the cultivar and the management of the cotton plant. The APCS remained between 0.55 m and 0.66 m (Table 1). This height, as well as the distribution of bolls in the plant, is directly related to the working height of the harvester platform, and, therefore, the greater the amplitude of these values, the greater the losses in the plant, since the platform has a fixed height, and it is possible to regulate it only in relation to the height of the first bollly (FERREIRA, 2007).

The number of bolls per plant and per area is the most important component of cotton crop production, since the number of bolls and mass are directly related to productivity (MOREIRA, 2008).

The NC observed in this property was 7.83 bolls per plant (Table 1), this value corroborates that found by Ferreira et al. (2013).

According to Embrapa (2001), the ideal number of plants should be between 80,000 and 120,000 plants per hectare, with row spacing between 0.80 and 0.90 meters. However, the result obtained from the final population was higher in the analyzed property due to the smaller row spacing, consistent with the work carried out by Jost and Cothren (2000), who found that the reduction of the row spacing generates an increase in the final population.

Regarding the symmetry of the distribution of the observed values, it can be seen from the distortion value (Table 1) that the AP and NC variables present asymmetry to the right ($0.15 < Cs < 1.0$). On the other hand, the APCS and PF variables present asymmetry on the left ($-0.15 < Cs < -1.0$), however, as the mean is practically equal to the median, this asymmetry can be considered moderate, according to the classification given by Góes (1980), cited by Mesquita et al., 2003.

The kurtosis coefficients (Table 1) show that the variables AP, APCS, NC and PF can be considered leptocurtic (Ck>0), indicating that the values are extreme in relation to the mean.

The pre-harvest losses found at the Mutum Farm are in accordance with the results found by Belot et al. (2002) for the state of Mato Grosso, which is between 0.50% and 4.79% (Table 2).

Table 2. Pre-harvest loss data from mechanized cotton harvesting

Factors	Average	Median	CV (%)	Ck	Cs
PPC ($^{Pk-1}$)	101,05	82,9	34,46	2,46	+0,66
PPC (@$^{A-1}$)	6,73	5,53			
PPC (%)	2,01		36,15		

PPC: pre-harvest loss. CV: Coefficient of Variation. Cs: Asymmetry coefficient. Ck: Kurtosis Coefficient

It is observed that the mean and median values (Table 2) for the PPC variable are not close. This is an indication that the values are not symmetrically distributed around the mean and the median and that these measures cannot be considered as typical values of the set of observations, that is, the observed results cannot be summarized by one of these measures.

The observation is confirmed by the value of the coefficient of variation (Table 2), which was 34.46%, which was considered to be of medium variation ($12\% \leq CV \leq 52\%$).

Regarding the symmetry of the distribution, the observed value (Table 2) shows moderate asymmetry on the right ($0.15 < Cs < 1.0$).

From the kurtosis coefficient (Table 2), it can be seen that the PPC variable can be considered leptocurtic (Ck>0), indicating that the value is extreme in relation to the mean.

The high rates of pre-harvest losses at the Mutum Farm were probably inherent to the delay in the harvest. Because, according to Belot et al. (2010), a one-month delay in harvesting can generate pre-harvest losses of around 4%, and at Mutum Farm, the start was delayed by 10 days.

Due to the existence of few studies on losses in the cotton harvest, Silva et al. (2007) suggest that in order to explain the losses found in the harvest of the cotton crop, a parallel should be drawn with the losses of other crops, because despite the distinct phenological characteristics, there are several similarities with regard to the harvesting process. Mesquita et al. (2001) explain that in order to avoid losses in the soybean harvest, a series of precautions must be taken, including monitoring the harvester's work speed.

Ferreira et al. (2013) evaluated the losses in mechanized cotton harvesting in different cultivars (FMT 701 and FMT 705) and travel speeds (3.6 and 7.2 km h-1), in the production field of Fazenda Mirandópolis (near Rondonópolis-MT), observed that the speed of 7.2 km h-1 caused the highest total losses (14.1%).

At the Mutum Farm, the values of total losses were below the maximum acceptable value of losses in the cotton harvest (Table 3).

Table 3. Average results of the survey of total losses as a function of velocities

Speeds (km $^{h-1}$)	PT (kg ha^{-1})	PT (@ ha^{-1})	PT (%)
5,0	344,2 a	22,95 a	6,85 a
6,6	352,2 a	23,48 a	7,01 a
CV (%)	28,61	25,01	

total loss. Means followed by the same letter in the column did not differ from each other by Tukey's test ($p \leq 0.05$)

However, the results did not differ significantly between the two speeds studied, with an increase in total losses with the increase in the harvester's working speed.

Correlating this study of losses at the Mutum Farm to that of Mesquita et al. (2001) who studied the influence of the speed of movement of the harvester on the quantitative losses in the soybean harvest, it is possible to verify an agreement in the results. In the study by Mesquita et al. (2001), with the increase in the speed of movement of the harvester, there is a significant increase in soybean losses; Ferreira et al. (2013) observed that with an increase in speed from 3.6 to 7.2 km h-1, total losses increased from 10.6% to 14.1%. These results corroborate those found in this property.

The values of total losses evaluated in this property are close to the values found by Ferronato et al. (2003) in the cotton harvest in the southeastern region of the state of Mato Grosso, which are between 5.4% and 9.4%. These values obtained are below the values of total losses found in the cotton harvest under cerrado conditions, which are between 9.4% (NOGUEIRA and SILVA, 1993) and 12.5% (FREIRE et al., 1995). And below the value cited by Vieira et al. (2001) as acceptable, whose maximum rate is 10% of losses.

The result of maximum yield of seed cotton was obtained from the manual harvesting of each template, before the passage of the harvester. The average water content in seed cotton at the time of harvest was 5.7%.

The value of the actual productivity was obtained by subtracting the value of the pre-harvest loss from the value of the maximum productivity.

Table 4 presents the values of the descriptive statistics parameters containing the mean, median, amplitude, standard deviation, coefficients of variation, asymmetry and kurtosis related to the maximum and actual yield of cotton.

Table 4. Data on the average of maximum and actual yields of cotton

Factors	Average	Median	Amplitude	Standard deviation	CV (%)	Ck	Cs
PM (kg ha^{-1})	5.021,72	5.021,72	1.953,32	690,87	12,58	1,60	-0,06
PM (@$^{A-1}$)	334,78	334,78	130,22	46,06			
PR (kg ha^{-1})	4.572,47	4.575,60	481,98	124,17	11,20	2,31	-022
PR (@$^{a-1}$)	304,83	305,00	32,13	8,28			

PM: Maximum productivity. PR: Real productivity. CV: Coefficient of Variation. Cs: Asymmetry coefficient. Ck: Kurtosis Coefficient

It is observed that the mean and median values (Table 4) are the same. This is an indication that the values are symmetrically distributed around the mean and the median and that these measures can be considered as typical values of the set of observations, that is, the observed results can be summarized by one of these measures.

The range of variation of the data is not very pronounced, when compared to the respective mean and median values. In other words, the data are not far from these measures of central tendency, which reinforces the hypotheses of less dispersion between the data and the symmetry of the distributions.

The coefficient of variation found in this study for the PM was 13.76% (Table 4), this value is considered to be of medium variation (12%≤CV≤52%). Ferreira et al. (2013) evaluating the same cultivar (FMT 705) reported a coefficient of variation of 15.20% for the maximum yield.

Regarding the symmetry of the distribution the observed value (Table 4), it can be seen, by the value of the distortion, that the variable PM presents asymmetry to the left (-0.15 < Cs < -1.0), however, as the mean is equal to the median, this asymmetry can be considered moderate, according to the classification given by Góes (1980 apud Mesquita et al., 2003).

CONCLUSION

The speed of movement did not have a significant influence on the losses in the cotton harvest. And the total losses found in this study are within the limit considered acceptable for the cotton harvest.

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